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Contents

CHAPTER 1

Introduction

1.1 What is Mosel?

Mosel is an environment for modeling and solving problems. To this aim, it provides a language that is both a modeling and a programming language. The originality of the Mosel language is that there is no separation between a modeling statement (*e.g.* declaring a decision variable or expressing a constraint) and a procedure that actually solves the problem (*e.g.* call to an optimizing command). Thanks to this synergy, one can program a complex solution algorithm by combining modeling and solving statements.

Each category of problem comes with its own particular types of variables and constraints and a single kind of solver cannot be efficient in all cases. To take this into account, the Mosel system does not integrate any solver by default but offers a dynamic interface to external solvers provided as modules. Each solver module comes with its own set of procedures and functions that directly extends the vocabulary and capabilities of the Mosel language. The link between Mosel and a solving module is achieved at the memory level and does not require any modification of the core system.

This open architecture can also be used as a means to connect Mosel to other software. For instance, a module could define the functionality required to communicate with a specific database.

The modeling and solving tasks are usually not the only operations performed by a software application. This is why the Mosel environment is provided either in the form of libraries or as a standalone program.

1.2 General organization

As input, Mosel expects a text file containing the source of the model/program to execute (henceforth we use just the term 'model' for 'model/program' except where there might be an ambiguity). This source file is first compiled by the Mosel compiler. During this operation, the syntax of the model is checked but no operation is executed. The result of the compilation is a BInary Model (BIM) that is saved in a second file. In this form, the model is ready to be executed and the source file is not required any more. To actually 'run' the model, the BIM file must be read in again by Mosel and then executed. These different phases are handled by different modules that comprise the Mosel environment:

The runtime library: This library contains the VIrtual MAchine (VIMA) interpreter. It knows how to load a model in its binary format and how to execute it. It also implements a model manager (for handling several models at a time) and a Dynamic Shared Objects manager (for loading and unloading modules required by a given model). All the features of this library can be accessed from a user application.

The compiler library: The role of this module is to translate a source file into a binary format suitable for being executed by the VIMA Interpreter.

The standalone application: The 'mosel' application, also known as 'Mosel Console', is a command line interpreter linked to the two previous modules. It provides a single program to compile and execute models.

Various modules: These modules complete the Mosel set of functionalities by providing, for instance,

optimization procedures. As an example, the *mmxprs* module extends the Mosel language with the procedure `maximize` that optimizes the current problem using the Xpress Optimizer.

This modularized structure offers various advantages:

- Once compiled, a model can be run several times, for instance with different data sets, without the need for recompiling it.
- The compiled form of the program is system and architecture independent: it can be run on any operating system equipped with the Mosel runtime library and any modules required.
- The BIM file can be generated in order to contain no symbols at all. It is then safe, in terms of intellectual property, to distribute a model in its binary form.
- As a library, Mosel can be easily integrated into a larger application. The model may be provided as a BIM file and the application only linked to the runtime library.
- The Mosel system does not integrate any kind of solver but is designed in a way that a module can provide solving facilities. The direct consequence of this is that Mosel can be linked to different solvers and communicate with them directly through memory.
- This open architecture of Mosel makes extensions of the functionality possible on a case by case basis, without the need to modify the Mosel internals.

1.3 Running Mosel

The Mosel environment may be accessed either through its libraries or by means of two applications, perhaps the simplest of which is Xpress Workbench, a development studio type environment for working with your Mosel models. Xpress Workbench is a complete modeling and optimization development environment that presents Mosel in an easy-to-use graphical interface with a built-in text editor.

In its standalone version, Mosel offers a simple interface to execute certain generic commands directly from the command prompt (or shell) of the operating system. The user may compile or execute source models or programs (`.mos` files), run binary models (`.bim` files) or retrieve information related to the Mosel environment itself (like properties of modules or version number of the system). An interactive debugger as well as a profiler are also included: the debugger allows to execute the model step by step, specify breakpoints from where status of the model can be examined. Running a model with the profiler provides detailed information on what part of the code is actually executed and how much time each statement requires. This information may be helpful for optimizing the model (by locating *hot spots* where the code is using a great deal of computer time) and also for building testsuites (by checking whether the data sets used in the test set exercise all statements of a given model).

1.3.1 `mosel` command: invocation

The `mosel` executable is typically used with the following syntax from an operating system console:

```
mosel command [-l lang] [-d dir] [-tf trf] [-sdm sdm] [-sr rst]
              [-dp dsopath] [-bx bimpfx] cmd_args
```

Where the option **`-l`** selects the language for message translation (see Section 2.21); the option **`-d`** sets the working directory of the process; the option **`-tf`** defines a trace file (see command `trace` below); the option **`-sdm`** specifies the maximum size of stack dumps (displayed when a model terminates on a runtime error, an assertion fails or triggered by a call to `dumpcallstack`; this can also be set via the environment variable `MOSEL_SDMAX`, the default value of 0 disables the display of the stack trace); the option **`-sr`** defines the active restrictions (see Section 1.3.4) and **`-dp`** specify an initial DSO path (to locate modules and packages) while **`-bx`** sets a list of bim file prefixes (used to find packages, see

Section 2.3.1). Both options **-dp** and **-bx** might be stated several times, the resulting setting will correspond to the concatenation of the provided values separated by the appropriate symbol. The *command* parameter is one of the following commands and *cmd_args* are the associated arguments that must be stated after the options described above (square brackets indicate optional arguments):

comp[**ile**] [**-gGIpwiweninaxSETVFD**] [**-pwd** pwd] [**-pk** priv] [**-k**|**-kf** pub]
[**-ix** incpfx] [**-o** outf] [**-c** usrcom] src [src2 ...]

Compile the model `src` and generate the corresponding Binary Model (BIM) file if the compilation succeeds. The extension `.mos` is appended to `src` if no extension is provided. If option '**-o** `outf`' (filename to use for saving BIM file) is not given, the extension `.bim` is used to form the name of the binary file. The flag '**-g**' adds debugging information: private object names (*e.g.* variables, constraints) are included in the BIM file as well as required information for locating runtime errors. The flag '**-G**' adds both debugging and tracing information: it is required to run the model with the debugger. When the '**-G**' flag is used, the compiler adds instructions in the generated code that may slow down execution speed of the model. The flag '**-I**' may also be added to enable the *xbim* extension (see Section 2.3.3). The flag '**-D**' enables generation of documentation annotations in the resulting BIM file (by default documentation annotations are ignored). The flag '**-na**' disables assertions when the model is compiled with debug information (see `assert`). With the flag '**-wi**', the compiler emits a warning message each time a symbol is implicitly declared and the flag '**-ni**' disables implicit declarations (see Section 2.8.1.5). When the flag '**-we**' is used warnings are handled like errors such that any warning will make the compilation fail. The option '**-c** `usrcom`' may be used to add a commentary to the BIM file (see debugger command `LSMODS`). The option '**-ix**' defines the file name prefix for file inclusion (see Section 2.5.2). If the flag '**-p**' is selected, only the syntax of the source file is checked, the compilation is not performed and no output file is generated.

The flag '**-x**' will be used to generate a POT file (Portable Object Template) for message translation (see Section 2.21).

The other options are related to handling encrypted or signed BIM files (see Section 1.3.5): option '**-S**' will be used to produce a *signed* file. Unless the option '**-pk**' is specified, the default private key `personal.key` (see `ssl_dir`) is used for the signature. The options '**-V**' and '**-T**' control how to handle signed packages: by default signature of packages is ignored but, if the first option is used, the signature is checked and the loading fails if it cannot be verified. With option '**-T**', only signed packages with a valid signature can be used (*i.e.* packages without signature are not allowed). Public keys that are required for the verification are searched for in the default public keys directory `pubkeys` (see `ssl_dir`).

BIM file encryption is enabled by the '**-E**' option: the encryption key is either deduced from the password stated via option '**-pwd**' (if the flag '**-F**' is active, the value of '**-pwd**' is interpreted as a text file the first line of which is the password) or generated randomly. Optionally, the encryption key can be stored in the BIM file itself in encrypted form (this is required if it has been randomly generated): in this case the encryption requires public keys of the recipients of the BIM file (who will be able to decrypt the file using their own private keys). Public keys can be listed by using the '**-k**' or '**-kf**' options: in the first case, one public key is listed at a time (the '**-k**' parameter may be used several times) and in the second case a file containing a list of keys is specified. Each line of this file is interpreted as a key file name (except empty lines or lines starting with '`!`' or '`#`' that are ignored). Unless they include a path specification, key files are considered to be located in the default public keys directory (for instance the key file `"somekey"` is searched in the public keys directory but the file `"./somekey"` comes from the current working directory). An encrypted BIM file can always be decrypted by its creator thanks to his private key.

Several source files may be passed to the compiler command in a single step (this is not compatible with option '**-o**'): each file gets compiled individually.

run [**-TVF**] [**-pwd** pwd] [**-pk** priv] [**-k**|**-kf** pub] [**-is** in] [**-os** out] [**-es** err]
[**-dbg**|**-prof**|**-cov**|**-trac**] [**-sdir** dir] [**-nl**] bim [param=value [...]]

Load the provided BIM file `bim` and then run it. Options '**-is** `in`', '**-os** `out`' and '**-es** `err`' can be specified to define alternative default input, ouput and error streams to be used by Mosel. With option '**-prof**' or '**-cov**' the model is run through the profiler (see commands `profile` and

coverage below), the option '**-trac**' activates the *tracing mode* (see command trace) and with option '**-dbg**' it is passed to the interactive debugger (see command debug). The option '**-sdir**' can be used in addition to the profiler or debugger to indicate alternative locations for source files (this option may be stated several times).
The options '**-V**' and '**-T**' control how to handle signed BIM files (see Section 1.3.5): by default signature of files is ignored but, if the first option is used, the signature is checked and the loading fails if it cannot be verified. With the second option, only signed BIM files with a valid signature can be used (*i.e.* files without signature are not allowed). For this verification task public keys are usually searched for in the default public keys directory pubkeys (see ssl_dir) but alternatively a list of expected keys may be specified with the '**-k**' or '**-kf**' options: in the first case, one public key is listed at a time (the '**-k**' parameter may be used several times) and in the second case a list of keys is read from the given file. Each line of this file is interpreted as a key file name (except empty lines or lines starting with '!' or '#' that are ignored). Unless they include a path specification, key files are considered to be located in the default public keys directory (for instance the key file "somekey" is searched in the public keys directory but the file "./somekey" comes from the current working directory). Moreover, the special file name * implies that keys stored in the default location can also be used.
The options '**-pwd**' and '**-pk**' may be required to load an encrypted BIM file: the former defines the password to use (if the flag '**-F**' is active, the value of '**-pwd**' is interpreted as a text file the first line of which is the password) and the option '**-pk**' servers to specify a private key file (to be used in place of the default personal.key in ssl_dir).
Optionally, a list of parameter values may be provided in order to initialize the run-time parameters of the model and/or the control parameters of the modules used. The syntax of such an initialization is *param_name = value* for a model parameter and *dsoname.ctrpar_name = value* for a control parameter, where *dsoname* is the name of a module and *ctrpar_name* the control parameter to set.
The option '**-nl**' can be used when running the debugger on Unix/Linux systems to deactivate the command history if the terminal is not properly handled by the command history mechanism.

exec[**ute**] [compile_opts] [run_opts] src [param=value [...]]
Compile src, load, and then run the model. This command is equivalent to the consecutive execution of compile and run except that no BIM file is generated. All options documented for both, compile and run, can be used with this command. The use of option '**-prof**', '**-cov**' or '**-trac**' implies the compiler flag '**-G**' and the use of option **-dbg** will also add compiler flag '**-G**' if flag '**-g**' is not explicitly specified.

debug [compile_opts] [run_opts] src [param=value [...]]
This command is equivalent to 'execute -dbg', the model is compiled and then run through the interactive debugger. If the model is compiled with flag '**-G**' (the default with this command), the execution is immediately suspended before the first statement. Otherwise the execution starts as usual but can be suspended by pressing ctrl-C. Note that if a critical operation is being processed, the interruption is delayed until the operation completes (for instance, the Optimizer cannot be interrupted during an iteration of its algorithm). Execution is suspended once more just before the program terminates: this makes it possible to inspect model data before the end of execution. Refer to the Section 1.3.2 below for further information on the use of the debugger.

prof[**ile**] [compile_opts] [run_opts] src [param=value [...]]
This command is equivalent to 'execute -prof', the model is compiled and then run through the profiler. After execution, the total execution time and some source coverage information is displayed. Moreover a file *sourcefile*.prof is generated based on the original source file. Each line of this file consists in:

- the number of times the corresponding statement has been executed;
- the total amount of time (in seconds) or the percentage of the total execution time (if option '**-prof** 2' is used) spent on this particular line (this measure is not valid if the statement is a recursive call);

- the elapsed time (in seconds) between the beginning of the execution and the last time the line was executed;
- the text of the model source

All lines of the original source file are transferred, lines that do not correspond to the beginning of a statement are directly copied without further information.
If the model runs additional submodels via `mmjobs`, a report for each model execution is also displayed and the associated annotated files are generated in a similar way as for the main model.

cover[**age**] [compile_opts] [run_opts] src [param=value [...]]
This command is equivalent to '`execute -cov`', the model is compiled and then run through the profiler. The difference with the *profile* command described above is the type of reports generated: the files produced are taking the `.cov` extension and only collect the number of times each statement has been executed (if option '**-cov** 2' is used it is 0 or 1). Moreover existing files are updated instead of being replaced (*i.e.* iteration counts of each statement are added up).

trace [compile_opts] [run_opts] src [param=value [...]]
This command is equivalent to '`execute -trac`', the model is compiled and then run in tracing mode: the activity of the program is logged in a *trace file* that is automatically generated or extended (if the file already existed). The file name for this report is either defined using the '**-tf**' option or taken from the environment variable `MOSEL_TRFILE`. In both cases a question mark in the file name will be replaced by the process ID expressed in hexadecimal. If no trace file is defined the default name '`tmpdir/xprm_?.trac`' will be used ('`tmpdir`' being the temporary directory of the system). Refer to the Section 1.3.3 below for further information on the trace file.

exam[**ine**] [**-pwd** pwd] [**-pk** priv] [**-cspthHirvaumLVF**] [mod|pkg [mod|pkg...]]
Display the list of constants, procedures/functions, types, IO drivers, control parameters and annotations of modules, packages or the Mosel core library. By default required packages are not loaded (but modules are loaded): using option '**-L**' will force loading of all dependencies. To load only the header of the bim file to check its dependencies use option '**-H**'. Optional flags may be used to select which type of information is displayed: '**-h**' for general information, '**-c**' for constants, '**-s**' for subroutines, '**-v**' for variables, '**-r**' for requirements, '**-t**' for types, '**-i**' for IO drivers, '**-p**' for control parameters and '**-a**' for annotations. By default, listings are sorted in alphabetical order, option '**-u**' disables sorting. If both, a package and a module of the same name, are available only the information relating to the package is displayed. To select either the package or the module, extension `.bim` or `.dso` can be appended to the library name. If the flag '**-m**' is used and no package or module can be located then a binary model file is searched for in the current working directory. The displayed information is related to the Mosel core library if no name is specified with the command.
The option '**-V**' can be added for checking the signature of signed BIM files (the result of the verification is reported in the header output). The options '**-pwd**' and '**-pk**' may be required to load an encrypted BIM file: the former defines the password to use (if the flag '**-F**' is active, the value of '**-pwd**' is interpreted as a text file the first line of which is the password) and the second option specifies a private key file (to be used in place of the default `personal.key` in `ssl_dir`).

lslib [**-p**|**-m**]
Display a list of available modules and packages. Use the optional flag '**-p**' to list only packages and '**-m**' to get modules only.

If none of the above keywords is recognized, the first argument of the command is interpreted as a Mosel file. In the case of a BIM file, the command '`run`' is executed; otherwise the file name is passed to the command '`execute`'.

The `mosel` command may also be started using only flags. Besides options '**-V**' (Mosel version information) and '**-h**' (short help message), all other options relate to starting Mosel in server mode when it is invoked from a remote instance: they should not be used directly (see the documentation of module `mmjobs` in Chapter 8 for further explanations).

After the completion of a command the `mosel` executable returns a non-zero status to the operating system in case of error and the execution status of the model if a model has been run (*e.g.* with the command `execute`). This execution status is the value provided via the procedure `exit` in the model (by default this is 0).

Some examples:

Execute model 'mymodel.mos' setting values for the model parameters A,B,C and D

```
> mosel mymodel A=33 B="word" C=true D=5.3e-5
```

Compile model 'm.mos' located on a web service and store the bim file locally in compressed form

```
> mosel comp -o zlib.gzip:m.bim.gz mmhttp.url:http://websrv/m.mos
```

Run 'optmod.bim' from the debugger enabling verbose mode of module 'mmxprs'

```
> mosel run -dbg optmod mmxprs.XPRS_verbose=true
```

List all available modules and packages

```
> mosel lslib
```

Display the list of subroutines defined by 'mmxprs'

```
> mosel exam -s mmxprs
```

Display all constants defined in the Mosel language

```
> mosel exam -c
```

Display version information of Mosel

```
> model -V
```

1.3.2 `mosel` command: interactive debugger

When a model that is executed through the debugger is interrupted (for instance, because the user has typed ctrl-C or an error has occured), the execution is suspended, the text source of the statement being processed is displayed and an interactive session starts. This mode is signaled by the specific prompt '`dbg>`' and the following commands may be entered (the arguments enclosed in square brackets [] are optional). The command line interpreter is case-insensitive, although we display commands in upper case for clarity:

`BCONDITION` *`bk`* `[`*`cond`*`]`
: Define or remove a condition on a breakpoint. This command may be used to put a condition (Boolean expression) on the specified break point: the execution is suspended at the breakpoint only if the given condition is verified. To remove a condition previously set up, enter this command without specifying any condition.

`BREAK [`*`procname`*`]|[`*`line`* `[`*`file`*`]]`
: Install a breakpoint. When a breakpoint has been set up, execution is interrupted whenever the statement corresponding to the specified location is reached. A procedure or function name may be used as the location: in this case a breakpoint is installed at the beginning of each procedure or function of the provided name. If this command is used without parameters, the breakpoint is defined at the current location.

`BREAKPOINTS`
: List the defined breakpoints.

`BREAKSUB [0|1]`
: Decide whether to suspend execution whenever a submodel is started.

`CONTINUE`
: Resume execution. If the interruption was not due to an error, execution of the model continues, otherwise the execution of the model is aborted and Mosel exits.

`DELETE [`*`bk`*`]`
: Delete a breakpoint.

`DISPLAY [`*`expression`*`]`
: Record an expression to be displayed at every interruption. Used with no expression, this command gives a list of all recorded expressions.

`DOWN [`*`nblev`*`]`
: Go down in the calling stack. If an argument is provided, it indicates how many levels down to go (default is 1).

`EXPORTPROB [-pms] [`*`filename`* `[`*`objective`*`]]`
: Display or save to the given file (option *`filename`*) the matrix corresponding to the active problem. The matrix output uses the *LP format* (default) or the *MPS format* (flag '`-m`'). A *problem* is available after the execution of a model. The flags may be used to select the direction of the optimization ('`-p`': maximize), the file format ('`-m`': MPS format) and whether real object names should be used ('`-s`': scrambled names — this is the default if the object names are not available). The objective may also be selected by specifying a constraint name.

`FINISH`
: Continue execution until the end of the current subroutine. The execution continues but will be interrupted again after the subroutine terminates.

`INFO [*|`*`symbol`* `[`*`symbol...`*`]]`
: Without arguments, this command displays information about the program being executed (this may be useful for problem reporting). Any specified argument is interpreted as a symbol from the current model. If the requested symbol exists in the model, this command displays some information about its type and structure. Several symbols may be given in a single call and if `'*'` is used in place of a symbol name then the information is displayed for every symbol of the model.

`LIST [[`*`start`*`]` *`nblines`*`]`
: Display the source file that corresponds to the model being executed. When used with no extra argument, this command lists 10 lines of the source model starting at the current statement; used with a single positive parameter *nblines*, it displays *nblines* lines instead of the default 10 lines. If the parameter *nblines* is negative, it is interpreted as a starting point for the listing relative to the current statement. When 2 parameters are used, the first one is understood as the first line to display (a negative value is relative to the current line) and the second one as the number of lines to display.
  Examples (assuming current line is 5):

```
>list        displays lines 5 to 14
>list 5      displays lines 5 to 9
>list -2     displays lines 3 to 14
>list -2 5   displays lines 3 to 7
```

`LSATTR [`*`typename`*`]`
: Display the list of available attributes for all used native types or only those related to the specified type *typename*

`LSLIBS`
: Display the list of all loaded dynamic shared objects (DSO) together with, for each module, its version number and its number of references (*i.e.* number of loaded models using it).

`LSLOCAL`
: Display the list of symbols defined locally to the current context.

`LSMODS`
: Display the list of all models currently loaded in core memory. The information displayed for each model is:

  - `name`: the model name and version number (given by the `model` and `version` statements in the source file);
  - `number`: the model number is automatically assigned when the model is loaded;
  - `size`: the amount of memory used by the model (in bytes);
  - `system comment`: a text string generated by the compiler indicating the source filename and if the model contains debugging information and/or symbols;
  - `user comment`: the comment defined by the user at compile time (*cf.* command `compile`);
  - `modules`: the name and version number of each module required by the model;
  - `pkg. req.`: if the model is a package, the name and version number of each package required by a model using this package;
  - `pkg. imp.`: the name and version number of each package included by this model.

  The active model is marked by an asterisk ('`*`') in front of its name.

`LSSYMB [-cspou]`
: Display the list of symbols published by the current model. The optional flags may be used to filter what kind of symbol to display: '`-c`' for constants, '`-s`' for subroutines, '`-p`' for parameters and '`-o`' for everything else. By default the list is sorted in alphabetical order, option '`-u`' disables sorting.

`MODEL [`*`modnum`*`]`
: With no argument this command lists all models running concurrently. The *active model* (debugger commands are applied to this model) is identified by a star (`"*"`). If provided, the argument is interpreted as a model number that becomes the active model.

`NEXT [`*`line`* `[`*`file`*`]]`
: Continue execution until the next statement. The execution continues but will be interrupted again after the current statement has been completed. If a location information is provided (by means of a line number and, if necessary, a file name), the next interruption will occur before the specified statement is executed.

`OPTION` *`name`* `[[=]` *`value`*`]`
: View or change the value of a command line parameter. These parameters are used by the command line interpreter to display real values (especially in command `PRINT`):

  - `realfmt`: C-style format for printing floating point numbers (default value: `"%.10g"`)
  - `zerotol`: zero tolerance to decide whether two values are equal (default value: `1e-13`). It is also used when printing very small numbers: if a value is smaller than `zerotol`, `"0"` is displayed instead.

  Although these parameters have the same name and function as those used by Mosel when running a model, they are not synchronised with their internal counterpart.

`PRINT` *`expression`* `[>>`*`filename`*`]`

Evaluate then display the value of the given arithmetic or Boolean expression. For building the expression, the following functions can be used: `getparam`, `ceil`, `floor`, `round`, `abs`, `getsize`, `getmodprop` as well as all attributes (see LSATTR command above). In addition to these Mosel functions, the interpreter implements `getnbdim` that returns the number of dimensions of an array and `getndx#` that gets the index set of dimension number `'#'` of an array (`'#'` being an integer between 1 and the number of dimensions of the array). *get-functions* may be called using the suffix notation (*e.g.* `getact(c)` is equivalent to `c.act`). For unions, the notation `symbol.type` is supported (*e.g.* `"myun.integer"`), it is also possible to use suffixes `array`, `set` and `list` to access union values. Some functions can be applied to arrays: the result is the evaluation of the function for each cell of the array. Symbols are expected to be fully qualified: even if a symbol is expressed without namespace reference in the model source (thanks to the namespace search, see Section 2.13) it is necessary to use its full name from the debugger. In particular private symbols of packages must be prefixed by the package name (for instance the identifier `aa` declared in the package `mypkg` can be accessed using `mypkg~aa`). It is possible to report only a part of a collection (array, set or list) by specifying range information. Ranges definitions take one of these two forms:

- `[ maxelt ]`: get at most 'maxelt' elements
- `[ skip maxelt ]`: get at most 'maxelt' entries after skipping 'skip' elements

Several range definitions may be specified (separated by blanks): they are used when exploring complex structures (*e.g.* a list of list).
The display format of this command is compatible with the data file format of Mosel. Use the operator *>>filename* to append output of the command to the file *filename*.
Examples:

```
>print getsol(x) >> solfile.txt
>print getact(C(1,"tut"))+c.size
>print toto~a
>print abs(mytol)>1
>print myarray.ndx2 [3]
```

`QUIT`

Terminate the debug session. Model execution is aborted and Mosel exits.

`STEP`

Continue execution until the next statement stepping into procedures and functions. The execution continues but will be interrupted again after the current statement has been completed. If the current statement contains function or procedure calls, interruption will happen in these procedures or functions.

`UNDISPLAY [`*`disp`*`]`

Remove an expression recorded with `DISPLAY`. If no parameter is provided, all recorded expressions are removed, otherwise the parameter is understood as a record number.

`UP [`*`nblev`*`]`

Go up in the calling stack. If an argument is provided, it indicates how many levels up to go (default is 1). Note that expressions are evaluated according to the current stack frame. For example, if variable *i* is defined in procedure B and execution is suspended in procedure A called by B; it is necessary to go up in the stack in order to view the value of *i* because it does not exist in the current frame.

`WHERE [`*`nblev`*`]`

Display the calling stack. The calling stack corresponds to the sequence of procedure and function calls being processed. For instance assume the model calls procedure A which calls procedure B and the execution is suspended in procedure B: the calling stack will contain 3 records (location where A is called, location where B is called and current statement).

If a command is not recognized, a list of possible keywords is displayed together with a short explanation. The command names can be shortened as long as there is no ambiguity (*e.g.* `un` can be used in place of `UNDISPLAY` but `u` is not sufficient because it could equally denote the `UP` command). String arguments (the parameter `10` is a number, but `"10"` or `'10'` are text strings) may be quoted with either single or double quotes. Quoting is required if the text string starts with a digit or contains spaces and/or quotes.

Execution step by step and breakpoints can be used only if the model has been compiled using option `-G`. In this case, before the execution starts, a breakpoint is automatically put at the first statement of the model. Otherwise (model has been compiled with option `-g`), the model will be interrupted only if an error occurs or keys ctrl-C are pressed.

When debugging a model that runs submodels via `mmjobs` a message is displayed each time a submodel starts or terminates. Moreover, interrupting the execution of the model also suspends the execution of all submodels: the entered commands are applied to the selected *active model*, the choice of which can be changed with the command `MODEL`.

A program may interrupt its execution and trigger the interactive debugger by using the following special annotation (See section 2.14):

```
!@mc.dbgmsg break
```

When the program is compiled with tracing information (option `-G`) this annotation is replaced by a special instruction that will cause an interruption when the program is being run through the debugger (otherwise it is silently ignored).

1.3.3 `mosel` command: tracing mode

Running a program in *tracing mode* results in the generation of a *trace file* that collects the activity of the program. Each record of this file consists in a single line of text that can take the following forms:

`0O` *`timestamp`*
: The file has been open

`0C` *`timestamp`*
: The file has been closed

`mm``S` *`timestamp modelname`*
: The model number *mm* with name *modelname* is starting. Line tracing is enabled

`mm``Trr` *`timestamp modelname`*
: The model number *mm* with name *modelname* is finishing, its status code is *rr*

`mm``-` *`timestamp msg`*
: The model number *mm* has disabled line tracing (with optional message *msg*), submodels are not affected

`mm``+` *`timestamp msg`*
: The model number *mm* has enabled line tracing (with optional message *msg*), submodels are not affected

`mm``!` *`timestamp msg`*
: The model number *mm* logs message *msg*

`mm``Lpp` *`timestamp`*
: The model number *mm* is loaded by model number *pp*

`mm``Upp` *`timestamp`*
: The model number *mm* is unloaded by model number *pp*

mm:*nn fname*
: The model number *mm* is executing the statement at line *nn* of file *fname* (that becomes the current file for this model). These records are not emitted when line tracing is disabled.

mm nn
: The model number *mm* is executing the statement at line *nn* of current file as specified previously for the given model These records are not emitted when line tracing is disabled.

A program may control the behaviour of the tracer using the special annotation `mc.dbgmsg` (See section 2.14). The following annotations are interpreted:

```
!@mc.dbgmsg traceoff msg
!@mc.dbgmsg traceon msg
!@mc.dbgmsg tracelog msg
```

When the program is compiled with tracing information (option `-G`) this annotation is replaced by a special instruction that communicates with the tracer (it is silently ignored if the program is not run in tracing mode). The first syntax disables the line tracing (it is active by default), the second has the opposite effect while the last syntax makes it possible to insert a message in the trace file. In all cases the message text `msg` is optional.

1.3.4 `mosel` command: restricted mode

Mosel may be run in *restricted mode*: by selecting which *restrictions* are to be applied, it is possible to control what operations models can perform (in particular regarding disk access). Upon startup, if the option `-sr` is not stated, the command line interpreter uses the value of the environment variable `MOSEL_RESTR` for setting the execution restrictions. These restrictions are bit-encoded as an integer (each bit corresponding to a specific restriction) but restrictions can also be expressed by a list of one or more of the following keywords (symbols are not case-sensitive and can be optionally separated by spaces):

`NoWrite (bit 0, value 1)`
: Disable write access on the local system. This restriction concerns all file access except databases. Access to the temporary directory is not affected.

`NoRead (bit 1, value 2)`
: Disable read access on the local system (this also implies `NoWrite`). This restriction concerns all file access except databases. When this option is selected, the current working directory is automatically set to the temporary directory (which can still be accessed).

`NoExec (bit 2, value 4)`
: Disable external command execution. This restriction deactivates some procedures/functions allowing execution of commands external to Mosel (for instance `system` or `command`). Also, Mosel can only load modules from read-only locations when this restriction is active.

`WDOnly (bit 3, value 8)`
: File access is limited to the current working directory and its subdirectories as well as the paths specified by the environment variables `MOSEL_RWPATH` (for reading and writing) and `MOSEL_ROPATH` (for reading only). The temporary directory can still be accessed.

`NoTmp (bit 4, value 16)`
: Access to the temporary directory is disabled.

`NoDB (bit 5, value 32)`
: Disable access to databases by blocking connection routines (*e.g.* `SQLconnect` or `OCIlogon`).

For example, to disable write access and execution of external commands the environment variable `MOSEL_RESTR` will have to be either the integer value `5` (1+4) or the string `"NoWrite NoExec"`.

Restricted mode is observed by the Mosel core libraries (when accessing files and managing directories) and the system requires that modules also satisfy the stated restrictions (although implementation of restrictions may vary depending on the type of functionality provided by a given module): a module that does not support the restricted mode of execution will fail to load when Mosel is running in this mode.

1.3.5 `mosel` command: securing bim files

The bim file format is secure with respect to the intellectual property of the author of the model (*i.e.* it is not possible to recover the original model from the bim file). However, further security mechanisms may be required when a bim file is to be transferred over an insecure media (like the internet): in particular it might be necessary to (1) make sure the file has not been modified during the transfer and (2) guarantee that only the addressee can access the file.

A *digital signature* ensures the first requirement: it is computed using a *private key* (exclusively owned by the sender of the document) such that any addressee having the corresponding *public key* (provided by the sender) can, at the same time, verify that the document has been prepared by the sender and that it has not been altered during the transfer. From the Mosel command line tool, creating a signed bim file can be done by using the '`-S`' compiler option. When loading a signed bim file with the `run` command, it is required to enable the signature verification with options '`-V`' or '`-T`' as verification is not performed by default.

The second requirement can be satisfied by *encrypting* the bim file such that it appears as random data during the transfer. Mosel supports two kinds of encryption processes: it can use a usual password based key. In this case the same password is used for both encrypting and decrypting the bim file (the sender and the recipient have to share this key). The alternative is to rely on private/public key pairs like for the signature procedure outlined above: encryption is achieved with the public key of the adressee. Only the recipient will be able to decrypt the bim file using his private key. From the Mosel command line tool, creating an encrypted bim file can be done by using the '`-E`' compiler option. A password is specified with the '`-pwd`' option otherwise the public keys of the recipients have to be stated with the '`-k`' or '`-kf`' options (a bim file can be encrypted for up to 128 public keys).

Both signature and encryption require the management of private and public keys. These keys are expected to be stored in a predefined location specified by the module parameter `ssl_dir`.

Mosel relies on the RSA cryptographic system for the management of private/public key pairs (keys must be of at least 1024bits). The signature procedure uses the SHA256 message digest algorithm. Bim files are encrypted using the AES block cipher with keys of 128 bits.

1.4 References

Mosel could be described as an original combination of a couple of well known technologies. Here is a non-exhaustive list of the most important 'originators' of Mosel:

- The overall architecture of the system (compiler, virtual machine, native interface) is directly inspired by the Java language. Similar implementations are also commonly used in the languages for artificial intelligence (*e.g.* Prolog, Lisp).
- The syntax and the major building blocks of the Mosel language are in some aspects a simplification and for other aspects extensions of the Pascal language.
- The aggregate operators (like 'sum') are inherited from the 'tradition of model builders' and can be found in most of today's modeling languages.
- The dynamic arrays and their particular link with sets are probably unique to Mosel but are at their origin a generalization of the sparse tables of the mp-model model builder.

1.5 Structure of this manual

The main body of this manual is essentially organized into two parts. In Chapter 2, the basic building blocks of Mosel's modeling and programming language are discussed.

Chapter 3 begins the reference section of this manual, providing a full description of all the functions and procedures defined as part of the core Mosel language. The functionality of the Mosel language may be expanded by loading *modules*: the following chapters describe the modules currently provided with the standard Mosel distribution.

I. Core System

CHAPTER 2

The Mosel Language

The Mosel language can be thought of as both a modeling language and a programming language. Like other modeling languages it offers the required facilities to declare and manipulate problems, decision variables, constraints and various data types and structures like sets and arrays. On the other hand, it also provides a complete set of functionalities proper to programming languages: it is compiled and optimized, all usual control flow constructs are supported (selection, loops) and can be extended by means of modules. Among these extensions, optimizers can be loaded just like any other type of modules and the functionality they offer may be used in the same way as any Mosel procedures or functions. These properties make of Mosel a powerful modeling, programming and solving language with which it is possible to write complex solution algorithms.

The syntax has been designed to be easy to learn and maintain. As a consequence, the set of reserved words and syntax constructs has deliberately been kept small avoiding shortcuts and 'tricks' often provided by modeling languages. These facilities are sometimes useful to reduce the size of a model source (not its readability) but also are likely to introduce inconsistencies and ambiguities in the language itself, making it harder to understand and maintain.

2.1 Introduction

2.1.1 Comments

A comment is a part of the source file that is ignored by the compiler. It is usually used to explain what the program is supposed to do. Either single line comments or multi lines comments can be used in a source file. For the first case, the comment starts with the '`!`' character and terminates with the end of the line. A multi-line commentary must be inclosed in '`(!`' and '`!)`'. Note that it is possible to nest several multi-line commentaries.

```
! In a comment
 This text will be analyzed
 (! Start of a multi line
   (! Another comment
   blabla
   end of the second level comment !)
 end of the first level !) Analysis continues here
```

Comments may appear anywhere in the source file.

2.1.2 Identifiers

Identifiers are used to name objects (variables, for instance). An identifier is an alphanumeric (plus '_') character string starting with an alphabetic character or '_'. All characters of an identifier are significant and the case is important (the identifier 'word' is not equivalent to 'Word').

2.1.3 Reserved words

The reserved words are identifiers with a particular meaning that determine a specific behaviour within the language. Because of their special role, these *keywords* cannot be used to name user defined objects (*i.e.* they cannot be redefined). The list of reserved words is:

`and`, `array`, `as`, `boolean`, `break`, `case`, `constant`, `count`, `counter`, `declarations`, `div`, `do`, `dynamic`, `elif`, `else`, `end`, `evaluation`, `false`, `forall`, `forward`, `from`, `function`, `hashmap`, `if`, `imports`, `in`, `include`, `initialisations`, `initializations`, `integer`, `inter`, `is`, `is_binary`, `is_continuous`, `is_free`, `is_integer`, `is_partint`, `is_semcont`, `is_semint`, `is_sos1`, `is_sos2`, `linctr`, `list`, `max`, `min`, `mod`, `model`, `mpvar`, `namespace`, `next`, `not`, `nsgroup`, `nssearch`, `of`, `options`, `or`, `package`, `parameters`, `procedure`, `public`, `prod`, `range`, `real`, `record`, `repeat`, `requirements`, `return`, `set`, `shared`, `string`, `sum`, `then`, `to`, `true`, `union`, `until`, `uses`, `version`, `while`, `with`.

Note that, although the lexical analyzer of Mosel is case-sensitive, the reserved words are defined both as lower and upper case (*i.e.* `AND` and `and` are keywords but not `And`).

2.1.4 Separation of instructions, line breaking

In order to improve the readability of the source code, each statement may be split across several lines and indented using as many spaces or tabulations as required. However, as the line breaking is the expression terminator, if an expression is to be split, it must be cut after a symbol that implies a continuation like an operator ('+', '−', ...) or a comma (', ') in order to warn the analyzer that the expression continues in the following line(s).

```
A+B       ! Expression 1
-C+D      ! Expression 2
A+B-      ! Expression 3...
C+D       ! ...end of expression 3
```

Moreover, the character '`;`' can be used as an expression terminator.

```
A+B ; -C+D  ! 2 expressions on the same line
```

Some users prefer to explicitly mark the end of each expression with a particular symbol. This is possible using the option `explterm` (see Section 2.3) which disables the default behaviour of the compiler. In that case, the line breaking is not considered any more as an expression separator and each statement finishing with an expression must be terminated by the symbol '`;`'.

```
A+B;      ! Expression 1
-C+D;     ! Expression 2
A+B       ! Expression 3...
-C+D;     ! ...end of expression 3
```

2.1.5 Conventions in this document

In the following sections, the language syntax is explained. In all code templates, the following conventions are employed:

- `word`: 'word' is a keyword and should be typed as is;
- *todo*: 'todo' is to be replaced by something else that is explained later;
- *[something]*: 'something' is optional and the entire block of instructions may be omitted;
- *[something ...]*: 'something' is optional but if used, it can be repeated several times.

2.2 Structure of the source file

The Mosel compiler may compile both *models* and *packages* source files. Once compiled, a model is ready for execution but a package is intended to be used by a model or another package (see Section 2.3).

The general structure of a model source file is as follows:

```
model model_name
[ Directives ]
[ Parameters ]
[ Body ]
end-model
```

The `model` statement marks the beginning the program and the statement `end-model` its end. Any text following this instruction is ignored (this can be used for adding plain text comments after the end of the program). The model name may be any quoted string or identifier, this name will be used as the model name in the Mosel model manager. An optional set of *directives* and a *parameters* block may follow. The actual program/model is described in the *body* of the source file which consists of a succession of declaration blocks, subroutine definitions and statements.

The structure of a *package* (see Section 2.12) source file is similar to the one of a model:

```
package package_name
[ Directives ]
[ Parameters ]
[ Body ]
end-package
```

The `package` statement marks the beginning the library and the statement `end-package` its end. The package name must be a valid identifier.

It is important to understand that the language is *procedural* and not *declarative*: the declarations and statements are compiled and executed in the order of their appearance. As a consequence, it is not possible to refer to an identifier that is declared later in the source file or consider that a statement located later in the source file has already been executed. Moreover, the language is *compiled* and not *interpreted*: the entire source file is first translated — as a whole — into a binary form (the *BIM file*), then this binary form of the program is read again to be executed. During the compilation, except for some simple constant expressions, no action is actually performed. This is why only some errors can be detected during the compilation time, any others being detected when running the program.

2.3 The compiler directives

The compiler accepts four different types of directives: the `uses` statement, the `imports` statement, the `options` statement and the `version` statement. Namespace declarations are also expressed by means of directives, see Section 2.13 for further explanations.

2.3.1 Directive `uses`

The general form of a `uses` statement is:

```
uses libname1 [, libname2 ...][;]
```

This clause asks the compiler to load the listed modules or packages and import the symbols they define. Both modules and packages must still be available for running the model. If the source file being

processed is a package, the bim files associated to the listed packages must be available for compiling another file using this package. It is also possible to merge bim files of several packages by using `imports` instead of `uses` when building packages.

By default the compiler tries first to find a package (the corresponding file is *libname.bim*) then, if this fails, it searches for a module (which file name is *libname.dso*). It is possible to indicate the type of library to look for by appending either `".bim"` or `".dso"` to the name (then the compiler does not try the alternative in case of failure). A package may also be specified by an extended file name (see Section 2.15) including the IO driver in order to disable the automatic search (*i.e.* `"a.bim"` searches the file *a.bim* in the library path but `":a.bim"` takes the file *a.bim* from the current directory).

For example,

```
uses 'mmsystem','mmxprs.dso','mypkg.bim'
uses ':/tmp/otherpkg.bim'
```

Both packages and modules are searched in a list of possible locations. Upon startup, Mosel uses as the default for this list the value of the environment variable `MOSEL_DSO` completed by a path deduced from the location (*rtdir*) of the Mosel runtime library (in the following # can be "32" on a 32bit system, "64" on a 64bit system or an empty string):

`"`*`rtdir`*`\..\dso#"` Under Windows if *rtdir* terminates by `"\bin#"` and `"`*`rtdir`*`\..\dso#"` exists or

`"`*`rtdir`*`/../dso#"` On Posix systems if *rtdir* terminates by `"/lib#"` and `"`*`rtdir`*`/../dso#"` exists or

`"`*`rtdir`*`/dso#"` if this directory exists or

`"`*`rtdir`*`"` if none of the above rules apply

The variable `MOSEL_DSO` is expected to be a list of paths conforming to the operating system conventions: for a Posix system the path separator is ':' (*e.g.* `"/opt/Mosel/dso:/tmp"`) and it is ';' under Win32 (*e.g.* `"E:\Mosel\Dso;C:\Temp"`). The search path for modules and packages may also be set from the `mosel` command (using the `-dp` option, see Section 1.3) as well as inspected and modified from the Mosel Libraries (see functions `XPRMgetdsopath` and `XPRMsetdsopath` in the *Mosel Libraries Reference Manual*). Note however that Mosel will ignore modules not located in read-only locations when the restriction `NoExec` is active (see Section 1.3.4).

For locating packages Mosel will use the list of prefixes defined by the compiler option `-bx` (Section 1.3) or the environment variable `MOSEL_BIM` before proceeding to the search as decribed above. This parameter consists in a list of strings separated by the sequence `||` that are used as prefixes to the package name. For instance if the option `-bx "bimdir/||tmp:"` is used with the directive `uses 'mypkg'`, the compiler will try to load the package `"bimdir/mypkg.bim"`, then `"tmp:mypkg.bim"` before looking for `"mypkg.bim"` and `"mypkg.dso"` in the usual locations.

2.3.2 Directive `imports`

The general form of an `imports` statement is:

`imports` *pkgname1 [, pkgname2 ...][;]*

This clause is a special version of the `uses` directive that can only be used for packages: it asks the compiler to load the listed packages, import the symbols they define and incorporate the corresponding bim file. As a consequence, the generated file provides the functionality of the packages it imports. When used on a model file it removes the dynamic dependency on the listed packages (*i.e.* these packages are no longer required to run the model).

For example,

```
imports 'mypkg'
```

2.3.3 Directive options

The compiler options may be used to modify the default behaviour of the compiler. The general form of an `options` statement is:

`options` *optname1 [, optname2 ...]*

The supported options are:

- `explterm`: asks the compiler to expect explicit expression termination (see Section 2.1.4).
- `noimplicit`: disables the implicit declarations (see Section 2.8.1.5). This option can also be activated by using the '**`-ni`**' compiler flag (see Section 1.3)
- `noautofinal`: by default initialization from blocks finalize sets they populate (section 2.8.2.2). This option disables this behaviour that may be activated afterwards using the `autofinal` control parameter (*cf.* `setparam`).
- `keepassert`: assertions (*cf.* `assert`) are compiled only in debug mode. With this option assertions are preserved regardless of the compilation mode.
- `xbim`: store additional symbol information in the generated bim file (in particular array index names). This option can also be enabled by using the '**`-I`**' compiler flag (see Section 1.3).
- `fctasproc`: by default return values of functions must be used such that a function call is not a valid statement. With this option functions can be used as procedures: when a statement consists in a function call its return value is silently ignored (see also `asproc`).
- `tagpriv`: when the model is compiled with debug information private symbols are preserved. When this option is used these symbols are prefixed with `'~'` such that they can be easily identified.
- `dynonly`: this option can only be applied to a package: it marks the package as dynamic only such that it cannot be imported (see Section 2.3.2).

For example,

```
options noimplicit,explterm
```

2.3.4 Directive version

In addition to the model/package name, a file version number may be specified using this directive: a version number consists in 1, 2 or 3 integers between 0 and 999 separated by the character `'.'`.

`version` *major [. minor [. release]]*

For example,

```
version 1.2
```

The file version is stored in the BIM file and can be displayed from the Mosel console (command `list`) or retrieved using the Mosel Libraries (see function `XPRMgetmodprop` in the *Mosel Libraries Reference Manual*). From the model itself, the version number is recorded as a string in the control parameter `model_version` (see function `getparam`).

2.4 The parameters block

A model parameter is a symbol, the value of which can be set just before running the model (optional parameter of the 'run' command of the command line interpreter). The general form of the parameters block is:

```
parameters
   ident1 = Expression1
[ ident2 = Expression2 ...]
end-parameters
```

where each identifier *identi* is the name of a parameter and the corresponding expression *Expressioni* its default value. This value is assigned to the parameter if no explicit value is provided at the start of the execution of the program (*e.g.* as a parameter of the 'run' command). Note that the type (integer, real, text string or Boolean) of a parameter is implied by its default value. Model parameters are manipulated as constants in the rest of the source file (it is not possible to alter their original value).

```
parameters
  size=12         ! Integer parameter
  R=12.67         ! Real parameter
  F="myfile"      ! Text string parameter
  B=true          ! Boolean parameter
end-parameters
```

In addition to model parameters, Mosel and some modules and packages provide *control parameters* : they can be used to give information on the system (*e.g.* success of an I/O operation) or control its behaviour (*e.g.* select output format of real numbers). These parameters can be accessed and modified using the routines `getparam` and `setparam`. Refer to the documentation of these functions for a complete listing of available Mosel parameters. The documentation of the modules include the description of the parameters they publish.

2.5 Source file preprocessing

2.5.1 Source file character encoding

The Mosel compiler expects source files to be encoded in UTF-8 and will handle properly UTF-16 and UTF-32 encodings when the file begins with a BOM (Byte Order Mark). It is also possible to select an alternative encoding using the `encoding` annotation (see section 2.14).

For instance to notify the compiler that the the source file is encoded using ISO-8859-1, the following comment has to be copied at the beginning of the fie:

```
!@encoding:iso-8859-1
```

2.5.2 Source file inclusion

A Mosel program may be split into several source files by means of file inclusion. The '`include`' instruction performs this task:

```
include filename
```

where *filename* is the name of the file to be included. This file name may contain environment variable references using the notation `${varname}` (*e.g.* '`${MOSEL}/examples/mymodel`') that are expanded to generate the actual name. The '`include`' instruction is replaced at compile time by the contents of

the file *filename*.

Assuming the file `a.mos` contains:

```
model "Example for file inclusion"
  writeln('From the main file')
  include "b.mos"
end-model
```

And the file `b.mos`:

```
  writeln('From an included file')
```

Due to the inclusion of `b.mos`, the file `a.mos` is equivalent to:

```
model "Example for file inclusion"
  writeln('From the main file')
  writeln('From an included file')
end-model
```

If the compiler option `-ix` is used (Section 1.3) all file names used in the 'include' instruction will be prefixed as requested. For instance, if the option `-ix "incdir/"` is used with the compiler, the statement `include "myfile.mos"` will be replaced by the content of `"incdir/myfile.mos"`.

Note that file inclusion cannot be used inside of blocks of instructions or before the body of the program (as a consequence, a file included cannot contain any of the following statements: `uses`, `options` or `parameters`).

2.5.3 Line control directives

In some cases it may be useful to process a Mosel source through an external preprocessor before compilation. For instance this may enable the use of facilities not supported by the Mosel compiler like macros, unrestricted file inclusion or conditional compilation. In order to generate meaningful error messages, the Mosel compiler supports *line control* directives: these directives are inserted by preprocessors (*e.g.* cpp or m4) to indicate the original location (file name and line number) of generated text.

```
# [line] linenum [filename]
```

To be properly interpreted, a line control directive must be the only statement of the line. Malformed directives and text following valid directives are silently ignored.

2.6 The declaration block

The role of the declaration block is to give a name, a type, and a structure to the entities that the processing part of the program/model will use. The type of a value defines its domain (for instance integer or real) and its structure, how it is organized, stored (for instance a reference to a single value or an ordered collection in the form of an array). The declaration block is composed of a list of declaration statements enclosed between the instructions `declarations` and `end-declarations`.

```
declarations
   Declare_stat
   [ Declare_stat ...]
end-declarations
```

Several declaration blocks may appear in a single source file but a symbol introduced in a given block

cannot be used before that block. Once a name has been assigned to an entity, it cannot be reused for anything else.

2.6.1 Elementary types

Elementary objects are used to build up more complex data structures like sets or arrays. It is, of course, possible to declare an entity as a reference to a value of one of these elementary types. Such a declaration looks as follows:

ident1 [, ident2 ...]: [`shared`] *type_name*

where *type_name* is the type of the objects to create. Each of the identifiers *identi* is then declared as a reference to a value of the given type. The type name may be either a basic type (`integer`, `real`, `string`, `boolean`), an MP type (`mpvar`, `linctr`), an external type or a user defined type (see section 2.6.9). MP types are related to Mathematical Programming and allow declaration of decision variables and linear constraints. Note that the linear constraint objects can also be used to store linear expressions. External types are defined by modules (the documentation of each module describes how to use the type(s) it implements). The qualifier `shared` identifies variables that will be shared between several concurrent models (see Section 8.2). Only entities of basic types and external types supporting sharing can be shared.

```
declarations
  i,j: integer
  str: string
  x,y,z: mpvar
end-declarations
```

2.6.1.1 Basic types

The basic types are:

- `integer`: an integer value between `-2147483648` and `2147483647`. Integers may also be expressed in hexadecimal by using the prefix `0x` or `0X` (*e.g.* `0x7b` is the same as `123`)
- `real`: an approximation of a real value stored as a double precision floating-point number (values ranging between `-1.7e+308` and `1.7e+308`). Floating point numbers expressed in hexadecimal can also be used as real constants. The general form of such a constant is `0x`*h*`.hhh`*p*`[+/-]ddd` where `'h'` are hexadecimal digits and `'d'` decimal digits (*e.g.* `0x1.9p+3` is the same as `12.5`)
- `string`: some text.
- `boolean`: the result of a Boolean (logical) expression. The value of a Boolean entity is either the symbol `true` or the symbol `false`.

After its declaration, each entity receives an initial value of `0`, an empty string, or `false` depending on its type.

2.6.1.2 MP types

Two special types are provided for mathematical programming.

- `mpvar`: a decision variable
- `linctr`: a linear constraint

2.6.2 Sets

Sets are used to group an unordered collection of elements of a given type. Set elements are unique: if an element is added several times it is only contained once in the set. Declaring a set consists of defining the type of elements to be collected.

The general form of a set declaration is:

ident1 [, *ident2* ...] : [`shared`] [`dynamic`] `set of` [`constant`] *type_name*

where *type_name* is one of the elementary types. Each of the identifiers *identi* is then declared as a set of the given type. The qualifier `shared` identifies sets that will be shared between several concurrent models (see Section 8.2). Only sets of basic types can be shared. If the qualifier `dynamic` is used the corresponding set(s) will never be finalized (see Section 2.8.2.2 and procedure `finalize`).

A set may collect references to constant elements of non-basic types: this kind of set will be created if the type name is preceded by the `constant` keyword. Only native types supporting the `constant` keyword and user defined types (see Section 2.6.9) referring to records including only basic types (see Section 2.6.5) or unions compatible only with basic types (see Section 2.6.7) can be used in this context. As opposed to an ordinary set, a set of *constant references* behaves as if it was collecting values of the native type entities instead of their references. For instance adding 2 different variables of some native type to a normal set will always result in 2 elements added to the set. However a single element will be added to a set of constant references if these 2 variables have the same content (or the same textual representation). Moreover, since references are not directly collected, any change to a variable previously added to a set of constant references has no impact on the content of this set.

A particular set type is also available that should be preferred to the general form wherever possible because of its better efficiency: the range set is an ordered collection of consecutive integers in a given interval. The declaration of a range set is achieved by:

ident1 [, *ident2* ...] : [`shared`] [`dynamic`] `range` [`set of integer`]

Each of the identifiers *identi* is then declared as a range set of integers. Every newly created set is empty.

```
declarations
  s1: set of string
  r1: range
  ds: set of constant date   ! type 'date' from module 'mmsystem'
end-declarations
```

2.6.3 Lists

Lists are used to group a collection of elements of a given type. An element can be stored several times in a list and order of the elements is specified by construction. Declaring a list consists of defining the type of elements to be collected.

The general form of a list declaration is:

ident1 [, *ident2* ...] : [`shared`] `list of` *type_name*

where *type_name* is one of the elementary types. Each of the identifiers *identi* is then declared as a list of the given type. The qualifier `shared` identifies lists that will be shared between several concurrent models (see Section 8.2). Only lists of basic types can be shared.

Every newly created list is empty.

```
declarations
```

```
  l1: list of string
  l2: list of real
end-declarations
```

A list element can be accessed using its order number. The first element has number `1` and index values inferior to `1` point to elements starting from the end of the list. For instance if `l` is a list, `l(2)` is the second element of this list, `l(0)` is the last element of the list and `l(-1)` its predecessor.

2.6.4 Arrays

An array is a collection of labelled objects of a given type. A label is defined by a list of indices taking their values in domains characterized by sets: the indexing sets. An array may be either dense or sparse: every possible index tuple is associated to a cell in a dense array while sparse arrays are created *empty*. The cells are then created explicitly (*cf.* procedure `create`) or when they are assigned a value (*cf.* Section 2.8.1.1) and the array may then grow 'on demand'. It is also possible to delete some or all cells of a dynamic array using the procedure `delcell`. A cell that has not been created can be identified using the `exists` function and its value is the default initial value of the type of the array. The general form of an array declaration is:

ident1 [, *ident2* ...] : [`shared`] [`dynamic`|`hashmap`] `array` (*list_of_sets*) `of` *type_name*

where *list_of_sets* is a list of set declarations/expressions separated by commas and *type_name* is one of the elementary types. Each of the identifiers *identi* is then declared as an array of the given type and indexed by the given sets. In the list of indexing sets, a set declaration can be anonymous (*i.e.* `rs:set of real` can be replaced by `set of real` if no reference to `rs` is required) or shortened to the type of the set (*i.e.* `set of real` can be replaced by `real` in that context). An anonymous indexing set is *attached* to the array: it is created at the same time as the array and, if its reference has not been saved separately, it will be cleared when the array is reset (see `reset`) and deleted when the array is released. Note also that different arrays sharing the same declaration including anonymous sets will not use the same indexing sets. For instance, in the following declaration the arrays `a1` and `a2` do not have the same first indexing set:

```
declarations
  a1,a2:array ( range, S:set of string ) of real
end-declarations
```

The qualifier `shared` identifies arrays that will be shared between several concurrent models (see Section 8.2). Only arrays of basic types and indiced by shared or constant sets of basic types can be shared.

```
declarations
  e: set of string
  t1:array ( e, rs:set of real, range, integer ) of real
  t2:array ( {"i1","i2"}, 1..3 ) of integer
end-declarations
```

By default an array is dense (or static). For best performane it is better to index static arrays with constant sets or initialize and finalize indexing sets as soon as possible (*cf.* procedure `finalize`). An array is sparse (or dynamic) and created empty if either the qualifier `dynamic` or `hashmap` is used. Arrays declared with either of these qualifiers behave the same but their internal representation differ: the *dynamic* representation requires less memory and is faster for linear enumeration while the *hashmap* representation is faster for random access.

Note that once a set is employed as an indexing set, Mosel makes sure that its size is never reduced in order to guarantee that no entry of any array becomes inaccessible. Such a set is called *fixed*.

2.6.4.1 Special case of dynamic arrays of a type not supporting assignment

Certain types do not have assignment operators: for instance, writing `x:=1` is a syntax error if `x` is of type `mpvar`. If an array of such a type is defined as dynamic the corresponding cells are not created. In that case, it is required to create each of the relevant entries of the array by using the procedure `create` since entries cannot be defined by assignment.

2.6.5 Records

A record is a finite collection of objects of any type. Each component of a record is called a *field* and is characterized by its name (an identifier) and its type. The general form of a record declaration is:

ident1 [, ident2 ...] : `record`
  field1 [, field2 ...]: *type_name*
  [...]
`end-record`

where *fieldi* are the identifiers of the fields of the record and *type_name* one of the elementary types. Each of the identifiers *identi* is then declared as a record including the listed fields.

Example:

```
declarations
  r1: record
       i,j:integer
       r:real
      end-record
end-declarations
```

Each record declaration is considered unique by the compiler. In the following example, although `r1` and `r2` have the same definitions, they are not of the same type (but `r3` is of course of the type of `r2`):

```
declarations
  r1: record
       i,j:integer
      end-record
  r2,r3: record
       i,j:integer
      end-record
end-declarations
```

2.6.6 Subroutine references

Subroutines are typically used to execute predefined operations, for instance, the function `cos` computes a cosine value while the procedure `write` displays some text on the console. A *subroutine reference* is an entity that is able to store a reference to a procedure or a function. The general form of a subroutine reference declaration is:

ident1 [, ident2 ...] : `procedure` *[(List_of_params)]*
or
ident1 [, ident2 ...] : `function` *[(List_of_params)]*: *Type*

Where *List_of_params* and *Type* are the properties of a compatible subroutine (see section 2.9). After its creation a subroutine reference does not refer to any actual routine and is considered as *undefined* (use `isdefined` to identify this state); it can only be used (see section 2.7 and 2.8.1.8) once it has been

associated to a proper routine via an assignment (see section 2.8.1.3). This association may be cancelled using `reset`.

The following example declares `myfunc` as a reference to a function returning a real and expecting a real as parameter; this symbol could be used to hold any function similar to `cos` or `arctan` for instance:

```
declarations
  myfunct: function (real):real
end-declarations
```

2.6.7 Unions

A union is a container capable of holding an object of one of a predefined set of types. Defining an entity of this kind consists in specifying this set of *compatible types* or using the predefined union type `any` than can handle any type without restriction. The general form of a union declaration is:

ident1 [`,` *ident2 ...*] : *type1* `or` *type2* [`or` *type3...*]
or
ident1 [`,` *ident2 ...*] : `any`

where *typei* is one of the compatible types for each of the identfiers *identi*. Although this enumeration is not ordered the first type (*type1*) has a special meaning as it defines the representation to use when the union is initialized from some textual form (see Section 2.8.2). In the case of the predefined union type `any` the textual representation is handled by a `string`. If one of the compatible types is also a union the resulting set of compatible types will include all types of this union.

Example:

```
declarations
  u: string or integer or boolean
  ua: text or any
 end-declarations
```

In the example above the identifier 'u' can contain either a string or an integer or a boolean (but not several values of these types at the same time). The identifier 'ua' can receive a value of any type as if it was declared as an 'any' except that the type 'text' will be used for textual initialisation (instead of 'string' as implied by 'any').

In its initial state a union is *undefined*: it gets a value (and a type) either via assignment (see Section 2.8.1.4) or with the help of the `create` function. The state of a union can be checked with `isdefined` and the function `reset` may be used to clear a union and restore its initial state.

2.6.8 Constants

A constant is an identifier for which the value is known at declaration time and that will never be modified. The general form of a constant declaration is:

identifier = *Expression*

where *identifier* is the name of the constant and *Expression* its initial and only value. The expression must be of one of the basic types, a set or a list of one of these types, a native type supporting constant definition, or a record type containing only basic types.

Example:

```
declarations
  STR='my const string'
```

```
  I1=12
  R=1..10          ! constant range
  S={2.3,5.6,7.01} ! constant set
  L=[2,4,6]        ! constant list
end-declarations
```

The compiler supports two kinds of constants: a *compile time constant* is a constant which value can be computed by the compiler. A *run time constant* will be known only when the model is run.

Example:

```
parameters
  P=0
end-parameters
declarations
  I=1/3            ! compile time constant
  J=P*2            ! run time constant
end-declarations
```

2.6.9 User defined types

2.6.9.1 Naming new types

A new type may be defined by associating an identifier to a type declaration. The general form of a type definition is:

identifier = Type_def

where *Type_def* is a type (elementary, set, list, array or record) to be associated to the symbol *identifier*. After such a definition, the new type may be used wherever a type name is required.

Example:

```
declarations
  entier=integer
  setint=set of entier
  arr=array(range) of integer
  myany=string or integer
  i:entier           ! <=> i:integer
  s:setint           ! <=> s:set of integer
  a:arr              ! <=> a:array(range) of integer
end-declarations
```

2.6.9.2 Combining types

Thanks to user defined types one can create complex data structures by combining structures offered by the language. For instance an array of sets may be defined as follows:

```
declarations
  typset=set of integer
  a1:array(1..10) of typset
end-declarations
```

In order to simplify the description of complex data structures, the Mosel compiler can generate automatically the intermediate user types. Using this property, the example above can be written as follows (both arrays `a1` and `a2` are of the same type):

```
declarations
  a2:array(1..10) of set of integer
end-declarations
```

2.7 Expressions

Expressions are, together with the keywords, the major building blocks of a language. This section summarizes the different basic operators and connectors used to build expressions.

Expressions are constructed using constants, operators and identifiers (of objects or functions). If an identifier appears in an expression its value is the value referenced by this identifier. In the case of a set, a list, an array or a record, it is the whole structure. To access a single cell of an array, it is required to 'dereference' this array. The dereferencing of an array is denoted as follows:

array_ident (*Exp1 [, Exp2 ...]*)

where *array_ident* is the name of the array and *Expi* an expression of the type of the i^{th} indexing set of the array. The type of such an expression is the type of the array and its value the value stored in the array with the label '*Exp1 [, Exp2 ...]*'. In order to access the cell of an array of arrays, additional indexing sequences may be appended or the list of indices for the second array can be added to the list of indices of the first array. For instance, the array `a:array(1..10) of array(1..10) of integer` can be dereferenced with `a(1)(2)` or `a(1,2)`.

Indexing sets of an array may be accessed using the following syntax:

array_ident`.index(`*i*`)` *[.type_name]*
or
array_ident`.index(`*i*`).range`

Where *array_ident* is a reference to an array and *i* an integer indicating which index to consider (*e.g.* `1` for the first index set, see `getnbdim`). The value of this expression is a set which type will be defined only when the index set number is a compile time constant. The type *type_name* (or the keyword `range`) might be added to the expression in order to enforce a type when it cannot be detected at compile time (a runtime error will be raised if this type does not correspond to the set or if the index number is not valid).

Similarly, to access the field of a record, it is required to 'dereference' this record. The dereferencing of a record is denoted as follows:

record_ident`.`*field_ident*

where *record_ident* is the name of the record and *field_ident* the name of the required field.

Dereferencing arrays of records is achieved by combining the syntax for the two structures. For instance `a(1).b`

Accessing the value of a union is about the same as dereferencing a record except that field names are replaced by type names:

union_ident`.`*type_name*

where *union_ident* is the name of the union and *type_name* the name of one of its compatible types (for instance `u.integer`). Trying to access a type that does not correspond to the actual value stored in the union will cause the execution of the program to terminate on an error: the properties of the union to inspect must be checked prior to its dereferencing (see functions `gettypeid`, `getstruct` and `geteltype` or Section 2.7.7 regarding the `is` operator). However, dereferencing a union for an assignment (see Section 2.8.1.1) will impose the type of the union: if the union is already of the designed type, its value will be updated, otherwise the current entity held in the union will be released and a new instance of the requested type will be created.

Unions may also be accessed via the expected structure they hold:

union_ident . *struct_name*[. *type_name*]

Where *struct_name* is either `array`, `set`, `range` or `list`. With only a structure this expression is untyped and can be only used in operations where knowing the structure is sufficient (*e.g.* with the function `getsize` or the construct `index` on an array as described above). Except for `range` it is necessary to append a type name to get a fully defined expression (for instance `u.set.integer`).

Arrays and lists held in a union can be directly dereferenced as follows:

union_ident . `array` (*Exp1* [, *Exp2* ...]) . *type_name*
or
union_ident . `list` (*Exp1*) . *type_name*

As for the preceding options for derefrencing unions, the structure and type of the entity stored in the union must match the expression otherwise a runtime error is raised.

Each type is associated with an *identification number*. This *ID*, a positive integer, can be retrieved using the following notation:

type_name . id

where *type_name* is the name of a type. The elementary types `integer`, `real`, `string`, `boolean`, `mpvar` and `linctr` have a constant ID (respectively 1,2,3,4,5 and 6) that never changes but all other types (like native types published by modules or user defined types) are assigned their ID at the beginning of the execution of the model such that it may change between executions (but this value is constant during a given execution).

A function call is denoted as follows:

function_ident
or
function_ident (*Exp1* [, *Exp2* ...])

where *function_ident* is either the name of a function or a function reference and *Expi* the i^{th} parameter required by this function (note that function parameters are evaluated from right to left). The first form is for a function requiring no parameter.

The special function `if` is an operator that allows one to make a selection among expressions. Its syntax is the following:

`if` (*Bool_expr*, *Exp1*, *Exp2*)

which evaluates to *Exp1* if *Bool_expr* is `true` or *Exp2* otherwise. The type of this expression is the type of *Exp1* and *Exp2* which must be of the same type.

Parentheses may be used to modify the predefined evaluation order of the operators (see Table 2.1) or simply to group subexpressions.

Operators that result in statements are discussed in other sections:

- assignment operators: `:=` `+=` `-=` (see Section 2.8.1.1)
- inline array initialization: `::` (see Section 2.8.1.6))

Table 2.2 summarizes the meaning and applicability of operators that are discussed for the different expression types in the following sections.

Table 2.1: Priority and evaluation order of operators in Mosel (smaller values indicate higher priority)

Priority	Operators	Sense of evaluation
1	`()` `{}` `[]` `.` `if` `count` function calls type conversions	→
2	$-_{unary}$ `^` `is`	←
3	`*` `/` `div` `mod` `prod` `inter`	→
4	`+` $-_{binary}$ `sum` `union` `max` `min`	→
5	`<` `<=` `>` `>=` `=` `<>` `in` `not in`	→
6	`not`	→
7	`and`	→
8	`or`	→
9	`array`	→

Table 2.2: Meaning of operators for different expression types

Type	Operators	Description
All expressions	`()`	Changing the evaluation order
All except linear constraints	`if`	Inline 'if'
Unions	`is` `is not`	Test properties
Symbols	`->`	'reference to' operator
Arithmetic expressions	`count`	Counter
	`^`	Exponential operator
	`*` `/` `prod`	Multiplication and division
	`div` `mod`	Integer division and modulo
	`+` `-` `sum`	Addition and substraction
	`max` `min`	Maximum and minimum value
	`<` `<=` `>` `>=` `=` `<>`	Comparators
String expressions	`+`	Concatenation
	`-`	Difference
	`<` `<=` `>` `>=` `=` `<>`	Comparators (see Section 2.7.7)
Set expressions	`{}`	Constant set definition
	`*` `inter`	Intersection
	`+` `union`	Union
	`-`	Difference
	`<=`	Subset
	`>=`	Superset
	`=` `<>`	Equality and difference of contents
	`in` `not in`	Set element
	`range` `set`	Constructors; clone operators
List expressions	`[]`	Constant list definition
	`+` `sum`	Concatenation
	`-`	Difference
	`=` `<>`	Equality and difference of contents
	`list`	Constructor; clone operator
Boolean expressions	`not`	Negation
	`and`	Logic 'and'
	`or`	Logic 'or'
Linear constraint expressions	`*`	Multiplication (one operand must be of numerical type)
	`+` `-` `sum`	Addition / subtraction
	`<=` `>=` `=`	Relational operators
Automatic arrays	`::`	Inline array initialization (see Section 2.8.1.6)
	`=` `<>`	Equality and difference of contents
	`array`	Constructor

2.7.1 Type conversions and constructors

The Mosel compiler operates automatic conversions to the type required by a given operator in the following cases:

- in the dereference list of an array:
  `integer` → `real`;
- in a function or procedure parameter list:
  `integer` → `real`, `linctr`;
  `real` → `linctr`;
  `mpvar` → `linctr`;
- anywhere else:
  `integer` → `real`, `string`, `linctr`;
  `real` → `string`, `linctr`;
  `mpvar` → `linctr`;
  `boolean` → `string`.

It is possible to force a basic type conversion using the type name as a function (*i.e.* `integer`, `real`, `string`, `boolean`). In the case of `string`, the result is the textual representation of the converted expression. Note that the conversion of a real to a string depends on the control parameters `realfmt`, `zerotol` and `txtztol` (see `setparam`). In the case of `boolean`, for numerical values, the result is `true` if the value is nonzero and for strings the result is `true` if the string is the word 'true'. When converting a real to an integer the result is the integral part of the number (no rounding is performed). Note that explicit conversions are not defined for MP types, and structured types (*e.g.* `linctr(x)` is a syntax error).
For generating numerical values from strings it is in general preferrable to use the subroutines `parseint`/`parsereal` that provide error handling functionality in place of the basic conversion available through `integer`/`real`.

```
! Assuming A=3.6, B=2
  integer(A+B)          ! = 5
  string(A-B)           ! = "1.6"
  real(integer(A+B))    ! = 5.6 (because the compiler simplifies
                                 the expression)
```

Some native and record types might be used as function names to create new instances of the corresponding type (see the documentation of each individual type for a list of possible constructors). If the only argument of such a function call is an entity of the same type the result is a copy of the argument (the type must support assignment). For record types a specific syntax makes it possible to create and initialize each field of the newly created entity in a single operation:

type_name (*.field1*:=*val1* [, *.field2*:=*val2* ...])

where *type_name* is the name of a record type and *fieldi* one of its fields to be initialised with the corresponding *vali* value.

A local instance of a given type can be obtained with the following syntax:

(*type_name*)

Where *type_name* is the name of a non basic type (*i.e.* any type except `integer`, `real`, `string` and `boolean`). The result of this expression is a newly created instance of the type local to the current expression.

The constructor `array` (see 2.7.9) for creating new arrays ad-hoc is an aggregate operator, via `list` (see 2.7.6), `set` and `range` (see 2.7.5) it is possible to perform transformations between set and list structures.

2.7.1.1 Union constructors and subroutine parameters

Similarly to native types a union type may be used as a function that takes a single parameter. As a result of such a construct a new instance of the specified union type is returned taking the same value and type as the given parameter. If this parameter is not of a basic type (like a native object) the newly created entity will contain a reference to this object. Moreover if the parameter is another union the resulting entity will receive a reference to the value of this union (instead of a reference to the union) if this value is also a reference. However it will receive a copy of this value if it is a basic type. Note that in this case the compiler may not be able to detect a type incompatibility and a runtime error may happen if the value of the entity given as parameter is not compatible with the target union.

This *wrapping* mechanism is also used when a subroutine expects a union but it receives a compatible type or a different union type: the compiler creates a local union of the required type initialized with the provided value or reference.

2.7.2 Aggregate operators

Table 2.3: Aggregate operators in Mosel with default values for empty expressions

Operator	Description	Default values
`count`	Counter	0
`prod`	Product	1
`inter`	Intersection of sets	empty set
`sum`	Sum (arithmetic); concatenation (list, text)	arithmetic: 0, list: empty list
`union`	Union of sets; concatenation of lists	empty set or list
`max`	Maximum value	real: -MAX_REAL, integer: -MAX_INT-1
`min`	Minimum value	real: MAX_REAL, integer: MAX_INT
`and`	Logic 'and'	`true`
`or`	Logic 'or'	`false`
`array`	Array creation	dynamic empty array

An operator is said to be *aggregate* when it is associated to a list of indices for each of which a set or list of values is defined. This operator is then applied to its operands for each possible tuple of values (*e.g.* the summation operator `sum` is an aggregate operator). The general form of an aggregate operator is:

Aggregate_ident (*Iterator1 [, Iterator2 ...]*) *Expression*
or
`count` (*Iterator1 [, Iterator2 ...]*)

where the *Aggregate_ident* is the name of the operator and *Expression* an expression compatible with this operator (see below for the different available operators). The type of the result of such an aggregate expression is the type of *Expression*. The `count` operator does not require an additional expression: its value, an integer, corresponds to the number of times the expression of another aggregate operator used with the same iterator list would be evaluated (*i.e.* it is equivalent to `sum(iteratorlist) 1`).

An iterator is one of the following constructs:

SetList_expr
or
ident1 [, ident2 ...] `in` *SetList_expr [*`|` *Bool_expr]*
or
ident = *Expression [*`|` *Bool_expr]*
or
ident `as counter`

The first form gives the list of the values to be taken without specifying an index name. With the second form, the indices named *identi* take successively all values of the set or list defined by *SetList_expr*. With the third form, the index *ident* is assigned a single value (which must be a scalar). For the second and third cases, the scope of the created identifier is limited to the scope of the operator (*i.e.* it exists only for the following iterators and for the operand of the aggregate operator). Moreover, an optional condition can be stated by means of *Bool_expr* which can be used as a filter to select the relevant elements of the domain of the index. It is important to note that this condition is evaluated as early as possible. As a consequence, a Boolean expression that does not depend on any of the defined indices in the considered iterator list is evaluated only once, namely *before* the aggregate operator itself and not for each possible tuple of indices. The last form of an iterator declares a *counter* for the operator: the value of the corresponding symbol is incremented each time the operator's expression is evaluated. For this case, if *ident* has been declared before, it must be integer or real and its value is not reset. Otherwise, as for indices, the scope of the created integer identifier is limited to the scope of the operator and its initial value is 0. There can be only one counter for a given aggregate operator.

The Mosel compiler performs loop optimization when function `exists` is used as the first factors of the condition in order to enumerate only those tuples of indices that correspond to actual cells in the array instead of all possible tuples. To be effective, this optimization requires that sets used to declare the array on which the exist condition applies must be named and the same sets must be used to define the index domains. Moreover, the maximum speedup is obtained when order of indices is respected and all indices are defined in the same aggregate operator.

An index is considered to be a constant: it is not possible to change explicitly the value of a named index (using an assignment for instance).

2.7.3 Arithmetic expressions

Numerical constants can be written using the common scientific notation. Arithmetic expressions are naturally expressed by means of the usual operators (+, –, `*`, `/` division, unary –, unary +,^raise to the power). For integer values, the operators `mod` (remainder of division) and `div` (integral division) are also defined. Note that `mpvar` objects are handled like real values in expression.

The `sum` (summation) aggregate operators is defined on integers, real and mpvar. The aggregate operators `prod` (product), `min` (minimum) and `max` (maximum) can be used on integer and real values.

```
x*5.5+(2+z)^4+cos(12.4)
sum(i in 1..10) (min(j in s) t(i)*(a(j) mod 2))
```

2.7.4 String expressions

Constant strings of characters must be quoted with single (') or double quote (") and may extend over several lines. Strings enclosed in double quotes may contain C-like escape sequences introduced by the 'backslash' character (`\a \b \f \n \r \t \v \xxx \uhhhh` with `xxx` being the character code as an octal number and `hhhh` a Unicode code as a four hexadecimal digits number).

Each sequence is replaced by the corresponding control character (*e.g.* `\n` is the 'new line' command) or, if no control character exists, by the second character of the sequence itself (*e.g.* `\\` is replaced by '\').

The escape sequences are not interpreted if they are contained in strings that are enclosed in single quotes.

Example:

```
'c:\ddd1\ddd2\ddd3' is understood as c:\ddd1\ddd2\ddd3
"c:\ddd1\ddd2\ddd3" is understood as c:ddd1ddd2ddd3
```

There are two basic operators for strings: the concatenation, written '+' and the difference, written '–'.

```
"a1b2c3d5"+"e6"    ! = "a1b2c3d5e6"
'a1b2c3d5'-"3d5"   ! = "a1b2c"
```

A constant string may also take 2 additional forms: initialised from the content of an external file or as a portion of the current input file. For the first case, a text string enclosed in backquotes will be replaced by the content of the file identified by this enclosed text. For the second case, a line ending by the backquote character optionally followed by some label (consisting in any sequence of characters not including backquote) will be interpreted as the beginning of a text block. The end of this text block is marked by a line starting with the previously used label (if any) followed by the backquote character.

Example:

```
`afile.txt` ! This string is the content of "afile.txt"
`MyMarker
line1
line2
MyMarker`  ! This string is equivalent to "line1\nline2\n"
```

2.7.5 Set expressions

Constant sets are described using one of the following constructs:

{[Exp1 [, Exp2 ...]]}
or
Integer_exp1 . . Integer_exp2

The first form enumerates all the values contained in the set and the second form, restricted to sets of integers, gives an interval of integer values. This form implicitly defines a range set.

The basic operators on sets are the union written +, the difference written – and the intersection written `*`.

The aggregate operators `union` and `inter` can also be used to build up set expressions.

```
{1,2,3}+{4,5,6}-(5..8)*{6,10}             ! = {1,2,3,4,5}
{'a','b','c'}*{'b','c','d'}               ! = {'b','c'}
union(i in 1..4|i<>2) {i*3}               ! = {3,9,12}
inter(i in [2,3]) union(j in 1..10) {i*j} ! = {6,12,18}
```

If several range sets are combined in the same expression, the result is either a range or a set of integers depending on the continuity of the produced domain. If range sets and sets of integers of more than one element are combined in an expression, the result is a set of integers. It is however possible to convert a set of integers to a range by using the notation `range(`*`setexpr`*`)` where *setexpr* is a set expression which result is either a set of integers or a range. Similarly stating `set(`*`lstexpr`*`)` will generate a set from the elements of the list expression *lstexpr*.

2.7.6 List expressions

A constant list consist in a list of expressions enclosed in square brackets:

[[Exp1 [, Exp2 ...]]]

There are two basic operators for lists: the concatenation, written '+' and the difference, written '–'. The aggregate operator `sum` can also be used to build up list expressions (the operator `union` behaves like `sum` when applied to lists).

```
[1,2,3]+[1,2,3]         ! = [1,2,3,1,2,3]
[1,2,3,4]-[3,4]         ! = [1,2]
sum(i in 1..3) [i*3]    ! = [3,6,9]
```

List expressions are *untyped* when they include values of different types. When possible the compiler will convert elements of an untyped list to the required type. For instance list of a mix of integers and reals (or a list of integers) will be converted to a list of reals to perform an assignment to a list of reals. Otherwise untyped lists are converted to lists of `any` (see Section 2.6.7).

A list can also be constructed from the elements of a set using the syntax `list(`*setexpr*`)` where *setexpr* is a set expression.

2.7.7 Boolean expressions

A Boolean expression is an expression whose result is either true or false. The traditional comparators are defined on integer and real values: <, <=, =, <> (not equal), >=, >. Comparisons are performed within the tolerance specified by the control parameter `"zerotol"` (see `setparam`) when these operators are applied to reals. For instance, two real values *a* and *b* will be considered equal if $abs(a - b) \leq zerotol$.

These comparison operators are also defined for string expressions. In that case, the order is defined by the ISO-8859-1 character set (*i.e.* roughly: punctuation <digits <capitals <lower case letters <accented letters).

With sets, the comparators <= ('is subset of'), >= ('is superset of'), = ('equality of contents') and <> ('difference of contents') are defined. These comparators must be used with two sets of the same type. Moreover, the operator '*expr* `in` *Set_expr*' is `true` if the expression *expr* is contained in the set *Set_expr*. The opposite, the operator `not in` is also defined.

With lists, the comparators = ('equality of contents') and <> ('difference of contents') are defined. These comparators must be used with two lists of the same type.

With arrays, the comparators = ('equality of contents') and <> ('difference of contents') are defined. These comparators must be used with two arrays of the same type and this type must support the requested operator (for instance arrays of `mpvar` cannot be compared).

With records, the comparators = ('equality of contents') and <> ('difference of contents') are defined. These comparators must be used with two records of the same type and all fields of this record type must support the requested operator (for instance records including `mpvar` entries cannot be compared).

With unions, the comparators = ('equality of contents') and <> ('difference of contents') are defined. These comparators can be used either between two unions (not necessarily from the same definition) or between a union and an entity of one of its compatible types. The result of the comparison is `true` if the two operands are of the same type, can be compared and have the same value. Two unions are also considered equal if they are both uninitialized.

The operator `is` (as well as its opposite `is not`) is also defined on unions: its left operand must be a union and its right operand can be either a type name (like `integer` or `string`) or a structure name (`array`, `set`, `range`, `list`, `record`, `procedure` or `function`) optionally followed by `of` and a type specification (for instance `u is list of real`). The value of the test is `true` if the type ID of the union (see `gettypeid`) corresponds to the specified type or if the union is of the specified structure (see `getstruct`).

To combine Boolean expressions, the operators `and` (logical and) and `or` (logical or) as well as the unary

operator `not` (logical negation) can be used. The evaluation of an arithmetic expression stops as soon as its value is known.

The aggregate operators `and` and `or` are the natural extension of their binary counterparts.

```
3<=v1 and v2>=45 or t<>r and not r in {1..10}
and(i in 1..10) 3<=arr(i)
```

2.7.8 Linear constraint expressions

Linear constraints are built up using linear expressions on the decision variables (type `mpvar`).

The different forms of constraints are:

Linear_expr
or
Linear_expr1 Ctr_cmp Linear_expr2
or
Linear_expr SOS_type
or
mpvar_ref mpvar_type1
or
mpvar_ref mpvar_type2 Arith_expr

In the case of the first form, the constraint is *unconstrained* and is just a linear expression. For the second form, the valid comparators are <=, >=, = (range constraints may be created using the procedure `setrange`). The third form is used to declare special ordered sets. The types are then `is_sos1` and `is_sos2`. The coefficients of the variables in the linear expression are used as weights for the SOS (as a consequence, a 0-weighted variable cannot be represented this way, procedure `makesos1` or `makesos2` has to be used instead).

The last two types are used to set up special types for decision variables. The first series does not require any extra information: `is_continuous` (default), `is_integer`, `is_binary`, `is_free`. Continuous and integer variables have the default lower bound 0, binary variables only take the values 0 or 1, and 'free' means that the variable is unbounded (*i.e.* ranging from - ∞ to + ∞). The second series of types is associated with a threshold value stated by an arithmetic expressions: `is_partint` for partial integer, the value indicates the limit up to which the variable must be integer, above which it is continuous. For `is_semcont` (semi-continuous) and `is_semint` (semi-continuous integer) the value gives the semi-continuous limit of the variable (that is, the lower bound on the part of its domain that is continuous or consecutive integers respectively). Note that these constraints on single variables are also considered as common linear constraints.

```
3*y+sum(i in 1..10) x(i)*i >= z-t
x is_free                          ! Define an unbounded variable
x <= -2                            ! Upper bound on x
t is_integer                       ! Define an integer variable t=0,1,2,...
t >= -7                            ! Change lower bound on t: t=-7,-6,-5,...
sum(i in 1..10) i*x(i) is_sos1     ! SOS1 {x(1),x(2),...} with
                                   ! weights 1,2,...
y is_semint 5                      ! y=0 or y=5,6,...
y <= 20                            ! Upper bound on y: y=0 or y=5,6,...,20
```

Internally all linear constraints are stored in the same form: a linear expression (including a constant term) and a constraint type (the right hand side is always `0`). This means, the constraint expression `3*x>=5*y-10` is internally represented by: `3*x-5*y+10` and the type 'greater than or equal to'. When a reference to a linear constraint appears in an expression, its value is the linear expression it contains. For example, if the identifier `ctl` refers to the linear constraint `3*x>=5*y-10`, the expression `z-x+ctl` is equal to: `z-2*x-5*y+10`.

Note that the value of a unary constraint of the type `x is_type threshold` is `x-threshold`.

2.7.9 Automatic arrays

The `array` keyword can be used as an aggregate operator in order to create an array that will exist only for the duration of the expression.

`array` (*Iterator1 [, Iterator2 ...]*) *Expression*

here, the iterators define the indices of the array and the expression, the associated values.

This *automatic array* may be used wherever a reference to an array is expected: for instance to save the solution values of an array of decision variables in an *initialization block* (see Section 2.8.2).

```
initializations to "mydata.txt"
  evaluation of array(i in 1..10) x(i).sol as "mylabel"
end-initializations
```

2.7.10 Operator -> (reference to)

The *reference to* operator creates a reference to its operand.

->NameRef
or
->(Expr)

Where *NameRef* is the name of a subroutine, the name of a global entity of any type, or any dereferencing of a non-basic type, and *Expr* an expression of a non-basic type.

When the *reference to* operator is applied to a subroutine name or to a subroutine reference, it returns a subroutine reference instead of trying to call the routine (see section 2.6.6). This subroutine reference can be used wherever the corresponding type is expected, in particular for an assignment that initialises another subroutine reference (see section 2.8.1.3). Note that the compiler does not guarantee which routine is returned if the name of a subroutine refers to several implementations (*i.e.* the routine has been overloaded, see section 2.9.5) and the context does not make it possible to select a particular version.

In all other cases this operator is essentially used to create aliases (see section 2.8.1.4).

2.8 Statements

Four types of statements are supported by the Mosel language. The simple statements can be seen as elementary operations. The initialization block is used to load data from a file or save data to a file. Selection statements allow one to choose between different sets of statements depending on conditions. Finally, the loop statements are used to repeat operations.

Each of these constructs is considered as a single statement. A list of statements is a succession of statements. No particular statement separator is required between statements except if a statement terminates by an expression. In that case, the expression must be finished by either a line break or the symbol '`;`'.

2.8.1 Simple statements

2.8.1.1 Assignment

An *assignment* consists in changing the value associated to an identifier. The general form of an

assignment is:

ident_ref := *Expression*
or
ident_ref += *Expression*
or
ident_ref –= *Expression*

where *ident_ref* is a reference to a value (*i.e.* an identifier or an array/record dereference) and *Expression* is an expression of a compatible type with *ident_ref*. The *direct assignment*, denoted := replaces the value associated with *ident_ref* by the value of the expression. The *additive assignment*, denoted +=, and the *subtractive assignment*, denoted –=, are basically combinations of a direct assignment with an addition or a subtraction. They require an expression of a type that supports these operators (for instance it is not possible to use additive assignment with Boolean objects).

The additive and subtractive assignments have a special meaning with linear constraints in the sense that they preserve the constraint type of the assigned identifier: normally a constraint used in an expression has the value of the linear expression it contains, the constraint type is ignored.

```
c:= 3*x+y >= 5
c+= y              ! Implies c is 3*x+2*y-5 >= 0
c:= 3*x+y >= 5
c:= c + y          ! Implies c is 3*x+2*y-5 (c becomes unconstrained)
```

2.8.1.2 Assignment of structured types

The direct assignment := can also be used with sets, lists, arrays and records under certain conditions. For sets and lists, reference and value must be of the same type, the system performing no conversion on structures. For instance it is not possible to assign a set of integers to a set of reals although assigning an integer value to a real object is valid.

When assigning records, reference and value must be of the same type and this type must be *assignment compatible*: two records having identical definitions are not considered to be the same type by the compiler. In most cases it will be necessary to employ a user type to declare the objects. A record is assignment compatible if all the fields it includes can be assigned a value. For instance a record including a decision variable (type `mpvar`) cannot be used in an assignment: copying a value of such a type has to be performed one field at a time skiping those fields that cannot be assigned.

Two arrays can be used in an assignment if they have strictly the same definition and are assignment compatible (*i.e.* their type supports assignment).

2.8.1.3 Assignment of subroutine references

Only the direct assignment := can be used with subroutine references, the value assigned to the entity must have a compatible type and will usually be the result of the –> operator to prevent calling of the operand. As the result of such a statement both subroutine references refer to the same routine and, if the source reference is undefined the destination of the assignment will also become undefined.

```
declarations
  myfunc,fct2,fct0:function (real):real
end-declarations
myfunc:=->cos                   ! 'myfunc' refers to 'cos'
fct2:=->myfunc                  ! as well as 'fct2'
writeln(myfunc(0),"=",fct2(0))  ! => 1=1
fct2:=->fct0                    ! fct2 becomes undefined
writeln(isdefined(->fct2))      ! => false
```

2.8.1.4 Assignment of unions

Only the direct assignment := can be used with union entities: the value associated with the union is replaced by a copy of the value of the expression that must have a type compatible with the union (otherwise a compilation error is raised). If the current value of the union is of the same type as the expression then a direct assignment between the entity stored in the union and the provided expression is performed. Otherwise, the current value of the union is released and a new instance of the required type is created before a direct assignment is performed. Note that although no implicit type conversion is performed, assigning an integer to a union compatible only with reals will succeed (*i.e.* the integer value will be automatically converted to real).

If the expression is also a union then the assignment operation is executed on the value stored in this union, if its type is not compatible with the destination of the assignment a runtime error will be raised. If the expression is an undefined union then the destination entity will also become undefined (*i.e.* the current value of the union is released and the entity returns to its initial state).

If the expression is the result of the –> operator then the union will become an alias to the source expression instead of receiving a copy of its value.

```
declarations
  S:set of integer
  u:any
end-declarations
u:=->S                          ! 'u' and 'S' refer to the same set
S:={1,2,3}
writeln(u)                      ! => {1,2,3}
u.set.integer+={4}
writeln(u)                      ! => {1,2,3,4}
writeln(S)                      ! => {1,2,3,4}
```

2.8.1.5 About implicit declarations

Each symbol should be declared before being used. However, an *implicit declaration* is issued when a new symbol is assigned a value the type of which is unambiguous.

```
! Assuming A,S,SE are unknown symbols
A:= 1               ! A is automatically defined
                    !   as an integer reference
S:={1,2,3}          ! S is automatically defined
                    !   as a set of integers
SE:={}              ! This produces a parser error as
                    ! the type of SE is unknown
```

In the case of arrays, the implicit declaration should be avoided or used with particular care as Mosel tries to deduce the indexing sets from the context and decides automatically whether the created array must be dynamic. The result is not necessarily what is expected.

```
A(1):=1             ! Implies: A:array(1..1) of integer
A(t):=2.5           ! Assuming "t in 1..10|f(t) > 0"
                    ! implies: A:dynamic array(range) of real
```

The option `noimplicit` disables implicit declarations (see Section 2.3.3).

2.8.1.6 Inline initialization

Using *inline initialization* it is possible to assign several cells of an array in a single statement. The general form of an inline initialization is:

ident_ref : : [*Exp1 [, Exp2 ...]*]
or
ident_ref : : (*Ind1 [, Ind2 ...]*) [*Exp1 [, Exp2 ...]*]

where *ident_ref* is the object to initialize (array, set or list) and *Expi* are expressions of a compatible type with *ident_ref*. The first form of this statement may be used with lists, sets and arrays indiced by ranges: the list of expressions is used to initialize the object. In the case of lists and sets this operation is similar to a direct assignment, with an array, the first index of each dimension is the lower bound of the indexing range or `1` if the range is empty.

The second form is used to initialize regions of arrays or arrays indiced by general sets: each *Indi* expression indicates the index or list of indices for the corresponding dimension. An index list can be a constant, a list of constants (*e.g.* `['a','b','c']`) or a constant range (*e.g.* `1..10`) but all values must be known at compile time.

```
declarations
 T:array(1..10) of integer
 U:array(1..9,{'a','b','c'}) of integer
end-declarations
T::[2,4,6,8]           ! <=> T(1):=2; T(2):=4;...
T::(2..5)[7,8,9,19]    ! <=> T(2):=7; T(3):=8;...
U::([1,3,6],'b')[1,2,3]! <=> U(1,'b'):=1; U(3,'b'):=2;...
```

2.8.1.7 Linear constraint expression

A linear constraint expression can be assigned to an identifier but can also be stated on its own. In that case, the constraint is said to be *anonymous* and is added to the set of already defined constraints. The difference from a *named constraint* is that it is not possible to refer to an anonymous constraint again, for instance to modify it.

```
10<=x; x<=20
x is_integer
```

2.8.1.8 Procedure call

Not all required actions are coded in a given source file. The Mosel language comes with a set of predefined procedures that perform specific actions (like displaying a message). It is also possible to import procedures from external locations by using modules or packages (*cf.* Section 2.3).

The general form of a procedure call is:

procedure_ident
procedure_ident (*Exp1 [, Exp2 ...]*)

where *procedure_ident* is either the name of a procedure or a procedure reference and, if required, *Expi* is the i^{th} parameter for the call (note that parameters of procedures are evaluated from right to left). Refer to Chapter 3 of this manual for a comprehensive listing of the predefined procedures.The modules documentation should also be consulted for explanations about the procedures provided by each module.

```
writeln("hello!")      ! Displays the message: hello!
```

2.8.2 Initialization block

The initialization block may be used to initialize objects (scalars, arrays, lists or sets) of basic type from files or to save the values of such objects to files. Scalars and arrays of external/user types supporting this feature may also be initialized using this facility.

The first form of an initialization block is used to *initialize* data from a file:

```
initializations from Filename
   item1 [ as Label1]
   or
   [itemT11, itemT12 [ , IdentT13 ...]] asLabelT1
[
     item2 [ as Label2]
     or
     [itemT21, itemT22 [ , IdentT23 ...]] asLabelT2
...]
end-initializations
```

where Filename, a string expression, is the name of the file to read, *itemi* any object identifier and *itemTij* an array identifier. Each identifier is automatically associated to a label: by default this label is the identifier itself but a different name may be specified explicitly using a string expression *Labeli*. If a given item is of a record type, the operation is permitted only if all fields it contains can be initialized. For instance, if one of the fields is a decision variable (type `mpvar`), the compilation will fail. Alternatively, the fields to be initialized can be listed using the following syntax as an item:

```
Identifier (field1 [ , filedi ...])
```

If a given item is a namespace (see Section 2.13) all the identifiers it includes at the time of parsing the statement are implicitly added to the block with the exception of namespaces and entities that are not compatible with initializations (like decision variables). The associated labels are the fully qualified names of the objects (*i.e.* the identifier prefixed by the namespace) unless a label is specified for this record: in this case it is used as a replacement for the default prefix when generating the per entity labels such that an empty string will remove entirely the prefix. Using the compiler option `–wi` makes it possible to get a list of included identifiers by means of a compiler warning (see Section 1.3).

When an initialization block is executed, the given file is opened and the requested labels are searched for in this file to initialize the corresponding objects. Several arrays may be initialized with a single record. In this case they must be all indexed by the same sets, have scalar types and the label is obligatory. After the execution of an `initializations from` block, the control parameter `nbread` reports the number of items actually read in. Moreover, if control parameter `readcnt` is set to `true` before the execution of the block, counting is also achieved at the label level: the number of items actually read in for each label may be obtained using function `getreadcnt`.

An initialization file must contain one or several records of the following form:

```
Label: value
```

where *Label* is a text string and *value* either a constant of a basic type (`integer`, `real`, `string` or `boolean`) or a collection of *values* separated by spaces and enclosed in square brackets. Collections of values are used to initialize lists, sets records or arrays — if such a record is requested for a scalar, then the first value of the collection is selected. When used for arrays, indices enclosed in round brackets may be inserted in the list of values to specify a location in the corresponding array.

Note also that:

- no particular formatting is required: spaces, tabulations, and line breaks are just normal separators
- the special value '*' implies a no-operation (*i.e.* the corresponding entity is not initialized)
- the special value '?' (*nil value*) implies a reset of the corresponding entity (the `reset` procedure is applied to references, `0`,`false` or and empty string is assigned to variables of basic types)

- single line comments are supported (*i.e.* starting with '`!`' and terminated by the end of the line)
- Boolean constants are either the identifiers `false` (FALSE) and `true` (TRUE) or the numerical constants `0` and `1`
- all text strings (including the labels) may be quoted using either single or double quotes. In the latter case, escape sequences are interpreted (*i.e.* use of '`\`').

By default Mosel expects that initialization files are encoded in UTF-8 and it can handle UTF-16 and UTF-32 when a BOM (Byte Order Mark) is used. To process files in another encoding, a special *encoding comment line* must be put at the beginning of the file (see section 2.5.1). For instance a data file encoded with CP1252 should start with the following comment line:

```
!@encoding:CP1252
```

The second form of an initialization block is used to *save* data to a file:

```
initializations to Filename
   item1 [as Label1]
   or
   [itemT11, itemT12 [ , IdentT13 ...]] as LabelT1
[
    item2 [ as Label2]
    or      [itemT21, itemT22 [ , IdentT23 ...]] as LabelT2
...]
end-initializations
```

In this form, any *itemi* can be replaced by the value of an expression using the following construct (*Labeli* is mandatory in this case):

```
evaluation of expression
```

When this second form is executed, the value of all provided labels is updated with the current value of the corresponding identifier[1] in the given file. If a label cannot be found, a new record is appended to the end of the file and the file is created if it does not yet exist.

For example, assuming the file `a.dat` contains:

```
! Example of the use of initialization blocks
t:[ (1 un) [10 11] (2 deux) [* 22] (3 trois) [30 33]]
t2:[ 10 (4) 30 40 ]
'nb used': ?
```

consider the following program:

```
model "Example initblk"
declarations
 nb_used:integer
 s: set of string
 ta,tb: dynamic array(1..3,s) of real
 t2: array(1..5) of integer
end-declarations

initializations from 'a.dat'
 [ta,tb] as 't'    ! ta=[(1,'un',10),(3,'trois',30)]
                   ! tb=[(1,'un',11),(2,'deux',22),(3,'trois',33)]
 t2                ! t2=[10,0,0,30,40]
```

[1] A copy of the original file is saved prior to the update (*i.e.* the original version of `fname` can be found in `fname~`).

```
 nb_used as "nb used" ! nb_used=0
end-initializations

nb_used+=1
ta(2,"quatre"):=1000

initializations to 'a.dat'
 [ta,tb] as 't'
 nb_used as "nb used"
 s
end-initializations
end-model
```

After the execution of this model, the data file contains:

```
! Example of the use of initialization blocks
t:[(1 'un') [10 11] (2 'deux') [* 22] (2 'quatre') [1000 *]
  (3 'trois') [30 33]]
t2:[ 10 (4) 30 40 ]
'nb used': 1
's': ['un' 'deux' 'trois' 'quatre']
```

In case of error (*e.g.* file not found, corrupted data format) during the processing of an initialization block, the execution of the model is interrupted. However if the value of control parameter `ioctrl` is true, executions continues. It is up to the user to verify whether data has been properly transfered by checking the value of control parameter `iostatus`.

2.8.2.1 Handling of unions

When initializing unions the procedure will consider only scalar values of basic types: integers, reals and booleans are assigned to the union; textual values are used to initialize the entity employing the first type from the list of compatible types specified for this union (for the union 'any' this is a string). An I/O error will be raised if this type does not support initialization.

When exporting unions, any non-scalar value and type that does not support conversion to string will result in a NIL value in the generated file.

2.8.2.2 About automatic finalization

During the execution of an *initializations from* block all sets are automatically finalized just after having been initialized (unless they have been explicitly declared as dynamic). This also applies to sets indirectly initialized through the non-dynamic arrays for which they are index sets. In addition, such an array is created as a static array if it has not been used before the initialization block.

This behaviour is controled by the `autofinal` control parameter which value may be changed using the `setparam` procedure (*i.e.* it is therefore possible to have automatic finalization active for only some initializations blocks). The compiler option `noautofinal` (see section 2.3.3) allows to disable this feature from the beginning of the model (although it can be re-enabled as required using the control parameter).

2.8.3 Selections

2.8.3.1 If statement

The general form of the `if` statement is:

```
if Bool_exp_1
then Statement_list_1
[
   elif Bool_exp_2
   then Statement_list_2
...]
[ else Statement_list_E ]
end-if
```

The selection is executed as follows: if *Bool_exp_1* is `true` then *Statement_list_1* is executed and the process continues after the `end-if` instruction. Otherwise, if there are `elif` statements, they are executed in the same manner as the `if` instruction itself. If, all boolean expressions evaluated are `false` and there is an `else` instruction, then *Statement_list_E* are executed; otherwise no statement is executed and the process continues after the `end-if` keyword.

```
if c=1
then writeln('c=1')
elif c=2
then writeln('c=2')
else writeln('c<>1 and c<>2')
end-if
```

2.8.3.2 Case statement

The general form of the `case` statement is:

```
case Expression_0 of
Expression_1: Statement_1
or
Expression_1: do Statement_list_1 end-do
[
   Expression_2: Statement_2
   or
   Expression_2: do Statement_list_2 end-do
...]
[ else Statement_list_E ]
end-case
```

The selection is executed as follows: *Expression_0* (that must be of type integer, real, string or boolean) is evaluated and compared sequentially with each expression of the list *Expression_i* until a match is found. Then the statement *Statement_i* (resp. list of statements *Statement_list_i*) corresponding to the matching expression is executed and the execution continues after the `end-case` instruction. If no matching is found and an `else` statement is present, the list of statements *Statement_list_E* is executed, otherwise the execution continues after the `end-case` instruction. Note that, each of the expression lists *Expression_i* can be either a scalar, a set or a list of expressions separated by commas. In the last two cases, the matching succeeds if the expression *Expression_0* corresponds to an element of the set or an entry of the list.

```
case c of
  1     : writeln('c=1')
  2..5  : writeln('c in 2..5')
  6,8,10: writeln('c in {6,8,10}')
  else writeln('c in {7,9} or c >10 or c <1')
end-case
```

2.8.4 Loops

2.8.4.1 Forall loop

The general form of the `forall` statement is:

`forall` (*Iterator_list*) *Statement*
or
`forall` (*Iterator_list*) `do` *Statement_list* `end-do`

The statement *Statement* (resp. list of statements *Statement_list*) is repeated for each possible index tuple generated by the iterator list (*cf.* Section 2.7.2).

```
forall (i in 1..10, j in 1..10 | i<>j) do
  write(' (' , i, ',' , j, ')')
  if isodd(i*j) then s+={i*j}
  end-if
end-do
```

2.8.4.2 While loop

The general form of the `while` statement is:

`while` (*Bool_expr*) *Statement*
or
`while` (*Bool_expr*) `do` *Statement_list* `end-do`

The statement *Statement* (resp. list of statements *Statement_list*) is repeated as long as the condition *Bool_expr* is `true`. If the condition is `false` at the first evaluation, the while statement is entirely skipped.

```
i:=1
while(i<=10) do
  write(' ',i)
  if isodd(i) then s+={i}
  end-if
  i+=1
end-do
```

2.8.4.3 Repeat loop

The general form of the `repeat` statement is:

`repeat`
Statement1
[Statement2 ...]
`until` *Bool_expr*

The list of statements enclosed in the instructions `repeat` and `until` is repeated until the condition *Bool_expr* is `true`. As opposed to the `while` loop, the statement(s) is (are) executed at least once.

```
i:=1
repeat
  write(' ',i)
  if isodd(i) then s+={i}
  end-if
  i+=1
until i>10
```

2.8.4.4 `break` and `next` statements

The statements `break` and `next` are respectively used to interrupt and jump to the next iteration of a loop. The general form of the `break` and `next` statements is:

```
break [n|label]
or
next [n|label]
```

where *n* is an optional integer constant: *n*-1 nested loops are stopped before applying the operation. This optional argument may also be a *label* (in the form an identifier or a string constant): in this case the loop to consider is identified by a label that must be defined just before the corresponding loop using the following syntax:

```
label :
```

The label can be either an identifier (that is not associated to any entity) or a constant string. The scope of each label is limited to the loop it identifies.

```
! in this example only the loop controls are shown
L1:                 ! 1: Define label "L1"
repeat              ! 2: Loop L1
 forall (i in S) do ! 3: Loop L2
  while (C3) do     ! 4: Loop L3
   break 3          ! 5: Stop the 3 loops and continue after line 12
   next             ! 6: Go to next iteration of L3 (line 4)
   next 2           ! 7: Stop L3 and go to next 'i' (line 3)
  end-do            ! 8: End of L3
  next "L1"         ! 9: Stop L2, go to next iteration of L1 (line 12)
  break             !10: Stop L2 and continue after line 11
 end-do             !11: End of L2
until C1            !12: End of L1
```

2.8.4.5 `with` statement

The general syntax of this statement is:

```
with locdef_1 [, locdef_2...] do
   Statement
   [ Statement ...]
end-do
```

Where *locdef_i* are local definitions of the following form:

```
ident=exp
or
ident (idndx_1 [, idndx_2...]) =id_arr
```

In the first form *ident* is defined as an alias to the given expression *exp* and in the second form *ident* is equivalent to the array reference *id_arr* and each *idndx_i* are the corresponding indexing sets.

Although the `with` statement is not a loop it is handled like a single iteration `forall` loop such that it is possible to use the `break` and `next` statements within the block of instructions.

```
! in this example LR is an array of records
with r=LR(10) do
 r.x:=10          ! update LR(10).x
 r.y:=20          ! update LR(10).y
```

```
end-do
```

2.9 Procedures and functions

It is possible to group sets of statements and declarations in the form of subroutines that, once defined, can be *called* several times during the execution of the model. There are two kinds of subroutines in Mosel, procedures and functions. *Procedures* are used in the place of statements (*e.g.* `writeln("Hi!")`) and *functions* as part of expressions (because a value is returned, *e.g.* `round(12.3)`). Procedures and functions may both receive arguments, define local data and call themselves recursively.

2.9.1 Definition

Defining a subroutine consists of describing its external properties (*i.e.* its name and arguments) and the actions to be performed when it is executed (*i.e.* the statements to perform). The general form of a procedure definition is:

```
procedure name_proc [(list_of_parms)]
  Proc_body
end-procedure
```

where *name_proc* is the name of the procedure and *list_of_parms* its list of formal parameters (if any). This list is composed of symbol declarations (*cf.* Section 2.6) separated by commas. The only differences from usual declarations are that the variable name can be omitted (the declaration states only the type of the entity) and no constants or expressions are allowed, including in the indexing list of an array (for instance `A=12` or `t1:array(1..4) of real` are *not* valid parameter declarations). The body of the procedure is the usual list of statements and declaration blocks except that no type, procedure or function definition can be included.

```
procedure myproc
  writeln("In myproc")
end-procedure

procedure withparams(a:array(r:range) of real, i,j:integer)
  writeln("I received: i=",i," j=",j)
  forall(n in r) writeln("a(",n,")=",a(n))
end-procedure

declarations
  mytab:array(1..10) of real
end-declarations

myproc                                  ! Call myproc
withparams(mytab,23,67)                 ! Call withparams
```

The definition of a function is very similar to the one of a procedure:

```
function name_func [(List_of_params)]: Type
  Func_body
end-function
```

The only difference with a procedure is that the function type must be specified: it can be any type. Inside the body of a function, a special variable of the type of the function is automatically defined: `returned`. This variable is used as the return value of the function, it must therefore be assigned a value during the execution of the function.

```
function multiply_by_3(i:integer):integer
  returned:=i*3
end-function

writeln("3*12=", multiply_by_3(12))    ! Call the function
```

Normally all statements of a subroutine are executed in sequence. It is however possible to interrupt the execution and return to the caller by using the special statement `return`.

2.9.2 Variable number of parameters

A subroutine may accept a variable number of parameters. To declare a routine of this kind, the last parameter of the list of parameters must have the special type `...`: this parameter will receive all the additional arguments as a list of `any` (see Section 2.6.7) when the routine is called.

```
procedure printall(prefix:string,argv:...)
 if argv.size=0 then
  writeln(prefix)                     ! just the prefix
 else
  forall(p in argv) writeln(prefix,p) ! prefix and other arguments
 end-if
end-procedure

printall("nothing")
printall("data ",1,"a",true)
```

The above code extract displays:

```
nothing
data 1
data a
data true
```

2.9.3 Formal parameters: passing convention

Formal Parameters of basic types are passed by *value* and all other types are passed by *reference*. In practice, when a parameter is passed by value, the subroutine receives a copy of the information so, if the subroutine modifies this parameter, the effective parameter remains unchanged. But if a parameter is passed by reference, the subroutine receives the parameter itself. As a consequence, if the parameter is modified during the process of the subroutine, the effective parameter is also affected.

```
procedure alter(s:set of integer,i:integer)
  i+=1
  s+={i}
end-procedure

gs:={1}
gi:=5
alter(gs,gi)
writeln(gs," ",gi)                    ! Displays: {1,6} 5
```

2.9.4 Local declarations

Several declaration blocks may be used in a subroutine and all identifiers declared are local to this subroutine. This means that all of these symbols exist only in the scope of the subroutine (*i.e.* between the declaration and the `end-procedure` or `end-function` statement) and all of the resource they use is released once the subroutine terminates its execution unless they are referenced outside of the routine (*e.g.* member of a set defined globally). As a consequence, active constraints (`linctr` that are not just linear expressions) declared inside a subroutine and the variables they employ are still effective after the

termination of the subroutine (because they are part of the current problem) even if the symbols used to name the related objects are not defined any more. Note also that a local declaration may hide a global symbol.

```
declarations                    ! Global definition
  i,j:integer
end-declarations

procedure myproc
  declarations
     i:string                   ! This declaration hides the global symbol
  end-declarations
  i:="a string"                 ! Local 'i'
  j:=4
  writeln("Inside of myproc, i=",i," j=",j)
end-procedure

i:=45                           ! Global 'i'
j:=10
myproc
writeln("Outside of myproc, i=",i," j=",j)
```

This code extract displays:

```
Inside of myproc, i=a string j=4
Outside of myproc, i=45 j=4
```

2.9.5 Overloading

Mosel supports overloading of procedures and functions. One can define the same function several times with different sets of parameters and the compiler decides which subroutine to use depending on the parameter list. This also applies to predefined procedures and functions.

```
! Returns a randomly generated integer in the interval [1,limit]
function random(limit:integer):integer
  returned:=round(.5+random*limit)          ! Use the predefined
                                            ! 'random' function
end-function
```

It is important to note that:

- a procedure cannot overload a function and vice versa;
- it is not possible to redefine any identifier; this rule also applies to procedures and functions. A subroutine definition can be used to overload another subroutine only if it differs for at least one parameter. This means, a difference in the type of the return value of a function is not sufficient.

2.9.6 Forward declaration

During the compilation phase of a source file, only symbols that have been previously declared can be used at any given point. If two procedures call themselves recursively (cross recursion), it is therefore necessary to be able to declare one of the two procedures in advance. Moreover, for the sake of clarity it is sometimes useful to group all procedure and function definitions at the end of the source file. A forward declaration is provided for these uses: it consists of stating only the header of a subroutine that will be defined later. The general form of a forward declaration is:

`forward procedure` *Proc_name [*(*List_of_params*)*]*

or

`forward function` *Func_name [*(*List_of_params*)*]*: *Type*

where the procedure or function *Func_name* will be defined later in the source file. Alternatively a subroutine can be declared by stating its header inside of a declarations block. Note that a forward declaration for which no actual definition can be found is considered as an error by Mosel.

```
forward function f2(x:integer):integer

function f1(x:integer):integer
  returned:=x+if(x>0,f2(x-1),0)             ! f1 needs to know f2
end-function

function f2(x:integer):integer
  returned:=x+if(x>0,f1(x-1),0)             ! f2 needs to know f1
end-function
```

2.9.7 Suffix notation

Functions which name begins with `get` and taking a single argument may be called using a *suffix notation*. This alternative syntax is constructed by appending to the variable name (the intended function parameter) a dot followed by the function name without its prefix `get`. For instance the call `getsol(x)` is the same as `x.sol`. The compiler performing internally the translation from the suffix notation to the usual function call notation, the two syntaxes are equivalent.

Similarly, calls to procedures which name begins with `set` and taking two arguments may be written as an assignment combined with a suffix notation. In this case the statement can be replaced by the variable name (the intended first procedure parameter) followed by a dot and the procedure name without its prefix `set` then the assignment sign `:=` and the value corresponding to the second parameter. For instance the statement `sethidden(ctl,true)` can also be written `ctl.hidden:=true`. As for the other alternative notation, the compiler performs the rewriting internally and the two syntaxes are equivalent.

2.10 Problems

In Mosel terms, a *problem* is a container holding various attributes and entities. The nature of the information stored is characterised by a *problem type*. The core system of Mosel provides the `mpproblem` problem type for the representation of mathematical programming problems with linear constraints. Other types may be published by modules either as entirely new problem types or as *problem type extensions*. An extension adds extra functionality or properties to an existing type; for instance, `mpproblem.xprs` provided by the module `mmxprs` adds support for *solving* `mpproblem` problems while the type `mpproblem.nl` of `mmnl` makes it possible to include non-linear constraints in an `mpproblem`.

When the execution of the model starts, an instance of each of the available problem types is created: this *main problem* constitutes the default *problem context*. As a consequence, all problem related operations (*e.g.*, add constraints, solve...) refer to this context. Further problem instances may be declared just like any other symbol using a declarations section. The specification of a problem type (that is used as an elementary type in a declaration) has two forms:

problem_type
or
problem_type1 `and` *problem_type2 [*`and` *problem_typen ...]*

where *problem_type** are problem type names. The second syntax allows to define a problem instance that refers to several problem types: this can be useful if a particular problem consists in the combination of several problem types. Note also that the main problem can be seen as an instance of the combination of all available problem types.

The `with` construct can be used to switch to a different problem context for the duration of a block of

instructions. The general form of this construct is:

```
with prob do
  Statement
  [ Statement ...]
end-do
```

where *prob* is a problem reference or a problem type specification. In the first case the referenced problem is selected, in the second case, a new problem instance is created for the duration of the block (*i.e.*, it is released after the block has been processed). Both statements and declaration blocks as well as other `with` constructs may be included in this section: they are all executed in the context of the selected problem.

```
declarations
  p1,p2:mpproblem
  p3:mpproblem and mypb      ! assuming 'mypb' is a problem type
  PT=mpproblem and mypb      ! user defined problem type
  a:array(1..10) of PT
  x,y:mpvar
end-declarations
with p1 do
 x+y>=0
end-do
with p2 do
 x-y=1
end-do
```

Some problem types support assignment (operator `:=`) and additive assignment (operator +=). These operators can be used between objects of same type but also when the right parameter of the operator is a component of the assigned object. For instance, assuming the declarations of the previous example we could state `p3:=p2` meaning that the `mpproblem` part of `p3` must be replaced by a copy of `p2`, the `mypb` part of `p3` remaining unchanged. From the same context, the assignment `p2:=p3` produces a compilation error.

2.10.1 The `mpproblem` type

An `mpproblem` instance basically consists in a set of linear constraints (the decision variables defined anywhere in a model are shared by all problems). A constraint is incorporated into a problem when it is expressed, so having the declaration of a `linctr` identifier in the context of a problem is not sufficient to attach it to this problem. The association will occur when the symbol is assigned its first value. Afterwards, the constraint will remain part of the same problem even if it is altered from within the context of another problem (a constraint cannot belong to several problems at the same time).

```
with p1 do
 C1:=x+y+z>=0
 x is_integer
end-do
with p2 do
 2*x-3*z=0    ! here we state constraints of p2
 ...
 minimize(z)
 C1+= x.sol*z.sol
end-do
```

In the example above, the constraint `C1` is part of problem `p1`. From the context of a second problem `p2` the constraint `C1` is modified using solution information of `p2`: this change affects only the first problem since the constraint does not belong to the current context. Note that since `is_integer` is a (unary) constraint, the decision variable `x` is integer for problem `p1` but it is a continuous variable in `p2`.

When a problem is released or reset (see `reset`), all its constraints are detached. Constraints which are not referenced (anonymous constraints) are released at the same time, named constraints however are not freed, they become available to be associated to some other problem.

```
with mpproblem do
 C1:=x+y+z>=0  ! (1)
 x-2*y=10      ! (2)
 x is_integer  ! (3)
end-do
with p1 do
 C1
end-do
```

In this example, at the end of the first `with` block, the local problem is released. As a consequence the constraint `C1` is detached from this problem (but remains unchanged) and the 2 other constraints are freed. The following statements add `C1` to the problem `p1`.

The type `mpproblem` supports both assignment (operator `:=`) and additive assignment (operator `+=`).

2.11 The `public` qualifier

Once a source file has been compiled, the identifiers used to designate the objects of the model become useless for Mosel. In order to access information after a model has been executed (for instance using the `print` command of the interractive debugger), a table of symbols is saved in the BIM file.

The qualifier `public` can be used in declaration and definition of objects to mark those identifiers (including subroutines) that must be *published* in the table of symbols. Without this qualifier a symbol is considered to be private and it is not recorded in the table of symbols (unless the source is compiled with debugging information).

```
public declarations
  e:integer                                  ! e is published
  f:integer                                  ! f is published
end-declarations

declarations
  public a,b,c:integer                       ! a,b and c are published
  d:real                                     ! d is private
end-declarations

forward public procedure myproc(i:integer)  ! 'myproc' is published
```

This qualifier can also be used when declaring record types in order to select the fields of the record that can be accessed from outside of the file making the definitions: this allows to make available only a few fields of a record, hidding what is considered to be internal data.

```
declarations
 public t1=record
     i:integer            ! t1.i is private
     public j:real        ! t1.j is public
    end-record
 public t2=public record
     i:integer            ! t2.i is public
     j:real               ! t2.j is public
    end-record
end-declarations
```

Note that a public record type can only contain public types even if it does not publish its fields.

2.12 Packages

Declarations may be stored in a package: once compiled, the package can be used by any model by means of the `uses` or `import` statements (see Section 2.3.1). Except for its beginning and termination (keyword `model` is replaced by `package`) a package source is similar to a normal model source. The following points should be noticed:

- all statements and declarations outside procedure or function definitions are used as an *initialization* routine: they are automatically executed before statements of the model using the package;
- symbols that should be published by the package must be made explicitly public using the `public` qualifier (see Section 2.11);
- model parameters of a package are automatically added to the list of parameters of the model using the package;
- a package cannot be imported several times by a model and packages publish symbols of packages they import. For instance, assuming package *P1* imports package *P2*, a model using *P1* cannot import or use explicitly *P2* but has access to the functionality of *P2* via *P1*.

2.12.1 Version management

When a package defines a version number (see Section 2.3.4) Mosel implements a compatility rule similar to the one used for modules: a package version A can be used in place of package version B if *major(A) = major(B)* and *minor(A)* $\geq$ *minor(B)*. This mechanism applies at compile time (when using different packages with the same dependencies) and at runtime when loading a model. It is recommended to update package version numbers as follows:

- major number: any changes that will require recompilation of models using the package (in particular removal of public functionality from the package)
- minor number: addition of new functionality that does not influence the behavior of existing uses of the package
- release number: bug fixes

2.12.2 The requirements block

Requirements are symbols a package requires for its processing but does not define. These required symbols are declared in *requirement blocks* which are a special kind of declaration blocks in which constants are not allowed but procedure/functions can be declared. The symbols of such a block have to be defined when the model using the package is compiled: the definitions may appear either in the model or in another package but cannot come from a module. Several packages used by a given model may have the same requirements (*i.e.* same identifier and same declaration). It is also worth noting that a package inherits the requirements of the packages it uses.

```
requirements
  an_int:integer
  s0: set of string
  bigar: array(S0) of real
  procedure doit(i:integer)
end-requirements
```

2.12.3 Control parameters

Packages may define *control parameters* that can be used just like those of modules via routines `getparam` and `setparam`. A control parameter is defined in the parameters block (see Section 2.4) using the following syntax:

pname: *type_name*

where *pname* is the name of the parameter as a constant string and *type_name* its type (either `integer`, `real`, `string` or `boolean`). In addition to this declaration accessor routines must be defined: for handling integer parameters the public function `pkgname~getiparam(pname:string):integer` and the public procedure `pkgname~setparam(pname:string,v:integer)` must be defined (`pkgname` being the name of the current package). The function will be called by `getparam` to retrieve the value of the specified parameter (as a string in lower case) and the procedure will be used by `setparam` to change the parameter value. Similar definitions will be required for the other types (assuming the package declares parameters of the corresponding types), namely `getrparam` (real parameters), `getsparam` (string parameters) and `getbparam` (Boolean parameters) as well as the associated procedures `setparam`. The following example shows the required definitions for the package `mypkg` to publish real parameters `p1` and `p2`:

```
parameters
  "p1":real
  "p2":real
end-parameters

declarations
 myp1,myp2:real    ! private variables to hold parameter values
end-declarations

! get value function for real parameters
public function mypkg~getrparam(p:string):real
 case p of
  "p1": returned:=myp1
  "p2": returned:=myp2
 end-case
end-function

! set value procedure for real parameters
public procedure mypkg~setparam(p:string,v:real)
 case p of
  "p1": myp1:=v
  "p2": myp2:=v
 end-case
end-procedure
```

2.13 Namespaces

All identifiers (variables and subroutines names) of a program are implicitly collected in a global dictionary shared by the program itself and all packages and modules it uses. It is also possible to group certain identifiers under a *namespace* that is characterised by a name. A given identifier may appear in several namespaces and each of its occurrences refers to a different entity, as a consequence an entity is unambiguously identified by its name and the namespace to which it is a member: this is the *fully qualified name* of this entity that is noted:

nspc~ident

Where *nspc* is a namespace name and *ident* an identifier in this namespace.

A namespace's name is also an identifier that must be declared before being used even if it is defined by

a package already loaded. This declaration is achieved using the `namespace` compiler directive:

```
namespace ns1 [, ns2 ...]
```

Where *nsi* are the names of the namespaces that will be used in the program. As an identifier a namespace may be declared as part of another namespace and any of the *nsi* may have the form `nsx~nsy` to declare `nsy` as a namespace included in `nsx`. Several `namespace` directives may be stated.

When the compilation starts a namespace is automatically created: it is used to collect all private symbols of the program. When compiling a model this namespace has an empty name (*i.e.* a fully qualified name of this namespace is of the form *~ident*) and for a package it has the same name as the package.

When looking for an identifier (that is not fully qualified) the compiler tries first to find it in the global dictionary and then searches in a predefined list of namespaces. This list is initialised with the namespace of private symbols and may be extended using the `nssearch` directive:

```
nssearch ns1 [, ns2 ...]
```

This statement adds the specified namespaces to the search list. If the directive is stated several times, each added list is appended to the current list of namespaces. The namespace search is not recursive: it is not sufficient to add a namespace to the search list to have all its included namespaces to be also part of the search list (*e.g.* if `ns1` includes `ns11` and `ns12`, the 3 names `ns1`,`ns1~ns11` and `ns1~ns12` must be put into the search list for all the identifiers to be searchable). Note that namespaces listed in a `nssearch` directive do not need to be declared in a `namespace` directive.

Any namespace defined in a package is available to any model or package using it (and all the identifiers it includes are implicitly public). Defining a *namespace group* makes it possible to allow only certain packages to access a given namespace. The definition of such a group requires the use of a dedicated compiler directive:

```
nsgroup nspc: pkg1 [, pkg2 ...]
or
nsgroup nspc
```

Where *pkgi* are the package names (as constant strings) that will be allowed to access namespace *nspc*. By default the automatic namespace containing the private symbols of a package has a group containing only the package itself such that it cannot be used by any external component. It is however possible to redefine this initial group with a `nsgroup` directive, in particular the second form of the directive (without specifying any package) makes the corresponding namespace available to any package. Note that namespaces listed in a `nsgroup` directive do not need to be declared in a `namespace` directive.

2.14 Annotations

Annotations are meta data expressed in the Mosel source file that are stored in the resulting bim file after compilation. Thanks to a dedicated API it is possible to retrieve the information both from the model itself during its execution (see `getannotations`) or before/after execution from a host application (see function `XPRMgetannotations` in the *Mosel Libraries Reference Manual*).

2.14.1 Syntax

Annotations are organised in *categories*. A category groups a set of annotations and other categories (or *sub-categories*). When expressing a full annotation name, categories are separated by the `'.'` symbol. For instance:

```
doc.name
```

will be used to select the annotation `name` that is a member of the `doc` category. Similarly:

```
mycat1.cat2.info
```

will reference the annotation `info` recorded in the category `cat2` that is itself part of category `mycat1`. Annotations and annotation categories must be valid Mosel identifiers: their names can only use alpha-numeric symbols plus `'_'`.

Some *predefined categories* are available at the beginning of the compilation:

- the default category (its name is empty) collects annotations that are not explicitly member of any particular category. For instance the annotation `myannot` will be recorded in the default category. This annotation may also be referenced by its full name `.myannot`
- `mc` (for *Mosel Compiler*) is used to pass information to the compiler during the compilation. For example, the `mc.def` annotation makes it possible to declare an annotation type (see section 2.14.3)
- `doc` can be used to document a model or package file (see section 2.20)

In the Mosel source file annotations are included in special comments. A *single-line annotation* is of the form:

```
!@ name value
```

Here `name` is the name of the annotation (spaces between `'@'` and the name are ignored) and the following text (up to the end of line) its corresponding value. The separation character between the name and the value can be a space, `':'` or `'='` (there must be no space between the name and the symbol). There is no restriction on the content of the value: it can be any kind of text (unless the annotation is typed—see section 2.14.3).

A *multi-line annotation* is of the form:

```
(!@name value
  ...
  @name2 value2
  ...
!)
```

where `name` is an annotation name while the text following this name is its associated value. With this syntax the value may spread over several lines, its termination is marked either by the end of the comment block or by a new annotation specification. In this context, a new annotation must start with the `'@'` symbol at the beginning of a new line (leading spaces are ignored). As for a one-line annotation, symbols `':'` and `'='` can be used instead of a space to separate the name and its value.

If several annotations of the same category have to be defined in the same block, a *current category* may be defined such that following annotation names can be shortened. This mechanism is activated by specifying the category name terminated by a dot (the remainder of this line is ignored) before the first annotation statement. The category selection is effective for the current comment block only and remains active until the next selection. Using a dot in place of a category name restores the default behaviour (*i.e.* the full path must be used for annotation reference). For instance:

```
(!@doc.        Switch to 'doc' category (this text is ignored)
  @name:my_function
  @type:integer
  @mycat.cat1. Switch to 'mycat.cat1'
```

```
  @memb1 10
  @memb2 20
  @.           Unselect current category
  @glb=useless
!)
```

Is equivalent to:

```
(!@doc.name:my_function
  @doc.type:integer
  @mycat.cat1.memb1 10
  @mycat.cat1.memb2 20
  @glb=useless
!)
```

By default any new annotation name is added to the internal dictionary and no checking is applied to the provided value. If a given annotation is defined several times only the last assignment is preserved. The compiler will however emit a warning if an attempt is made to assign a value to a category or to use an annotation as a category. For instance:

```
!@mycat.memb1 10
!@mycat.memb1.memb2 20
```

The second definition will fail to use `mycat.memb1` as a category because the first one has already implicitly declared it as an annotation.

2.14.2 Symbol association

An annotation is either global or associated with a specific public symbol (see section 2.11). The association depends on the location of the definition in the source code:

- annotations preceding a subroutine declaration (*forward statement*) or definition are associated with the subroutine name
- annotations preceding a declarations block are distributed to all the symbols declared in the block
- inside of a declarations block: annotations preceding or terminating the line of a declaration are associated with the corresponding symbols

In all other cases the annotations are global (*i.e.* not associated with any particular symbol) — in particular trying to associate annotations to private symbols will result in global annotations.

Annotations that precede a subroutine declaration, a declarations block or an entity in a declarations block can be turned into global annotations by inserting the compiler annotation `mc.flush` between the annotation and the following code.

2.14.3 Declaration

Declaration of annotations is achieved via the `mc.def` compiler annotation. Once an annotation is declared, the compiler checks the validity of definitions and rejects those that are not compliant, issuing a warning message (invalid annotations will not make the compilation fail unless the flag `strict` is used).

The general syntax of the annotation declaration statement is:

```
!@mc.def aname [prop1[,prop2...]]
```

Where `aname` is an annotation name and `prop?` a property keyword. The possible keywords are:

`alias name1 name2... aname` Defining an alias to `name1`, `name2`...

`text|integer|real|boolean` Type of the annotation value (default:`text`).

`last|first|merge|multi` Handling of multiple definitions of an annotation (default:`last`)

- `last`: the last definition is kept
- `first`: keep the first definition (the following ones are ignored)
- `merge`: definitions are concatenated (separated by new lines)
- `multi`: all definitions are kept

`global|specific` By default, the association of annotations depends on the location of the definition. If `global` is stated, the annotation is always global; with option `specific`, the annotation will be kept only if it can be associated with a symbol (otherwise it is ignored instead of being stored as a global one).

`values=v1 v2 v3...` If used, this option must be the last one of the definition and it cannot be combined with `range`. It defines a list of possible values for the annotation.

`range=lb ub` If used, this option must be the last one of the definition, it requires the type to be specified (`integer` or `real`) and it cannot be combined with `values`. It defines a range of possible values.

`strict` When this option has been stated any error detected on this annotation (or path when applied to a category) will make the compilation fail

Example:

```
!@mc.def person.name text,first,specific
!@mc.def person.age integer,first,specific,range=0 150
!@mc.def person.gender values=male female
```

Categories are implicitly declared by the annotations they include (for instance declaring `@mycat.myann` implies the creation of `mycat` as a category). It is also possible to explicitly declare an empty category (*i.e.* containing no annotation) using the `mc.def` construct by appending a dot to the category name (the only supported property is `strict`). For instance:

```
!@mc.def mycat.
```

For a given annotation the declaration may be stated several times but the properties of an annotation cannot be changed. For instance, the following declarations can be used in the same source:

```
!@mc.def myann
!@mc.def myann text,last
```

But the following declaration cannot be combined with any of the two preceding ones as they both result in the annotation type `text`:

```
!@mc.def myann integer
```

Declarations included in models are not exported to the bim file (*i.e.* they are only used during the compilation procedure) but declarations stated in packages are *published* if they are relative to a user defined category: any model using the package inherits the annotation declarations of the package.

Additional properties can be set using the `mc.set` compiler annotation. The general syntax of this special statement is:

```
!@mc.set name flag
```

Where `name` is an annotation or category name and `flag` one of the following keywords:

`complete`	Applied to a category this flag indicates that no other annotation can be added to this category (ignored for an annotation). It is however still possible to declare aliases. Note that sub-categories are not concerned by this flag: if required each sub-category has also to be tagged.
`disable`	Disable the named category or annotation. From the point where this flag has been set onwards, all definitions deriving from the provided name are silently ignored.
`enable`	Revert the effect of `disable`.
`unpublish`	Disable the automatic publication of the specified declaration.
`publish`	Publish the specified declaration.

Note that `mc.set` expects a full explicit name: for this command `ann` refers to category `ann` and not to annotation `.ann` as in other places.

2.15 File names and input/output drivers

Mosel handles data streams using I/O drivers: a driver is an interface between Mosel and a physical data source. Its role is to expose the data source in a standard way such that from the user perspective, all data sources can be accessed using the same methods (*i.e.* `initializations` blocks, file handling functions). Drivers are specified in file names: all Mosel functions supporting I/O operations through drivers can be given an extended file name. This type of name is composed of the pair *driver_name:file_name*. When Mosel needs to access a file, it looks for the specified driver in the table of available drivers. This table contains all predefined drivers as well as drivers published by modules currently loaded in memory. If the driver is provided by a module, the module name may also be indicated in the extended file name: *module_name.driver_name:file_name*. Using this notation, Mosel loads the required module if necessary (otherwise the file operation fails if the module is not already loaded). For instance it is better to use `mmodbc.odbc:database` than `odbc:database`.

The *file_name* part of the extended file name is specific to the driver and its structure and meaning depends on the driver. For instance, the `sysfd` driver expects a numerical file descriptor so file `sysfd:1` is a valid name but `sysfd:myfile` cannot work. A driver may act as a filter and expects as *file_name* another extended file name (*e.g.* `zlib.deflate:mem:myblk`).

When no driver name is specified, Mosel uses the default driver which name is an empty string (`myfile` is equivalent to `:myfile`). This driver relies on OS functions to access files from the file system. Note that on the Windows operating system Mosel does not support relative paths on a specified drive (*i.e.* the file `"C:myfile"` is equivalent to `"C:\myfile"`, the behaviour may be different in other environments).

The `tmp` driver is an extension to the default driver: it locates the specified file in the temporary directory used by Mosel (*i.e.* `"tmp:toto"` is equivalent to the expression `getparam("tmpdir")+"/toto"`).

The `null` driver can be used to *disable* a stream: whatever written to file `"null:"` is ignored and reading from it is like reading from an empty file.

The `mem` driver uses a memory block instead of a file handled by the operating system. A file name for this driver is of the form `mem:label[/minsize[/incstep]]` where `label` is an identifier whose first character is a letter and `minsize` an optional initial amount of memory to be reserved (size is expressed in bytes, in kilobytes with suffix `"k"` or in megabytes with suffix `"m"`). The `label` being recorded in the dictionary of the model symbols it cannot be identical to any of the identifiers of the model (the function `newmuid` might be used to generate a unique identifier). The memory block is allocated dynamically and resized as necessary. By default the size of the memory block is increased by pages of 4 kilobytes: the

optional parameter `incstep` may be used to change this page size (*i.e.* the default setting is `"label/0/4k"`). The special value 0 modifies the allocation policy: instead of being increased of a fixed amount, the block size is doubled. In all cases unused memory is released when the file is closed. The `mem` driver may also be used to exchange data with an application using the Mosel libraries (refer to the *Mosel Libraries Reference Manual* for further explanation).

The `tee` driver can only be open for writing and expects as file name a list of up to 6 extended file names separated with '&': it opens all the specified files and duplicates what it receives to each of them. If only one file is given or if the string terminates with '&', output is also sent to the default output stream (or error stream if the file is used for errors). For instance, writing to the file `"tee:log1&log2&"` has the effect of writing at the same time to files `"log1"` and `"log2"` as well as sending a copy to the console.

The `bin` driver can only be used for `initializations` blocks as a replacement of the default driver: it allows to write (and read) data files in a platform independent binary format. This file format is generally smaller than its ASCII equivalent and preserves accuracy of floating point numbers. This driver can be used in 2 different ways: a single file including all records of the initialisations block is produced if a file name is provided. For instance, in the following example the file `"mydata"` will contain both `A` and `B`:

```
initialisations to "bin:mydata"
  A
  B
end-initialisations
```

With the second form (without file name) one file is generated for each record of the block. The following example produces 2 files: `"mydata_A"` to contain the values of record `A` and `"mydata_B"` for values of `B`:

```
initialisations to "bin:"
  A as "mydata_A"
  B as "mydata_B"
end-initialisations
```

When using this form in an `initialisations to` block, the option `append` may be specified such that files are open in append mode.

The other predefined drivers (`sysfd`, `cb` and `raw`) are useful when interfacing Mosel with a host application. They are described in detail in the *Mosel Libraries Reference Manual*.

I/O drivers provided by modules of the Mosel distribution are documented with the corresponding module (see Part II of this manual).

2.16 Character encoding of text files

Mosel uses UTF-8 for its internal representation of text strings and this is also the default character encoding for text files. It is however possible to read and write text files in different encodings: for model source and initialization block files the selection can be achieved by means of a special comment (see sections 2.5.1 and 2.8.2) but the encoding may also be specified at the time of opening a file by prefixing its name with the "`enc:`" prefix:

`enc:`*encoding [*`+unix/+dos/+sys`*] [*`+bom/+nobom`*], filename*

Mosel supports natively the encodings UTF-8, UTF-16, UTF-32, ISO-8859-1, ISO-8859-15, CP1252 and US-ASCII. For UTF-16 and UTF-32 the byte ordering depends on the architecture of the running system (*e.g.* this is Little Endian on an x86 processor) but it can also be specified by appending `LE` (Little Endian) or `BE` (Big Endian) to the encoding name (*e.g.* `UTF-16LE`). The availability and names of other encodings depends on the operating system.

The following aliases may also be used in place of an encoding name: `RAW` (no encoding), `SYS` (default

system encoding), WCHAR (wide character for the C library), FNAME (encoding used for file names), TTY (encoding of the output stream of the console), TTYIN (encoding of the input stream of the console), STDIN, STDOUT, STDERR (encoding of the default input/output/error stream).

In addition to the encoding name a couple of options might be applied: +unix and +dos select the line termination (note that +dos is automatically used when writing to a physical file on Windows). Options +bom and +nobom decides whether a Byte Order Mark is to be inserted at the beginning of the file (this option only applies to UTF encodings when the file is not open in appending mode). By default a BOM is inserted when the encoding is UTF-16 or UTF-32, the option +nobom disables this insertion. The option +bom implies the insertion of a BOM on UTF-8 encoded files (this is usually not required for this encoding but often used on Windows systems). The option +sys selects the line termination and BOM convention of the running system (*i.e.* it is equivalent to +unix on a Posix system and +dos+bom on a Windows machine).

2.17 Working directory and temporary directory

Except for absolute path names, file or path name expansion are relative to the *current working directory*. By default this reference location corresponds to the operating system current working directory which usually is the directory from which Mosel has been started. Since the working directory is an execution parameter, a model may be running with a current working directory which might be different from the one used by the operating system. It is therefore recommended to use absolute file names when a Mosel model communicates with an external component (for instance when a file name is part of the DSN to be used for an ODBC connection).

In addition to the current working directory, Mosel creates a *temporary directory* that is shared by all models for storing temporary data handled as physical files. This directory is identified by the environment variable MOSEL_TMP or located in the system temporary directory as specified by one of the environment variables TMP, TEMP or USERPROFILE under Windows and TMPDIR on Posix systems. If none of these environment variables is defined, the default base directory will be "C:\" on Windows and "/tmp" on Posix systems. The Mosel temporary directory is automatically created when needed and deleted at program termination.

The path names of the working directory and the temporary directory are identified respectively by the "workdir" and "tmpdir" control parameters and can be retrieved using the getparam function. It is possible to change the current working directory of a running model by updating the "workdir" parameter using setparam.

2.18 Handling of input/output

At the start of the execution of a program/model, three text streams are created automatically: the standard input, output and error streams. The standard output stream is used by the procedures writing text (write, writeln, fflush). The standard input stream is used by the procedures reading text (read, readln, fskipline). The standard error stream is the destination of error messages reported by Mosel during its execution. These streams are inherited from the environment in which Mosel is being run: usually using an output procedure implies printing something to the console and using an input procedure implies expecting something to be typed by the user.

The procedures fopen and fclose make it possible to associate text files to the input, output and error streams: in this case the IO functions can be used to read from or write to files. Note that when a file is opened, it is automatically made the active input, output or error stream (according to its opening status) but the file that was previously assigned to the corresponding stream remains open. It is however possible to switch between different open files using the procedure fselect in combination with the function getfid.

```
model "test IO"
```

```
 def_out:=getfid(F_OUTPUT)      ! Save file ID of default output
 fopen("mylog.txt",F_OUTPUT)    ! Switch output to 'mylog.txt'
 my_out:=getfid(F_OUTPUT)       ! Save ID of current output stream

 repeat
  fselect(def_out)              ! Select default ouput...
  write("Text? ")               ! ...to print a message
  text:=''
  readln(text)                  ! Read a string from the default input
  fselect(my_out)               ! Select the file 'mylog.txt'
  writeln(text)                 ! Write the string into the file
 until text=''
 fclose(F_OUTPUT)               ! Close current output (='mylog.txt')
 writeln("Finished!")           ! Display message to default output
end-model
```

2.19 Deploying models

Once a model has been compiled to a BIM file it may be deployed in a variety of ways. It may be

- run from some remote code using the remote invocation library XPRD (see the *XPRD reference manual*),
- be integrated in an application through the Mosel libraries (see *Mosel libraries reference manual*),
- form part of an Xpress Insight application (see the *Xpress Insight Developer Guide*), or
- simply be invoked from a command window or shell.

For the last option the usual approach consists in using the `mosel` command line tool (see section 1.3) with the `run` command. For instance, the following command may be used to run the model *mycmd.bim*:

```
> mosel run mycmd.bim
```

The aim of the *deploy* module is to ease the use of a model published this way. This module makes it possible to generate an executable program from the BIM file. Moreover, it gives the model access to the command line arguments and exposes a method for embedding configuration files into the resulting program. The *deploy* module is usually used through one of its two IO drivers: the first driver, `csrc`, generates a C program (based on the Mosel libraries) from a BIM file and the second one, `exe`, produces directly the executable by running a C compiler on the generated C source (this requires the availability of a C compiler on the system). For example the following command will create the program `runmycmd` (or `runmycmd.exe` on Windows) from the model `mycmd.mos`:

```
> mosel comp mycmd.mos -o deploy.exe:runmycmd
```

In addition to its IO drivers, the *deploy* module publishes two functions for accessing the program arguments: `argc` returns the number of parameters passed to the command (counting the command itself as the first) and `argv(i)` returns the i^{th} argument (as a string). As an example, the following model displays the arguments it receives:

```
model mycmd
uses 'deploy'

writeln("My arguments:")
forall(i in 1..argc) writeln(argv(i))
end-model
```

After compiling this example into an executable with the command shown above, an execution of the command `runmycmd a b c` will display:

```
My arguments:
runmycmd
a
b
c
```

In addition to giving access to command line arguments, *deploy* makes it possible to embed files into the resulting executable. File locations are passed via model parameters. The following example outputs its source when the program is called with the argument 'src' — otherwise it reports an error message:

```
model mycmd2
uses 'deploy','mmsystem'

parameters
 SRC="null:"
end-parameters

if argc<>2 or argv(2)<>"src" then
 writeln("Usage: ", argv(1), " src")
 exit(1)
else
 writeln("Source:")
 fcopy(SRC,"")
end-if
end-model
```

In this example, the source file is identified by the model parameter `SRC`. To generate the program, the following command has to be issued:

```
> mosel comp mycmd2.mos -o deploy.exe:runmycmd2,SRC=mycmd2.mos
```

With the command above, the file `mycmd2.mos` is included in the executable and the `SRC` parameter is redefined such that the model can access the file through memory. Note that the model file can also be included in the executable in compressed form. To enable this feature, the parameter name has to be suffixed with `-z` in the compilation command:

```
> mosel comp mycmd2.mos -o deploy.exe:runmycmd2,SRC-z=mycmd2.mos
```

2.20 Documenting models using annotations

The predefined `doc` annotation category can be used to document a Mosel file. Using a dedicated set of annotations the model author can add descriptions to the various entities defined in the source, the user-defined descriptions are completed by definitions automatically generated by the Mosel compiler.

From a bim file that includes such definitions a documentation processor may produce a complete document: as an example, the Xpress distribution comes with the *moseldoc* processor that generates an HTML documentation from an annotated bim file.

2.20.1 `doc` annotation category

Unlike other annotation categories, the `doc` annotation category is disabled by default such that the corresponding annotations are silently ignored. To generate a documentation-enabled bim file the compiler has to be run with the option `-D`. In addition to enabling the `doc` category, this flag also activates the automatic generation of certain documentation annotations by the compiler. Alternatively to using this flag, a model may define the following annotations:

```
!@mc.set doc enable
!@doc.autogen=true
```

Note that these special annotations can also be used in the source file as a means to exclude some definitions from the documentation, setting `doc.autogen` to `false` right before the definitions to be excluded and back to `true` immediately after.

2.20.1.1 Global definitions

The following global annotations are automatically generated by the compiler:

`@doc.name`	Name of the package or model
`@doc.version`	Version number as stated by the 'version' statement
`@doc.date`	Current date
`@doc.ispkg`	Set to 'true' if the file is a package

All automatic annotations can also be defined explicitly in the Mosel source to overwrite their default values.

The following annotations may be added to complete the general appearance of the document to be produced (they are used by the *moseldoc* documentation processor):

`@doc.title`	Title of the document
`@doc.subtitle`	Subtitle of the document
`@doc.xmlheader`	Header of the XML document
`@doc.xmlroot`	Name of the XML element containing the documentation
`@doc.id`	Prefix used to generate IDs of chapters, sections, and subsections. If the documentation for several packages is generated from a single master model then a unique ID must be explicitly defined in each of the packages in order to avoid ID collision

The `@doc` category is complete (*i.e.* it is not possible to create new `doc.X` annotations), however, the category `@doc.ext` can be used to define further information assuming a particular documentation processor can exploit it.

2.20.1.2 Document structure

Optionally, the resulting document may be organised in chapters, sections and subsections. Each of these constructs can contain both text paragraphs and entity descriptions (declarations and subroutines). To enter a new documentation component, one of the following annotations has to be defined:

`@doc.chapter`	Start a chapter
`@doc.section`	Start a section inside of a chapter
`@doc.subsection`	Start a subsection inside of a section

Chapters and sections may also be taken from external files: the annotation `@doc.include` specifies a file name that must be a valid XML document including either chapters (tag `<chapter>`) or sections (tag `<section>`). The Mosel compiler will record the location of the inclusion that will be executed by the *moseldoc* processor.

In addition to the provided title a *short title* might also be defined (using `@doc.shorttitle`) that will be used in place of the (long) title in the table of contents. Whenever a new division starts, a unique ID is

automatically generated based on the section number and any defined prefix specified in the header of the document with `@doc.id`. It is also possible to explicitly define an ID using `@doc.id` just after entering the section (this is required when the section has to be referenced using a `<ref>` tag).

From inside of any of these divisions a new paragraph is added with the `@doc.p` annotation. By default any new addition (paragraph or entity description) is appended to the current component but it is possible to select an alternative location. A *target location* has first to be defined using the annotation `@doc.location`: this creates a label associated with the current section. Defining the annotation `@doc.relocate` with this target elsewhere in the source file will move all subsequent additions to the target location; this relocation will continue up to the next division marker or relocation definition. Note that defining an empty relocation reverts to the effective current location. Example:

```
(!@doc.
  @chapter My first chapter
  @p some text related to the first chapter
  @location first_chap
  @section first section of first chapter
  @p something about the section
  @relocate first_chap
  @p this paragraph will be inserted directly under first chapter
  @relocate
  @p but this one will remain in the section
!)
```

2.20.1.3 Symbol definitions

The following sections list the various documentation annotations that can be defined depending on the kind of the entity (parameter, variable, type or subroutine) to be documented. Some of these annotations are automatically defined by the compiler: in the case of values (like the value of a constant) the automatic definition may not be performed if the value is the result of a calculation that cannot be evaluated at compile time ("runtime constant"). In this case it is required to explicitly specify the text that should be retained in the documentation.

Parameters

`@doc.descr`	Description (1-2 text lines)
`@doc.default`	Default value (automatically generated)
`@doc.type`	Type (automatically generated)
`@doc.value`	Possible value and explanation of its meaning (may be defined several times)
`@doc.info`	Some more detailed explanations (may be defined several times)
`@doc.ignore`	The symbol will be ignored by the documentation processor
`@doc.deprecated`	The parameter is deprecated and should no longer be used (an explanation can be given)

Types, constants and variables

This set of annotations apply to symbols declared in *declarations blocks*. Record fields (both for a type declaration and for a variable) can be described using `@doc.recflddescr`: the value of this annotation consists in the name of the field followed by its description (a space should separate these two components)

`@doc.descr`	Description (1-2 text lines)
`@doc.const`	For a constant: value (automatically generated)

`@doc.type`	Type (automatically generated)
`@doc.typedef`	For a type definition: type (automatically generated)
`@doc.value`	Possible value and explanation of its meaning (may be defined several times)
`@doc.info`	Some more detailed explanations (may be defined several times)
`@doc.setby`	Name of subroutines modifying this entity
`@doc.recfldtype`	Type of a record field (automatically generated)
`@doc.recflddescr`	Description of a record field
`@doc.ignore`	The symbol will be ignored by the documentation processor
`@doc.reqmt`	The symbol is a requirement (automatically generated)
`@doc.deprecated`	The type or variable is deprecated and should no longer be used (an explanation can be given)

Procedures and functions
Information from different overloaded versions of a given subroutine is merged automatically. The `@doc.group` annotation may be used to merge information of routines with different names but used for a similar task (up to 3 different subroutine names can be grouped). The `@doc.param` annotation is used to describe the parameters of the routine: the value of this annotation consists in the name of the parameter followed by its description (a space should separate these two components)

`@doc.group`	Name of another subroutine that this one should be grouped with
`@doc.descr`	Description (1-2 text lines)
`@doc.shortdescr`	Shortened description for table of contents and list display
`@doc.syntax`	Routine signature (automatically generated)
`@doc.param`	Name and meaning of a subroutine argument (may be defined several times)
`@doc.paramval`	Possible value and meaning of a subroutine argument (may be defined several times). The value of this annotation is the name of the parameter (as specified with a preceding `@doc.param`) followed by the value and the explanation
`@doc.return`	For functions only: what is returned
`@doc.err`	Possible error code (may be defined several times)
`@doc.example`	Example of use (may be defined several times)
`@doc.info`	Some more detailed explanations (may be defined several times)
`@doc.related`	List of related symbols
`@doc.ignore`	The subroutine will be ignored by the documentation processor
`@doc.reqmt`	The subroutine is a requirement (automatically generated)
`@doc.deprecated`	The subroutine is deprecated and should no longer be used (an explanation can be given)

2.20.1.4 Annotation definitions

A special set of annotations (category `@doc.annot`) is available for documenting annotation definitions in Mosel packages (not supported for Mosel models). The annotations for documenting annotation definitions are global annotations, their value must start with an annotation name in order to associate them with the corresponding annotation definition.

`@doc.annot.descr` Annotation name followed by a short description (1-2 text lines)

`@doc.annot.default` Annotation name and default value

`@doc.annot.value` Annotation name, possible value and explanation of its meaning (may be defined several times)

`@doc.annot.type` Annotation type

`@doc.annot.info` Annotation name and some more detailed explanations (may be defined several times)

`@doc.annot.deprecated` Annotation name and optionally some explanatory text

`@doc.annotcat` Annotation category to document (may be defined several times), if undefined all categories are documented

`@doc.annotloc` Insertion point (specified via `@doc.location`) for annotations documentation

2.20.1.5 Package control parameters

A special set of annotations (category `@doc.cparam`) is available for documenting control parameters of Mosel packages. The annotations for documenting control parameters are global annotations, their value must start with a parameter name in order to associate them with the corresponding control parameter.

`@doc.cparam.descr` Parameter name followed by a short description (1-2 text lines)

`@doc.cparam.default` Parameter name and default value

`@doc.cparam.value` Parameter name, possible value and explanation of its meaning (may be defined several times)

`@doc.cparam.type` Parameter type (automatically generated by the compiler)

`@doc.cparam.info` Parameter name and some more detailed explanations (may be defined several times)

`@doc.cparam.deprecated` Parameter name and optionally some explanatory text

`@doc.cparamloc` Insertion point (specified via `@doc.location`) for control parameters documentation

2.20.2 moseldoc documentation processor

2.20.2.1 Running *moseldoc*

The *moseldoc* program takes as input either a bim file produced from a Mosel model compiled with the `-D` compiler option or directly a Mosel source file (in which case a compilation step is automatically executed). Typically the generation of the documentation from a source file will be obtained with the following command:

```
>moseldoc mymodel.mos
```

The result of this process is an XML file (`"mymodel_doc.xml"`) and a directory containing an HTML version of the documentation (`"mymodel_html"`). The program will produce only the XML file (from a bim or source file) if option `–xml` is used and only the HTML output (from an XML file) if `–html` is selected. The option `–f` is required to force the replacement of existing files.

As a Mosel program available in source form, *moseldoc* can be adapted to fit specific requirements. To re-generate the executable use this compilation command:

```
>mosel comp -s moseldoc.mos -o deploy.exe:moseldoc,css-z=moseldoc.css
```

2.20.2.2 Structure of the generated document

The resulting document respects the structure defined by the dedicated annotations (chapter, section, subsection). In each of these divisions, the paragraphs are exposed first, then the parameters and variables and finally the list of subroutines. If no structural elements have been defined, a chapter per entity type is automatically created to group similar objects (Parameters, Constants, Types, Variables and Subroutines).

2.20.2.3 Processing of annotation values

Values associated with descriptive text annotations (like section titles or descriptions) are interpreted as XML. Paragraphs (`@doc.p`) and examples (`@doc.example`) are handled in a specific way: by default the value is inserted as XML but, if the value starts with `[TXT]`, the content is treated as plain text; if it starts with `[SRC]`, the value is considered to be some example code and it is reproduced preserving spacing. If it starts with `[NOD]`, it is interpreted as a self-contained XML node (*i.e.* it is not inserted in a paragraph block). In an XML block of text, the markers `ref` (chapter/section/subsection reference), `fctRef` (subroutine reference) and `entRef` (entity reference) are processed such that in the HTML document they are turned into hyperlinks to the corresponding objects. Similarly, the `tt` element type is replaced by an appropriate style for displaying code samples.

2.21 Message translation

Mosel supports a message translation mechanism that makes it possible to display messages in the current language of the operating environment. This system requires that all messages are originally written in English and identified as messages to be translated (it is usually not desirable to translate all text strings of a model). The Mosel compiler can then collect all messages to be translated for building *message catalogs*. Each message catalog file contains the translations of the messages for a given language: Mosel will select the appropriate file for the current language during its execution to use the right set of translations. The system is designed such that it will not fail if a translation or an entire language is missing: in such a case the original English text is used.

2.21.1 Preparing the model source

Most often, not all text strings occurring in a program are to be translated to native language. This is why it is necessary to *tag* each message to be translated such that the automatic message translation system can process only the relevant texts. The tagging is achieved by using the operators `_c(),_()` or the modified procedures `write_(),writeln_(),fwrite_()` and `fwriteln_()`.

The operator `_c()` is used to identify constant strings that should be collected for translation but the string will not be translated at the place where it is used. This operator can be applied to a list of string constants. A similar effect can be obtained with the annotation `mc.msgid`.

The function `_()` applies to both constant strings and variables: it replaces its argument by the translated string. As with the operator `_c()` constant strings are collected for the message catalogs, but they will also be replaced by their translation at the place where the operator is applied to the string.

The `write_` and `writeln_` procedures are equivalent to their normal versions except that they process the constant strings they have to display for translation.

All translations of a model (or package) are grouped under a *domain*: this identifier is used to name the message catalog files. The default domain name is the model (or package) name after having replaced spaces and non-ascii characters by underscores (for instance the domain name of the model `"my mod"` is `"my_mod"`). The domain name can also be specified using the `mc.msgdom` annotation.

The following model example shows the use of the various markers:

```
model translate
! The message domain is 'trs' (default name would be the model name 'translate')
!@mc.msgdom trs

 declarations
  ! The elements of 'nums' are kept in English, but collected for translation
  nums=[_c("one","two","three")]
  ! Add 'four' to the message catalogs (although it is not used here)
  !@mc.msgid:four
 end-declarations

 ! Translate the message text, without translating 'nums'
 writeln_("all numbers (in English): ", nums)
 n:=getfirst(nums)
 ! Translate the message text and the first occurrence of 'n', but not
 ! its second occurrence
 writeln_("the first number is: ", _(n), " (in English:", n, ")")
end-model
```

2.21.2 Building the message catalogs

Once the model source has been prepared, the list of messages to be translated can be extracted. This operation is performed by the Mosel compiler when executed with the option `-x`:

```
>mosel comp -x mymod.mos -o trs.pot
```

The output of this command is a *Portable Object Template* (POT): this is a text file consisting of a list of pairs `msgid` (message to translate), `msgstr` (translation) for which only the first entry is populated.

With the example model from the previous section the generated POT file results in the following:

```
# Created by Mosel v4.0.0 from 'translate.mos'
# Domain name: trs

msgid "all numbers (in English): %L\n"
msgstr ""

msgid "four"
msgstr ""

msgid "one"
msgstr ""

msgid "the first number is: %s (in English:%s)\n"
msgstr ""

msgid "three"
msgstr ""

msgid "two"
msgstr ""
```

For each of the supported languages a separate PO (*Portable Object*) file that will contain the corresponding translations has to be created from this template. The command `xprnls` is used for this

task (for further details please refer to the XPRNLS Reference Manual). For instance the following command will create the file for the Italian translations of the messages:

```
>xprnls init –o trs.it.po trs.pot
```

Here we name the file *domain.language.po* in order to ease the management of these translation files (where *language* stands for the ISO639 language code).

The generated file is a copy of the template with an additional header that should be completed by the translator (it is pre-populated with information obtained from the system), in particular the language (property `"Language"`) and the encoding (property `"Content-Type"`). For each of the `msgid` records the translation in the language associated to the file has to be provided in the `msgstr` record. Note that some messages include escape sequences (like `"\n"`) and format markers (*e.g.* `"%s"`): the corresponding translation must include the same format markers as the original text and they must appear in the same order (otherwise the translation will be ignored).

The beginning of the translation file of our example for French (named `"trs.fr.po"`) should be similar to the following (the extract below shows only the header and the translation of the first message):

```
msgid ""
msgstr ""
"Project-Id-Version: My translation example\n"
"POT-Creation-Date: 2015-12-04 18:16+0100\n"
"PO-Revision-Date: 2015-12-04 18:16+0100\n"
"Last-Translator: Jules Verne\n"
"Language: fr\n"
"Content-Type: text/plain; charset=ISO8859-15\n"

msgid "all numbers (in English): %L\n"
msgstr "tous les nombres (en anglais): %L\n"
```

The *message catalogs* for the PO files are obtained by running once more the `xprnls` command, this time using the option `mogen`:

```
>xprnls mogen –d locale trs.*.po
```

This command will compile each of the PO files into a Machine Object (MO) file named *trs.mo* that will be saved under the directory `locale/`*lang*`/LC_MESSAGES`. This directory tree must be distributed along with the model file for the automatic translation to work.

2.21.3 Model execution

During the execution of the model the message catalogs for the current language (as indicated by the operating system) are loaded automatically from the 'locale' directory. This location is defined by the `"localedir"` control parameter (by default this is `"./locale"`). If no message catalog can be found for the requested language then the original English text is used. This will also be the case if a translation is missing (*e.g.* if the message catalog has not been updated after some model source change).

When run on a computer configured for French our example displays:

```
tous les nombres (en anglais): [`one',`two',`three']
le premier nombre est: un (en anglais:one)
```

CHAPTER 3

Predefined functions and procedures

This chapter lists in alphabetical order all predefined functions and procedures included in the Mosel language. Certain functions or procedures take predefined constants as input values or return values that correspond to predefined constants. In every case, these constants are documented with the function or procedure. In addition, Mosel defines a few other useful numerical constants:

`MAX_INT`	maximum integer number
`MAX_REAL`	maximum real number
`M_E`	base of natural logarithms *e*
`M_PI`	value of π
`INFINITY`	Infinity
`NAN`	Not A Number

abs

Purpose

Get the absolute value of an integer or real.

Synopsis

```
function abs(i:integer):integer
function abs(r:real):real
```

Arguments

`i`	Integer number for which to calculate the absolute value
`r`	Real number for which to calculate the absolute value

Return value

Absolute value of an integer or real number.

Further information

This function returns the absolute value of an integer or real number. The returned type corresponds to the type of the input.

Related topics

`exp`, `ln`, `log`, `sqrt`.

arctan

Purpose

Get the arctangent of a value.

Synopsis

```
function arctan(r:real):real
```

Argument

`r` Real number to which to apply the trigonometric function

Return value

Arctangent of the argument.

Example

The following functions compute the arcsine and arccosine of a value:

```
function arcsin(s:real):real
 returned:=arctan(s/sqrt(1-s^2))
end-function

function arccos(c:real):real
 returned:=arctan(sqrt(1-c^2)/c)
end-function
```

Related topics

`cos`, `sin`

asproc

Purpose

Ignore the return value of a function call.

Synopsis

```
procedure asproc(fctcall)
```

Argument

`fctcall` A function call

Example

```
asproc(splithead(L,2))
```

Further information

This procedure makes it possible to call a function and ignore its return value (see also option `fctasproc` in section 2.3.3).

assert

Purpose

Abort execution if a condition is not satisfied.

Synopsis

```
procedure assert(c:boolean)
procedure assert(c:boolean,m:string)
procedure assert(c:boolean,m:string,e:integer)
```

Arguments

`c`	Condition to verify
`m`	Error message to display in case of failure
`e`	Error code to return in case of failure (default: 8)

Example

```
assert(and(i in I) mydata(i)>0)
assert(isodd(a),"a is not odd!!")
```

Further information

1. If the condition `c` is satisfied, this procedure has no effect, otherwise it displays an error message, calls `dumpcallstack(0)`, and aborts execution by calling `exit`. The versions of the procedure with 2 and 3 parameters can be used to replace the default message (location of the statement in the source) and default exit value (8).

2. If the message `m` starts with the symbols `":"` or `"::"` (*e.g.* `": my error"`) the resulting message will be prefixed by the location of the statement in the source. Otherwise the provided message will replace the default text and be printed unchanged.

3. Assertions are usually used as a debugging tool and are ignored (*i.e.* the statemens are not included at all) when the model is compiled without debugging information (*i.e.* none of options `-g` or `-G` is used) or if the compiler flag `-na` is used. It is however possible to keep assert statements even when no debugging information is included by specifying the compiler directive `keepassert` (see Section 2.3).

Related topics

`exit`, `dumpcallstack`

bitflip

Purpose

Flip bits (bitwise XOR).

Synopsis

```
function bitflip(i:integer, j:integer):integer
```

Arguments

`i` Integer to be set

`j` Value to flip

Return value

Bitwise XOR of the operands.

Example

In the following, `i` takes the value 9, `j` takes the value 141, and `k` takes the value 7:

```
i:= bitflip(12, 5)
j:= biflip(13, 128)
k:= bitflip(13, 10)
```

Further information

This function computes the bitwise exclusive OR of its operands.

Related topics

`bittest`, `bitshift`, `bitset`, `bitneg`, `bitval`

bitneg

Purpose

Bitwise negation (bitwise NOT).

Synopsis

```
function bitneg(i:integer):integer
```

Argument

`i` Integer to negate

Return value

Negated value of argument.

Example

In the following, `i` takes the value -6, `j` takes the value 2147483647, and `k` takes the value -4:

```
i:= bitneg(5)
j:= bitneg(-2147483647-1)
k:= bitneg(3)
```

Further information

The bitwise NOT (or complement) consists in computing the logical negation of each bit: 1 is replaced by 0 and 0 is replaced by 1.

Related topics

`bitset`, `bittest`, `bitflip`, `bitshift`, `bitval`

bitset

Purpose

Set bits (bitwise OR).

Synopsis

```
function bitset(i:integer, j:integer):integer
```

Arguments

`i` Integer to be set

`j` Value to set

Return value

Bitwise OR of the operands.

Example

In the following, `i` takes the value 13, `j` takes the value 141, and `k` takes the value 15:

```
i:= bitset(12, 5)
j:= bitset(13, 128)
k:= bitset(13, 10)
```

Further information

This function computes the bitwise OR of its operands.

Related topics

`bittest`, `bitshift`, `bitflip`, `bitneg`, `bitval`

bitshift

Purpose

Shift an integer by a number of bits.

Synopsis

```
function bitshift(i:integer, n:integer):integer
```

Arguments

`i` Integer to be shifted

`n` Number of bits: >0 for shifting to the left and <0 for shifting to the right

Return value

Shifted integer.

Example

In the following, `i` takes the value 160, `j` takes the value 32, and `k` takes the value 1:

```
i:= bitshift(5, 5)
j:= bitshit(1, 5)
k:= bitshit(128, -7)
```

Further information

Shifting of 1 bit to the right is the same as dividing it by 2 and shifting of 1 bit to the left is the same as multiplying by 2.

Related topics

`bitset`, `bittest`, `bitflip`, `bitneg`, `bitval`

bittest

Purpose

Test bit settings (bitwise AND).

Synopsis

```
function bittest(i:integer, mask:integer):integer
```

Arguments

`i`	Integer to be tested
`mask`	Bit mask

Return value

Bits selected by the mask.

Example

In the following, `i` takes the value 4, `j` takes the value 5, and `k` takes the value 8:

```
i:= bittest(12, 5)
j:= bittest(13, 5)
k:= bittest(13, 10)
```

Further information

This function compares a given number with a bit mask and returns those bits selected by the mask that are set in the number (bit `0` has value `1`, bit `1` has value `2`, bit `2` has value `4`, and so on - use function `bitval` to get the value of a bit).

Related topics

`bitset`, `bitshift`, `bitflip`, `bitneg`, `bitval`

bitval

Purpose

Compute the value corresponding to a bit number.

Synopsis

```
function bitval(i:integer):integer
```

Argument

`i` Bit number (between 0 and 31)

Return value

Value of the selected bit.

Example

In the following, `i` takes the value 1, `j` takes the value -2147483648, and `k` takes the value 16:

```
i:= bitval(0)
j:= bitval(31)
k:= bitval(4)
```

Further information

This function computes the value corresponding to a bit number. The evaluation of `bitval(i)` corresponds to `bitshift(1,i)`

Related topics

`bitset`, `bitshift`, `bitflip`, `bitneg`, `bittest`

ceil

Purpose

Round a number to the next largest integer.

Synopsis

```
function ceil(r:real):integer
```

Argument

`r` Real number to be rounded

Return value

Rounded value.

Example

In the following, `i` takes the value 6, `j` takes the value -6, and `k` takes the value 13:

```
i := ceil(5.6)
j := ceil(-6.7)
k := ceil(12.3)
```

Related topics

`floor`, `round`.

compare

Purpose

Compare 2 values.

Synopsis

`function compare(arg1:`*`ordered type`*`, arg2:`*`same type as arg1`*`):integer`

Arguments

`arg1` First operand for the comparison

`arg2` Second operand for the comparison (same type as `arg1`)

Return value

`0` if arguments are identical, `–1` if the first argument is less than the second argument and `1` otherwise.

Further information

This function is defined for integer, real, string and boolean variables. It is also available for module types that implement the necessary functionality.

cos

Purpose

Get the cosine of a value.

Synopsis

```
function cos(r:real):real
```

Argument

`r` Real number to which to apply the trigonometric function

Return value

Cosine value of the argument.

Example

The function tangent can be implemented as follows:

```
function tangent(x:real):real
 returned:=sin(x)/cos(x)
end-function
```

Related topics

arctan, sin.

create

Purpose

Create explicitly a cell of a dynamic array.

Synopsis

```
procedure create(x:array reference)
procedure create(u:union reference)
```

Arguments

`x`	Cell to be created
`u`	Union to initialize

Example

The following declares a dynamic array of variables, creating only those corresponding to the odd indices. It also initializes a union as a decision variable. Finally, it defines the linear expression `ux + x(1) + x(3) + x(5) + x(7)`:

```
declarations
 x: dynamic array(1..8) of mpvar
 ux: any
end-declarations

create(ux.mpvar)
forall(i in 1..8| isodd(i)) create(x(i))
C:= ux.mpvar + sum(i in 1..8) x(i)
```

Further information

1. Usually cells of dynamic arrays are created by means of assignments. This procedure can be used as a replacement for an assignment, in particular when the type of a dynamic array does not provide any assignment operator (like `mpvar` for instance).
2. In a similar way as for an array cell the `create` procedure may be used to initialize and set the type of a union. If the union has already the requested type no operation if performed, otherwise the current value is deleted and the new type is assigned to the entity (in association with the corresponding default value).

Related topics

Section 2.6.4, Section 2.6.7, `reset`, `delcell`.

currentdate

Purpose

Return the current date as a Julian Day Number (JDN).

Synopsis

```
function currentdate:integer
```

Return value

The number of days elapsed since 1/1/1970 as an integer.

Further information

1. The control parameter `"UTC"` indicates whether this function returns a date in local or UTC time.
2. Refer to the module mmsystem for a set of dedicated types for handling date and time.

Related topics

`setparam`,`timestamp`,`currenttime`

currenttime

Purpose

Return the current time as the number of milliseconds since midnight.

Synopsis

```
function currenttime:integer
```

Return value

The number of milliseconds since midnight as an integer.

Further information

1. The control parameter `"UTC"` indicates whether this function returns a time in local or UTC time.
2. Refer to the module mmsystem for a set of dedicated types for handling date and time.

Related topics

`setparam`,`timestamp`,`currentdate`

cutelt

Purpose

Extract an element from a set or a list.

Synopsis

```
function cutelt(e:set):type_of_e
function cutelt(l:list):type_of_l
function cutelt(l:list,p:integer):type_of_l
```

Arguments

`e`	A set
`l`	A list
`p`	Index of the element to remove (default:1)

Return value

An element of the set or list after it has been removed from its container.

Further information

When applied to a range set or list this function behaves like `cutfirst`. An error is generated if the argument of the function is empty.

Related topics

`getelt`.

cutfirst

Purpose

Extract the first element of a range set or a list.

Synopsis

```
function cutfirst(r:range):integer
function cutfirst(l:list):type_of_l
```

Arguments

`r`	A range set
`l`	A list

Return value

The first element of the set or list after it has been removed from its container.

Further information

This function is equivalent to calling `getfirst` and then `cuthead` for dropping one element.

Related topics

`cutlast`, `cutelt`.

cuthead

Purpose

Cut the first elements of a list.

Synopsis

```
procedure cuthead(l:list, o:integer)
```

Arguments

`l`	A list
`o`	Number of elements to remove if >0 or number of elements to keep if <0

Example

```
L:=[1,2,3,4,5]
cuthead(L,2)     ! => L=[3,4,5]
cuthead(L,-1)    ! => L=[5]
```

Further information

If the second parameter is 0, the list is unchanged. If the same parameter is larger than the size of the list, all elements are deleted.

Related topics

`cuttail`

cutlast

Purpose

Extract the last element of a range set or a list.

Synopsis

```
function cutlast(r:range):integer
function cutlast(l:list):type_of_l
```

Arguments

`r`	A range set
`l`	A list

Return value

The last element of the set or list after it has been removed from its container.

Further information

This function is equivalent to calling `getlast` and then `cuttail` for dropping one element.

Related topics

`cutfirst`, `cutelt`.

cuttail

Purpose

Cut the last elements of a list.

Synopsis

```
procedure cuttail(l:list, o:integer)
```

Arguments

`l`	A list
`o`	Number of elements to remove if >0 or number of elements to keep if <0

Example

```
L:=[1,2,3,4,5]
cuttail(L,2)     ! => L=[1,2,3]
cuttail(L,-1)    ! => L=[1]
```

Further information

If the second parameter is 0, the list is unchanged. If the same parameter is larger than the size of the list, all elements are deleted.

Related topics

`cuthead`

delcell

Purpose

Delete a cell or all cells of a dynamic array.

Synopsis

```
procedure delcell(x:array reference)
procedure delcell(a:array)
```

Arguments

`x`	Cell to be deleted
`a`	An array

Further information

1. The first form of the routine can only be applied to dynamic arrays (it is not possible to delete a cell of a dense array). Using the second syntax of the procedure will release all cells of the array, note that in the case of a dense array the entire data set will be reallocated when the array is accessed again.
2. Deleting a cell of an array of referenced objects (like `mpvar`) may not effectively release that object. Actually, a referenced object is released only when all its references have been removed. For instance, if an object appears in a set, deleting its main reference using `delcell` will not remove this object from the set.

Related topics

Section 2.6.4, `create`, `reset`.

datablock

Purpose

Get the file name of an embedded data block .

Synopsis

```
function datablock(src:string, prefix:string):string
function datablock(src:string):string
```

Arguments

`src`	Name of the file to be embedded
`prefix`	Prefix to be used for accessing the data block (default: `"zlib.deflate:"`)

Return value

A file name pointing to the data block

Example

In the following code extract the bim file for `submod.mos` is generated during the compilation of the current (master) model and is included in the resulting bim file for this model. At execution time the master model will therefore not require any additional file for this submodel:

```
load(submod,datablock("mmsystem.pipe:mosel comp -o - submod.mos"))
run(submod)
waitforend(submod)
```

Note that the output of the compilation for the file `submod.mos` is redirected via the 'pipe' onto the master model while this model itself is being compiled.

Further information

1. This function makes it possible to embed in a bim file any data files that are available during the compilation of the model source but cannot be accessed at execution time. The files specified by this routine are made available as memory blocks (see Section 2.15) during the execution of the model.
2. The file specified by the `src` argument is loaded into memory and saved in the resulting bim file during the compilation of the source model. At execution time this function call results in a file name pointing to a memory location storing the previously saved data.
3. The file name `src` is handled in the same way as for source file inclusion (see Section 2.5.2), in particular the same rules apply regarding the file location and the expansion of environment variables.
4. The `prefix` argument can be used to select a driver for processing the file. With its default value (`"zlib.deflate:"`) the file is compressed before being stored in the bim file, the decompression occurs when the file is accessed during execution (*i.e.* the file name returned by the function begins with the string `"zlib.deflate:"`). To keep the file in its original form use an empty string as the prefix (*i.e.* `""`).
5. When several data blocks with the same name and prefix are used in a model source the corresponding file is loaded and stored only once.
6. If the file to store is empty (or if its name is an empty string) the function call is replaced by the constant `"null:"` and no memory block is created.

dumpcallstack

Purpose

Display the current call stack of the system.

Synopsis

```
procedure dumpcallstack(ml:integer)
```

Argument

`ml` Maximum number of levels to display

Further information

1. This procedure displays the call stack of the running model, that is the sequence of subroutine calls leading to the current statement. The parameter `ml` sets a limit on the number of steps to report, if this value is 0 the default value defined at the global level will be used (see Section 1.3.1).
2. Stack dumps require debugging information: if the model has not been compiled with options `-g` or `-G` calling the procedure will have no effect.

Related topics

`assert`.

exists

Purpose

Check if a given entry in a dynamic array has been created.

Synopsis

```
function exists(x):boolean
```

Argument

`x` Array reference (*e.g.* `t(1)`)

Return value

`true` if the entry exists, `false` otherwise.

Example

The following, a dynamic array of decision variables only has its even elements created, which is checked by displaying the existing variables:

```
declarations
 S=1..8
 x: dynamic array(S) of mpvar
end-declarations

forall(i in S| not isodd(i)) create(x(i))
forall(i in S| exists(x(i)))
 writeln("x(", i, ") exists")
```

Further information

1. If an array is declared dynamic its elements are not created at its declaration. This function indicates if a given element has been created.
2. Under certain conditions, the `exists` function call is optimized by the compiler when used for filtering an aggregate operator: the loop is only performed for the existing entries instead of enumerating all possible tuples of indices for finding the relevant ones.

Related topics

Section 2.7.2, `create`.

exit

Purpose

Terminate the program.

Synopsis

```
procedure exit(code:integer)
```

Argument

`code` Value to be returned by the program

Further information

This procedure terminates the current program and returns the given value. Models exit by default with a value of `0` unless this is changed using `exit`. The Mosel command line interpreter uses this value as exit status.

Related topics

Section 1.3.

exp

Purpose

Get the natural exponent of a value.

Synopsis

```
function exp(r:real):real
```

Argument

`r` Real value the function is applied to.

Return value

Natural exponent (e^r) of the argument.

Related topics

`abs`, `exp`, `ln`, `log`, `sqrt`.

exportprob

Purpose

Export the current LP/MIP problem held in Mosel core (the portion of a problem defined with mpvar and linctr only) to a file.

Synopsis

```
procedure exportprob(options:integer, filename:string, obj:linctr)
procedure exportprob(options:integer, filename:string)
procedure exportprob(filename:string, obj:linctr)
procedure exportprob(filename:string)
procedure exportprob
```

Arguments

`options` File format options:

`EP_MIN`	minimization (default)
`EP_MAX`	maximization
`EP_MPS`	MPS format
`EP_STRIP`	Use scrambled names
`EP_HEX`	Ouput numbers in hexadecimal when using MPS format

Several options may be combined using `+`.

`filename` Name of the output file. If the empty string `""` is given, output is printed to the standard output (the screen)

`obj` Objective function constraint

Example

The following prints the current problem to the screen using the default format and with `MinCost` as objective function. The second statement exports the problem in LP-format and with scrambled names to the file `prob1.lp` maximizing the constraint `Profit`:

```
declarations
 MinCost, Profit:linctr
end-declarations

exportprob(0, "", MinCost)
exportprob(EP_MAX+EP_STRIP, "prob1", Profit)
```

Further information

1. **Problem types:** This function exports only the LP/MIP problem directly handled by the Mosel core libraries. It cannot report problem extensions managed by external modules—these are silently ignored. For instance, quadratic constraints, indicator constraints or general constraints provided by the Xpress Optimizer are not shown by this routine: for this type of problems, the module-specific `writeprob` routine has to be used instead of `exportprob`.

2. **Number format:** Except when option `EP_MPS+EP_HEX` is used numbers are ouput according to the `realfmt`, `txtztol` and `zerotol` model parameters (see `setparam`). Mosel's real number formatting follows C printing format which is different, for example, from the formatting rules applied by Xpress Optimizer, in particular in the module-specific `writeprob` routine.

3. **File extension:** If the given filename uses the default IO driver (no driver specified) and has no extension, Mosel appends `.lp` to it for LP format files and `.mps` for MPS format.

4. **Entity names:** Normally, local symbols (*i.e.* defined in a procedure or function) are replaced by generated names in the exported matrix. However, if the model has been compiled with option `-G`, names defined locally to the routine calling `exportprob` are used in the exported matrix. Moreover, if a local symbol hides a global one, this symbol is prefixed by '~'.

5. If the model is compiled with `-G` and the control parameter `recloc` is set to `true` (see `setparam`), missing constraint names are replaced by the source location of the constraint definition (*i.e.* a combination of the row number, source file name and line number in the file).

6. If no option is provided, the default format is LP for a minimization; if no constraint is given, the current objective (if available) is exported. The matrix is printed to the standard output when this function is used without parameter.

Related topics

`setname`.

fclose

Purpose

Close the active input, output or error stream.

Synopsis

```
procedure fclose(stream:integer)
```

Argument

`stream` The stream to close:

`F_INPUT`	Input stream
`F_OUTPUT`	Output stream
`F_ERROR`	Error stream

Further information

1. This procedure closes the file that is currently associated with the given stream. The file preceding the closed file (in the order of opening) is then assigned to the corresponding stream. A file that is closed with this procedure must previously have been opened with `fopen`. This function has no effect if the corresponding stream is not associated with any explicitly opened file (*i.e.* it is not possible to close the default input, output or error streams). All open streams are automatically closed when the program terminates.
2. An IO error will be raised if the operation does not succeed.

Related topics

`fflush`, `fopen`, `fselect`, `getfid`, `iseof`.

fflush

Purpose

Force the operating system to write buffered data.

Synopsis

```
procedure fflush
```

Further information

This procedure forces a write of all buffered data of the default output stream. `fflush` is automatically called when the stream is closed either with `fclose` or when the program terminates.

Related topics

`fclose`, `fopen`.

finalize

Purpose

Finalize the definition of a set or list.

Synopsis

```
procedure finalize(s:set)
procedure finalize(l:list)
```

Arguments

`s`	Dynamic set
`l`	Dynamic list

Further information

1. This procedure finalizes the definition of a set (or list), that is, it turns a dynamic set into a constant set consisting of the elements that are currently in the set.
2. Using this routine on sets declared dynamic has no effect.

findfirst

Purpose

Find the first occurrence of an element in a list.

Synopsis

```
function findfirst(l:list, e:type_of_l):integer
```

Arguments

`l`	A list
`e`	The element to look for (it must be of the type of `l`)

Return value

The position of the element or 0 if the element is not included in the list.

Example

```
L:=['a','b','c','d','b']
i:=findfirst(L,'b')     ! => i=2
i:=findlast(L,'f')      ! => i=0
```

Related topics

`findlast`

findlast

Purpose

Find the last occurrence of an element in a list.

Synopsis

```
function findlast(l:list, e:type_of_l):integer
```

Arguments

`l`	A list
`e`	The element to look for (it must be of the type of `l`)

Return value

The position of the element or 0 if the element is not included in the list.

Example

```
L:=['a','b','c','d','b']
i:=findlast(L,'b')      ! => i=5
i:=findlast(L,'f')      ! => i=0
```

Related topics

`findfirst`

floor

Purpose

Round a number to the next smallest integer.

Synopsis

```
function floor(r:real):integer
```

Argument

`r` Real number to be rounded

Return value

Rounded value.

Example

In the following, `i` takes the value 5, `j` the value -7, and `k` the value 12:

```
i := floor(5.6)
j := floor(-6.7)
k := floor(12.3)
```

Related topics

`ceil`, `round`.

fopen

Purpose

Open a file and make it the active input, output or error stream.

Synopsis

```
procedure fopen(f:string, mode:integer)
```

Arguments

`f` The name of the file to be opened

`mode` The open mode that consists in a stream selection and optional flags. The stream is one of:

`F_INPUT`	Input stream (for reading)
`F_OUTPUT`	Output stream (for writing)
`F_ERROR`	Error stream (for writing error messages)

Possible optional flags (to be combined with the stream selection):

`F_APPEND`	Open for writing, appending new data to the end of the file (otherwise the file is cleared before opening)
`F_TEXT`	Text mode (the default)
`F_BINARY`	Binary mode
`F_LINBUF`	If open for writing, flushes buffer after end of each line (default when writing to a console or for an error stream)
`F_SILENT`	Do not display IO error messages

Further information

1. This procedure opens a file for reading or writing. If the operation succeeds, depending on the opening mode, the file becomes the active input, output or error stream. The procedures `write` and `writeln` are used to write data to the default output stream and the functions `read`, `readln`, and `fskipline` are used to read data from the default input stream. Error messages are sent to the error stream.

2. The behavior of this function in case of an IO error (*i.e.* the file cannot be opened) is directed by the control parameter `ioctrl` (see `setparam`): if the value of this parameter is 'false' (default value), the interpreter stops. Otherwise, the interpreter ignores the error and continues. The error status of an IO operation is stored in the control parameter `iostatus` (see `getparam`) which is 0 when the last operation has been executed successfully. Note that this parameter is automatically reset once its value has been read using the function `getparam`. The behavior of IO operations after an unhandled error is not defined.

3. The *binary mode* disables character encoding conversion (see section 2.16).

Related topics

`fclose`, `fselect`, `getfid`.

fselect

Purpose

Select the active input, output or error stream.

Synopsis

```
procedure fselect(stream:integer)
```

Argument

`stream` The stream number

Example

The following saves the file ID of the default output before switching output to the file `mylog.txt`. Subsequently, the file ID of the current output stream is saved and the default output is again selected.

```
def_out:= getfid(F_OUTPUT)
fopen("mylog.txt", F_OUTPUT)
  ...
my_out:= getfid(F_OUTPUT)
fselect(def_out)
```

Further information

1. This procedure selects the given stream as the active input, output or error stream. The concerned stream is designated by the opening status of the given stream (that is, if the given stream has been opened for reading, it will be assigned to the default input stream). The stream number can be obtained with the function `getfid`.
2. The default input, output and error streams have respectively numbers 0, 1 and 2.
3. An IO error will be raised if the requested file ID does not exist.

Related topics

`fclose`, `fopen`, `getfid`, `fwrite`, `fwriteln`.

fskipline

Purpose

Advance in the default input stream as long as comment lines are found.

Synopsis

```
procedure fskipline(filter:string)
```

Argument

`filter` List of comment signs

Example

In the following, the first statement skips all lines beginning with either '`#`' or '`!`'. The second statement skips any following blank lines:

```
fskipline("!#")
fskipline("\n")
```

Further information

This procedure advances in the input stream using the given list of comment signs as a filter. Each character of the given string is considered to be a symbol that marks the beginning of a comment line. Note that the character '\n' designates lines starting with nothing, that is, empty lines. During the parsing, spaces and tabulations are ignored.

Related topics

`read`, `readln`.

fwrite, fwriteln

Purpose

Send an expression or list of expressions to the specified output stream.

Synopsis

```
procedure fwrite(fd:integer, e1:expr[, e2:expr...])
procedure fwriteln(fd:integer)
procedure fwriteln(fd:integer, e1:expr[, e2:expr...])
```

Arguments

`fd`	An output stream number
`e1, e2,...`	Expression or list of expressions

Further information

1. These procedures are equivalent to calling `fselect` before using the corresponding output procedure and then restore the initial current stream with a second call to `fselect`.
2. The selected stream may also be an error stream.

Related topics

`write`, `writeln`, `fselect`, `getfid`.

getact

Purpose

Get the activity value of a constraint.

Synopsis

```
function getact(c:linctr):real
```

Argument

`c` A linear constraint

Return value

Activity value or 0.

Further information

This function returns the activity value of a constraint if the problem has been solved successfully, otherwise 0 is returned.

Related topics

`getdual`, `getslack`, `getsol`.

getcoeff

Purpose

Get a constraint coefficient or constant term.

Synopsis

```
function getcoeff(c:linctr):real
function getcoeff(c:linctr, x:mpvar):real
function getcoeff(c:linctr, n:integer):real
```

Arguments

`c` A linear constraint

`x` A decision variable

`n` `-1` for constant term, `-2` for range lower bound

Return value

Coefficient of the variable or a constant term.

Example

In this example a single constraint with three variables is defined. The calls to `getcoeff` result in `r` taking the value `-1` and `s` taking the value `-12`.

```
declarations
 x,y,z:mpvar
end-declarations

c:= 4*x + y -z <= 12
r:= getcoeff(c, z)
s:= getcoeff(c)
```

Further information

This function returns the coefficient of a given variable in a constraint, or if no variable is given, the constant term (= -RHS) of the constraint. The returned values correspond to a normalised constraint representation with all variable and constant terms on the left side of the (in)equality sign.

Related topics

`getcoeffs`, `getvars`, `setcoeff`.

getcoeffs

Purpose

Get all variable coefficients of a constraint.

Synopsis

```
procedure getcoeffs(c:linctr, a:array(set of mpvar) of real, s:set of
      mpvar)
```

Arguments

`c`	A linear constraint
`a`	An array of reals indiced by decision variables
`s`	A set of decision variables

Further information

1. This procedure returns in the parameter `a` the coefficients of all variables of a constraint. After calling this procedure, the coefficient of variable `v` of constraint `c` is `a(v)`. The set `s` is used to specify for which variables the coefficients have to be retrieved (if this set is empty all variables are considered).

2. If set `s` is empty all cells of array `a` are updated (*i.e.* cells corresponding to variables not included in constraint `c` are set to 0). Otherwise only cells corresponding to elements of `s` are modified.

Related topics

`getcoeffs`, `getcoeff`

getdual

Purpose

Get the dual value of a constraint.

Synopsis

```
function getdual(c:linctr):real
```

Argument

`c` A linear constraint

Return value

Dual value or 0.

Further information

This function returns the dual value of a constraint if the problem has been solved successfully and the constraint is contained in the problem, otherwise 0 is returned.

Related topics

`getrcost`, `getslack`, `getsol`.

getelt

Purpose

Get an element of a set or a list.

Synopsis

```
function getelt(e:set):type_of_e
function getelt(l:list):type_of_l
```

Arguments

`e`	A set
`l`	A list

Return value

An element of the set or list.

Further information

When applied to a range set or list this function behaves like `getfirst`. An error is generated if the argument of the function is empty.

Related topics

`cutelt`.

geteltype

Purpose

Get the type ID of an element of a collection type.

Synopsis

```
function geteltype(u: union): integer
function geteltype(tid: integer): integer
```

Arguments

`u`	A union
`tid`	A type ID

Return value

A type ID or `-1` if the provided parameter is not a valid type ID or the union is not defined.

Example

```
declarations
 MYSET=set of integer
 s: MYSET
 u1,u2,u3: any
end-declarations
  ...
u1:=s
u2:="bla"
writeln("ElType of MYSET: ", geteltype(MYSET.id),    ! = integer.id=1
        "\nElType of u1: ", u1.eltype,               ! = integer.id=1
        "\nElType of u2: ", u2.eltype,               ! = string.id=3
        "\nElType of u3: ", u3.eltype)               ! = -1
```

Further information

1. This function retrieves the type ID of an element of a collection (array, set or list) represented by a type ID or the value stored in a union. If the referenced type is not a collection (*i.e.* it is a constant or a reference) the type of the entity itself will be returned (that is the same value as `gettypeid`).
2. There are 2 versions of this routine: when used with a union the information reported comes from the current value of this union (`-1` is returned if the union is not initialized). If applied to an integer the function expects this integer to be a type ID (`-1` is returned if this value does not correspond to a type ID).

Related topics

`getstruct`, `gettypeid`, `geteltype`.

getfid

Purpose

Get the stream number of the active input, output or error stream.

Synopsis

```
function getfid(stream:integer):integer
```

Argument

`stream` The stream to query:

`F_INPUT`	Input stream
`F_OUTPUT`	Output stream
`F_ERROR`	Error stream

Return value

Stream number.

Further information

The returned value can be used as parameter for the function `fselect`.

Related topics

`fselect`.

getfirst

Purpose

Get the first element of a range set or a list.

Synopsis

```
function getfirst(r:range):integer
function getfirst(l:list):type_of_l
```

Arguments

`r` A range set

`l` A list

Return value

The first element of the set or list.

Example

In this example the range set `r` is defined before its first and last elements are retrieved and displayed:

```
declarations
 r=2..8
end-declarations
  ...
writeln("First element of r: ", getfirst(r),
        "\nLast element of r: ", getlast(r))
```

Further information

When applied to a list, the type of the function is the type of the list. An error is generated if the argument of the function is empty.

Related topics

`getlast`, `cutfirst`.

gethead

Purpose

Get a copy of the first elements of a list.

Synopsis

```
function gethead(l:list, o:integer):list
```

Arguments

`l`	A list
`o`	Number of elements to copy if >0 or number of elements to ignore if <0

Return value

A (partial) copy of the list.

Example

```
L:=[1,2,3,4,5]
L2:=gethead(L,2)     ! => L2=[1,2]
L2:=gethead(L,-1)    ! => L2=[1,2,3,4]
```

Further information

This function does not alter its input list. If the second parameter is 0 an empty list is returned. If the same parameter is larger than the size of the list the function returns a copy of the original list.

Related topics

`gettail`

getfname

Purpose

Get the file name associated to the active input, output or error stream.

Synopsis

```
function getfname(stream:integer):string
```

Argument

`stream` The stream to query:

`F_INPUT`	Input stream
`F_OUTPUT`	Output stream
`F_ERROR`	Error stream

Return value

File name.

getlast

Purpose

Get the last element of a range set or a list.

Synopsis

```
function getlast(r:range):integer
function getlast(l:list):type_of_l
```

Arguments

`r` A range set

`l` A list

Return value

The last element of the set or list.

Example

In this example the range set `r` is defined before its first and last elements are retrieved and displayed:

```
declarations
 r=2..8
end-declarations
  ...
writeln("First element of r: ", getfirst(r),
        "\nLast element of r: ", getlast(r))
```

Further information

When applied to a list, the type of the function is the type of the list. An error is generated if the argument of the function is empty.

Related topics

`getfirst`.

getnbdim

Purpose

Get the number of dimensions of an array.

Synopsis

```
function getnbdim(a:array):integer
```

Argument

`a` An array

Return value

Number of dimensions of the array.

getobjval

Purpose

Get the objective function value.

Synopsis

```
function getobjval:real
```

Return value

Objective function value or 0.

Further information

This function returns the objective function value if the problem has been solved successfully. If integer feasible solution(s) have been found, the value of the best is returned, otherwise the value of the last LP solved.

Related topics

getsol.

getparam

Purpose

Get the current value of a control parameter.

Synopsis

```
function getparam(name:string):integer|string|real|boolean
```

Argument

`name` Name of the control parameter whose value is to be returned (case insensitive).

Return value

Current setting of the control parameter.

Further information

1. Parameters whose values may be returned by this function include the settings of Mosel as well as those of any loaded module or package. The location of the parameter may be specified by prefixing its name with the name of the module or package defining it (*e.g.* `mmxprs.XPRS_verbose`). The type of the return value corresponds to the type of the parameter.

2. This function can be applied only to control parameters whose value can be accessed.

3. The `name` argument must be a constant string: a model parameter, variable or string expression cannot be used as a control parameter name.

4. The following control parameters are supported by Mosel:
   `realfmt` Default C printing format for real numbers (string)
   `zerotol` zero tolerance in comparisons between reals (real)
   `txtztol` zero tolerance is used when converting real values to their textual representation (Boolean)
   `ioctrl` the interpreter ignores IO errors (Boolean)
   `iostatus` status of the last IO operation (integer), which is 0 when the last operation has been executed successfully. This parameter is automatically reset once its value has been read. Not doing so may result in undefined behavior. When `ioctrl` is active the IO status must be read (and reset) after every IO operation
   `nbread` number of items recognized by the last `read` procedure or read in by the last initializations block (integer)
   `readcnt` generate per label counting when executing 'initializations from' blocks (Boolean)
   `UTC` indicate whether the time functions return time expressed in local (false) or UTC (true) time (Boolean)
   `autofinal` indicate whether initialisation from blocks are finalizing sets (Boolean)
   `tmpdir` the Mosel temporary directory (string)
   `workdir` the current working directory of the model (string)
   `restrict` active restrictions (integer). See Section 1.3.4 for further details.
   `modelname` internal unique name of the model being executed.
   `modelnumber` order number of the model being executed.
   `recloc` indicate whether automatic recording of source location of constraints definitions is active (Boolean)
   `localedir` directory where message catalogs are stored (string)
   `lang` current language (string)
   `runparams` parameter string used for the current execution (string)
   `bimprefix` list of bim file prefixes (string)
   `sharingstatus` sharing status of the model (integer). This parameter is `-1` if the model does not share any data; `0` if the model shares data but no submodel is using it; `1` when shared data is in use; `2` if the model is a submodel using shared data (see Section 8.2)

5. Function `getparam` may also be used to retrieve *parser parameters*. As opposed to the other parameters whose value is computed at run time, these parameters are evaluated as soon as they are parsed:
   `parser_line` number of the line being parsed (integer)
   `parser_file` current source file name (string)
   `parser_date` current local date (string)
   `parser_time` current local time (string)
   `parser_UTCdate` current UTC date (string)
   `parser_UTCtime` current UTC time (string)
   `parser_version` Mosel version (string)
   `model_version` Version of the model as given by the `version` directive (string)

Related topics

`setparam`, `getdsoparam`.

getrcost

Purpose

Get the reduced cost value of a variable.

Synopsis

```
function getrcost(v:mpvar):real
```

Argument

`v` A decision variable

Return value

Reduced cost value or 0.

Further information

This function returns the reduced cost value of a variable if the problem has been solved successfully and the variable is contained in the problem, otherwise 0 is returned.

Related topics

`getslack`, `getsol`, `getdual`.

getreadcnt

Purpose

Get the number of items read in during last ‘initializations from’ for a given label.

Synopsis

```
function getreadcnt(l:string):integer
```

Argument

`l` A label

Return value

Number of items read in for label `l`.

Further information

Value 0 is returned if the given string does not correspond to a label or if control parameter `readcnt` has not been set to `true` before execution of the initializations block.

getreverse

Purpose

Duplicate and reverse a list.

Synopsis

```
function getreverse(l:list):list
```

Argument

`l` A list

Return value

A reversed copy of the provided list.

Example

```
L:=[1,2,3,4,5]
L2:=L.reverse    ! => L=[5,4,3,2,1]
```

Related topics

reverse.

getsize

Purpose

Get the size of an array, set, list, constraint or string.

Synopsis

```
function getsize(a:array):integer
function getsize(s:set):integer
function getsize(l:list):integer
function getsize(t:string):integer
function getsize(c:linctr):integer
```

Arguments

`a`	An array
`s`	A set
`l`	A list
`t`	A string
`c`	A linear constraint

Return value

Number of effective entries for an array, number of elements for a set or a list, number of characters for a string, number of terms for a constraint.

Example

In the following, a dynamic array is declared holding eight elements, of which only two are actually defined. Calling `getsize` on this array returns `2` rather than `8`. The length `lw` of the string `w` is `9`.

```
declarations
 a:dynamic array(1..8) of real
 w = "some text"
end-declarations

a(1):= 4
a(5):= 7.2
la:= getsize(a)
lw:= getsize(w)
```

Further information

In the case of a dynamic array that has been declared with a maximal range this number may be smaller than the size of the range, but it cannot exceed it. When used with a string, this function returns the length of the string (*i.e.* the number of characters it contains). If used with a linear constraint, this function returns the number of terms of the constraint (the constant term is not taken into account).

getslack

Purpose

Get the slack value of a constraint.

Synopsis

```
function getslack(c:linctr):real
```

Argument

`c` A linear constraint

Return value

Slack value or 0.

Further information

This function returns the slack value of a constraint if the problem has been solved successfully and the constraint is contained in the problem, otherwise 0 is returned.

Related topics

`getdual`, `getrcost`, `getsol`.

getsol

Purpose

Get the solution value of a variable or a linear expression (constraint).

Synopsis

```
function getsol(v:mpvar):real
function getsol(c:linctr):real
```

Arguments

`c` A linear constraint

`v` A decision variable

Return value

Solution value or 0.

Further information

This function returns the (primal) solution value of a variable if the problem has been solved successfully and the variable is contained in the problem (otherwise 0). If used with a constraint, it returns the evaluation of the corresponding linear expression using the current solution.

Related topics

`getdual`, `getrcost`, `getobjval`.

getstruct

Purpose

Get the structure of a type.

Synopsis

```
function getstruct(u: union): integer
function getstruct(tid: integer): integer
```

Arguments

`u`	A union
`tid`	A type ID

Return value

Type structure as an integer. Possible structures are:

`STRUCT_CONST`	A constant
`STRUCT_REF`	A reference
`STRUCT_ARRAY`	An array
`STRUCT_SET`	A set
`STRUCT_LIST`	A list
`STRUCT_ROUTINE`	A subroutine
`STRUCT_NATTYPE`	A native type
`STRUCT_PROBLEM`	A problem
`STRUCT_RECORD`	A record
`STRUCT_USRTYPE`	A user type
`STRUCT_UNION`	A union
`-1`	If the provided parameter is not a valid type ID or the union is not defined

Example

```
declarations
 MYSET=set of integer
 s: MYSET
 u1,u2,u3: any
end-declarations
  ...
u1:=s
u2:="bla"
writeln("ElType of MYSET: ", getstruct(MYSET.id),    ! = STRUCT_SET=12288
        "\nElType of u1: ", u1.struct,               ! = STRUCT_SET=12288
        "\nElType of u2: ", u2.struct,               ! = STRUCT_CONST=0
        "\nElType of u3: ", u3.struct)               ! = -1
```

Further information

1. This function retrieves the structure (constant, reference, array, set, list, or subroutine) of a type represented by its ID or by the value stored in a union. The type ID of an element of a non-scalar type may be obtained with `geteltype`.
2. When applied to the ID of a basic type (integer, real, string or boolean) this function will return `STRUCT_CONST` although a variable of these types is a reference and a union may hold either a reference or a constant for basic types.
3. There are 2 versions of this routine: when used with a union the information reported comes from the current value of this union (`-1` is returned if the union is not initialized). If applied to an integer the function expects this integer to be a type ID (`-1` is returned if this value does not correspond to a type ID).

Related topics

geteltype, gettypeid.

gettail

Purpose

Get a copy of the last elements of a list.

Synopsis

```
function gettail(l:list, o:integer):list
```

Arguments

`l`	A list
`o`	Number of elements to copy if >0 or number of elements to ignore if <0

Return value

A (partial) copy of the list.

Example

```
L:=[1,2,3,4,5]
L2:=gettail(L,2)     ! => L2=[4,5]
L2:=gettail(L,-1)    ! => L2=[2,3,4,5]
```

Further information

This function does not alter its input list. If the second parameter is 0 an empty list is returned. If the same parameter is larger than the size of the list the function returns a copy of the original list.

Related topics

`gethead`

gettype

Purpose

Get the type of a constraint.

Synopsis

```
function gettype(c:linctr):integer
```

Argument

`c` A linear constraint

Return value

Constraint type. Values applicable to any type of linear constraint are:

`CT_EQ` Equality, '='

`CT_GEQ` Greater than or equal to, '$\geq$'

`CT_LEQ` Less than or equal to, '$\leq$'

`CT_RNG` Range

`CT_UNB` Non-binding constraint

`CT_SOS1` Special ordered set of type 1

`CT_SOS2` Special ordered set of type 2

Values applicable for unary constraints are:

`CT_CONT` Continuous

`CT_INT` Integer

`CT_BIN` Binary

`CT_PINT` Partial integer

`CT_SEC` Semi-continuous

`CT_SINT` Semi-continuous integer

`CT_FREE` Free

Related topics

`settype`.

gettypeid

Purpose

Get the type ID of the value of a union.

Synopsis

```
function gettypeid(u: union): integer
```

Argument

`u` A union

Return value

A type ID, `0` if the information is not available or `-1` if the union is not defined.

Example

```
declarations
 MYSET=set of integer
 s: MYSET
 u1,u2,u3,u4: any
end-declarations
  ...
u1:=s
u2:={1,2,3}
u4:=13.3
writeln("ElType of u1: ", u1.typeid,            ! = MYSET.id
        "\nElType of u4: ", u4.typeid,          ! = real.id=2
        "\nElType of u2: ", u2.typeid,          ! = 0
        "\nElType of u3: ", u3.typeid)          ! = -1
```

Further information

1. This function retrieves the type ID of the value stored in a union. This information is always defined if the value is a scalar (*i.e.* a constant or a reference) but it will be available for a structured type only if the value comes from an entity that is defined as an instance of a defined user type.
2. When the function returns 0, the properties of the value stored in the union can still be obtained via `getstruct` and `geteltype`.

Related topics

`getstruct`, `geteltype`.

getvars

Purpose

Get the set of variables of a constraint.

Synopsis

```
procedure getvars(c:linctr,s:set of mpvar)
```

Arguments

`c` A linear constraint

`s` A set of decision variables

Example

The following returns the set of variables in a linear constraint to the set variable `vset`, and then loops through them to find their solution values:

```
declarations
 c:linctr
 vset: set of mpvar
end-declarations

getvars(c,vset)
forall(x in vset) writeln(getsol(x))
```

Further information

This procedure returns in the parameter `s` the set of variables of a constraint. Note that this procedure replaces the content of the set.

Related topics

`getcoeffs`, `getcoeff`

isdefined

Purpose

Check whether an entity is defined.

Synopsis

```
function isdefined(v:reference):boolean
```

Argument

`v` A variable of a reference type

Return value

`true` if the provided entity is defined.

Example

```
declarations
 f: function(real):real
 u: any
end-declarations
writeln(isdefined(u))    ! = false
u:=1.5
writeln(isdefined(u))    ! = true

writeln(isdefined(->f))  ! = false
f:=->cos
writeln(isdefined(->f))  ! = true
reset(->f)
writeln(isdefined(->f))  ! = false
```

Further information

This function returns `true` if the provided entity is not a `NULL` reference and, in the case of a union or a subroutine, if it has been assigned a value.

isdynamic

Purpose

Check whether an array, set, or list is dynamic.

Synopsis

```
function isdynamic(a:array):boolean
function isdynamic(s:set):boolean
function isdynamic(l:list):boolean
```

Arguments

`a`	An array
`s`	A set
`l`	A list

Return value

`true` if the provided entity is dynamic.

Further information

This function returns `true` when applied to sparse arrays (*i.e.* declared either as `dynamic` or `hashmap`).

iseof

Purpose

Test whether the end of the default input stream has been reached.

Synopsis

```
function iseof:boolean
```

Return value

`true` if the end of the default input stream has been reached, `false` otherwise.

Example

The following opens a datafile of integers, reads one from each line and prints it to the console until the end of the file is reached:

```
declarations
 d:integer
end-declarations
  ...
fopen("datafile.dat", F_INPUT)
while(not iseof) do
  readln(d)
  writeln(d)
end-do
fclose(F_INPUT)
```

Further information

This function returns the “end of file” status of the active input stream.

Related topics

`fclose`, `fopen`.

isfinite

Purpose

Test whether a real value is finite.

Synopsis

```
function isfinite(r: real):boolean
```

Argument

`r` The value to test

Return value

`true` if the value is neither `(-)INFINITY` nor `NAN`.

Further information

The call `isfinite(v)` is equivalent to `(not isnan(v) and not isinf(v))`.

Related topics

`setmatherr`, `isnan`, `isinf`.

ishidden

Purpose

Test whether a constraint is hidden.

Synopsis

```
function ishidden(c:linctr):boolean
```

Argument

`c` A linear constraint

Return value

`true` if the constraint is hidden, `false` otherwise.

Further information

This function tests the current status of a constraint. At its creation a constraint is added to the current problem, but using the function `sethidden` it may be hidden. This means, the constraint will not be contained in the problem that is solved by the optimizer but it is not deleted from the definition of the problem in Mosel.

Related topics

`sethidden`.

isinf

Purpose

Test whether a real value is an infinity.

Synopsis

```
function isinf(r: real):boolean
```

Argument

`r` The value to test

Return value

`true` if the value is `INFINITY` or `-INFINITY`.

Further information

When the parameter `matherr` is set to `true` (see `setparam`) mathematical functions return the constant `NAN` or `INFINITY` instead of failing. This function can be used to identify incorrect results (direct comparison to `NAN` or `INFINITY` always fails).

Related topics

`setmatherr`, `isnan`, `isfinite`.

isnan

Purpose

Test whether a real value is valid.

Synopsis

```
function isnan(r: real):boolean
```

Argument

`r` The value to test

Return value

`true` if the value is not valid (*i.e.* it corresponds to *Not A Number*).

Further information

When the parameter `matherr` is set to `true` (see `setparam`) mathematical functions return the constant `NAN` or `INFINITY` instead of failing. This function can be used to identify incorrect results (direct comparison to `NAN` or `INFINITY` always fails).

Related topics

`setmatherr`, `isinf`, `isfinite`.

isodd

Purpose

Test whether an integer is odd.

Synopsis

```
function isodd(i:integer):boolean
```

Argument

`i` An integer number

Return value

`true` if the given integer is odd, `false` if it is even.

ln

Purpose

Get the natural logarithm of a value.

Synopsis

```
function ln(r:real):real
```

Argument

`r` Real value the function is applied to. This value must be positive.

Return value

Natural logarithm of the argument.

Example

The following example provides a function for calculating logarithms to any (positive) base:

```
function logn(base,number: real):real
 if (number > 0 and base > 0) then
  returned:= ln(number)/ln(base)
 else
  exit(1)
 end-if
end-function
```

Related topics

`exp`, `log`, `sqrt`.

localsetparam

Purpose

Set the value of a control parameter locally to a subroutine.

Synopsis

```
procedure localsetparam(name:string,val:integer|string|real|boolean)
```

Arguments

`name` Name of a control parameter (case insensitive).

`val` New value for the control parameter

Further information

1. This procedure is a special version of `setparam` that can only be used from a subroutine: the effect of the parameter change is reverted at the end of the subroutine.
2. Independently of the location of the call to this procedure and whether other modifications are performed on the parameter (using for instance `setparam`) the original value of the parameter is saved at the beginning of the execution of the routine and restored before its termination.

Related topics

`setparam`, `setdsoparam`, `restoreparam`.

log

Purpose

Get the base 10 logarithm of a value.

Synopsis

```
function log(r:real):real
```

Argument

`r` Real value the function is applied to. This value must be positive.

Return value

Base 10 logarithm of the argument.

Related topics

`exp`, `ln`, `sqrt`.

makesos1, makesos2

Purpose

Creates a special ordered set (SOS) using a set of decision variables and a linear constraint.

Synopsis

```
procedure makesos1(cs:linctr, s:set of mpvar, c:linctr)
procedure makesos1(s:set of mpvar, c:linctr)
procedure makesos2(cs:linctr, s:set of mpvar, c:linctr)
procedure makesos2(s:set of mpvar, c:linctr)
```

Arguments

`cs` A linear constraint

`s` A set of decision variables

`c` A linear constraint

Example

The following generates the SOS1 set `mysos` based on the linear constraint `rr`. The resulting set contains the variables `x`, `y`, and `z` with the weights 0,2, and 4.

```
declarations
 x,y,z: mpvar
 rr,mysos: linctr
end-declarations

rr:= 2*y+4*z
makesos1(mysos, {x,y,z}, rr)
```

Further information

These procedures generate a SOS set containing the decision variables of the set `s` with the coefficients of the linear constraint `c`. The resulting set it assigned to `cs` if it is provided. Note that these procedures simplify the generation of SOS with weights of value 0.

maxlist

Purpose

Get the maximum value of a list of integers or reals.

Synopsis

```
function maxlist(i1:integer, i2:integer[, i3:integer...]):integer
function maxlist(r1:real, r2:real[, r3:real...]):real
```

Arguments

`i1,i2,...` List of integer numbers

`r1,r2,...` List of real numbers

Return value

Largest value in the given list.

Example

In the following `r` is assigned the value `7` by `maxlist`:

```
r:= maxlist(-1, 4.5, 2, 7, -0.3)
```

Further information

The returned type corresponds to the type of the input.

Related topics

`minlist`.

memoryuse

Purpose

Get an estimate of the memory usage of an entity, a module or the entire model.

Synopsis

```
function memoryuse:real
function memoryuse(ent:any entity):real
function memoryuse(mname:string):real
```

Arguments

`ent` An entity

`mname` A Module name

Return value

An estimate of the memory usage in bytes or `-1` if the evaluation cannot be performed.

Further information

1. When used with no argument this function returns the total amount of memory used by the running model including the loaded modules (if they implement the functionality). A constant string is interpreted as the name of a module: the returned value is the memory consumed by this module that must be currently used by the model.

2. For entities of type `integer`, `real`, `boolean` and `mpvar` the value returned is the constant amount of memory required by a variable of the corresponding type. For a reference to a `string` or `linctr` the effective memory used by the internal datastructure is returned. In the case of a set or a list only the memory used to represent the collection is accounted, not its content. However the value reported for an array or record includes the memory used by the content of the structure except for strings.

Related topics

`getmodpropnum`.

minlist

Purpose

Get the minimum value of a list of integers or reals.

Synopsis

```
function minlist(i1:integer, i2:integer[, i3:integer...]):integer
function minlist(r1:real, r2:real[, r3:real...]):real
```

Arguments

`i1,i2,...` List of integer numbers

`r1,r2,...` List of real numbers

Return value

Smallest value in the given list.

Example

In the following `r` is assigned the value `-1` by `maxlist`:

```
r:= minlist(-1, 4.5, 2, 7, -0.3)
```

Further information

The returned type corresponds to the type of the input.

Related topics

`maxlist`.

newmuid

Purpose

Generate a unique identifier.

Synopsis

```
function newmuid:string
```

Return value

An identifier string.

Further information

This function returns a string of the form `muid#_xxx` where `#` is an execution number in hexadecimal (specific to this model execution) and `xxx` a random hexadecimal number. It is guaranteed that each generated value does not correspond to any symbol of the model and that it will never be returned again.

publish

Purpose

Publish a symbol.

Synopsis

`procedure publish(name:string, ref:`*`string, external or structured`*`)`

Arguments

`name` Symbol to identify the object

`ref` A reference to an object of an external type, a structure (*e.g.* set, list or array) or a string

Further information

1. This procedure can be used to publish an object in the model dictionary such that it can be found by native code using `name`. Any entity (including local and private) can be exposed with this routine as long as it is of a referenced type (basically any type except integer, real and boolean). If a string variable is used the published symbol corresponds to a string constant initialized with the current value of this variable.
2. The provided `name` must be a valid identifier that is not yet being used by the model as symbol name (including entity and subroutine names). In case of error the procedure raises an IO error.

Related topics

`unpublish`, `newmuid`.

random

Purpose

Generate a random number.

Synopsis

```
function random:real
```

Return value

A randomly generated number in the interval [0,1).

Example

In the following `i` is assigned a random integer value between `1` and `10`:

```
i:= integer(round((10*random)+0.5))
```

Further information

Each model uses its own generator which is randomly initialized when the model execution starts. The sequence may also be reset using procedure `setrandseed`.

Related topics

`setrandseed`.

read, readln

Purpose

Read in formatted data from the active input stream.

Synopsis

```
procedure read(e1:expr[, e2:expr...])
procedure readln
procedure readln(e1:expr[, e2:expr...])
```

Argument

`e1, e2,...` Expression or list of expressions of basic type

Example

The following reads (possible split over several lines) `12 45 word`, followed by `toto(12 and 45)=word`:

```
declarations
 i,j:integer
 s:string
 ts:array (range,range) of string
end-declarations
read(i, j, s)
readln("toto(", i, "and", j, ")=", ts(i,j))
```

Further information

1. These procedures assign the data read from the active input stream to the given symbols or try to match the given expressions with what is read from the input stream. If `ei` is a symbol that can be assigned a value, the procedure tries to recognise from the input stream a constant of the required type and, if successful, assigns the resulting value to `ei`. If `ei` is a constant or a symbol that cannot be reassigned, the procedure tries to read in a constant of the required value and succeeds if the resulting value corresponds to `ei`. These procedures do not fail but set the control parameter `nbread` to the number of items actually recognized.
2. Note that the `read` procedures are based on the lexical analyser of Mosel: items are separated by spaces and a string that contains spaces must be quoted using either single or double quotes (the quotes are automatically removed once the string has been identified).
3. The procedure `readln` expects all the items to be recognized to be contained in single line. The function `read` ignores changes of line. If the procedure `readln` is used without parameters it skips the end of the current line.

Related topics

`write`, `writeln`, `readtextline`.

reset

Purpose

Reset an entity.

Synopsis

```
procedure reset(x:resettable entity)
```

Argument

`x` A reference to a set, a list, an array, a union, a record, an object of an external type or a problem

Further information

Only types supporting the 'copy' operation (*i.e.* they can be assigned a value) can be reset, as a consequence, a record can be reset only if all its fields can also be reset. The effect of this routine depends on the type of the object, typically the object returns to its state just after being created. For instance, applying it to an `mpproblem` will clear the problem by detaching all constraints it contains.

Related topics

`delcell`.

restoreparam

Purpose

Restore the value of a control parameter.

Synopsis

```
procedure restoreparam(name:string)
```

Argument

`name` Name of a control parameter (case insensitive).

Further information

1. This procedure can only be used from a subroutine to restore the value of a parameter to its state at the beginning of the routine.
2. Independently of the location of the call to this procedure and whether modifications are performed on the parameter (using for instance `setparam`) the original value of the parameter is saved at the beginning of the execution of the routine and restored before its termination.

Related topics

`setparam`, `setdsoparam`, `localsetparam`.

reverse

Purpose

Reverse a list.

Synopsis

```
procedure reverse(l:list)
```

Argument

`l` A list

Example

```
L:=[1,2,3,4,5]
reverse(L)    ! => L=[5,4,3,2,1]
reverse(L)    ! => L=[1,2,3,4,5]
```

Related topics

`getreverse`.

round

Purpose

Round a number to the nearest integer.

Synopsis

```
function round(r:real):integer
```

Argument

`r` Real number to be rounded

Return value

Rounded value.

Example

In the following, `i` takes the value 6, `j` the value -7, and `k` the value 12:

```
i := round(5.5)
j := round(-6.7)
k := round(12.3)
```

Related topics

`ceil`, `floor`.

setcoeff

Purpose

Set the coefficient of a variable or the constant term.

Synopsis

```
procedure setcoeff(c:linctr, x:mpvar, r:real)
procedure setcoeff(c:linctr, r:real)
```

Arguments

`c`	A linear constraint
`x`	A decision variable
`r`	Coefficient or constant term

Example

The following declares a constraint `c` and then changes some of its terms:

```
declarations
 x,y,z: mpvar
end-declarations

c:= 4*x + y -z <= 12

setcoeff(c, y, 2)
setcoeff(c, 8.1)
```

The constraint is now $4 \cdot x + 2 \cdot y - z \leq -8.1$.

Further information

If a variable is given then this procedure sets the coefficient of this variable in the constraint to the given value. Otherwise, it sets the constant term of the constraint.

Related topics

`getcoeff`.

sethidden

Purpose

Hide or unhide a constraint.

Synopsis

```
procedure sethidden(c:linctr, b:boolean)
```

Arguments

`c` A linear constraint

`b` Constraint status:

`true`	Hide the constraint
`false`	Unhide the constraint

Example

THe following defines a constraint and then sets it as hidden:

```
declarations
 x,y,z: mpvar
end-declarations

c:= 4*x + y -z <= 12
sethidden(c, true)
```

Further information

At its creation a constraint is added to the current problem, but using this procedure it may be hidden. This means that the constraint will not be contained in the problem that is solved by the optimizer but it is not deleted from the definition of the problem in Mosel. Function `ishidden` can be used to test the current status of a constraint.

Related topics

`ishidden`.

setioerr

Purpose

Raise an IO error.

Synopsis

```
procedure setioerr(msg:string)
```

Argument

`msg` Error message to display (or an empty string)

Further information

This function sets the control parameter *iostatus* (see `getparam`) such that an IO error is raised. If IO errors are not handled by the model (see `setparam`), the execution is interrupted.

Related topics

`setmatherr`.

setmatherr

Purpose

Raise a Math error.

Synopsis

```
procedure setmatherr(msg:string)
```

Argument

`msg` Error message to display (or an empty string)

Further information

If mathematical errors are not handled by the model (see `setparam`), the execution is interrupted. A function ending with a call to this routine may set its return value to `NAN` or `INFINITY` in order to indicate its error status.

Related topics

`setioerr`, `isnan`, `isinf`, `isfinite`.

setname

Purpose

Associate a matrix name to a constraint or variable.

Synopsis

```
procedure setname(c:linctr, n:string)
procedure setname(v:mpvar, n:string)
```

Arguments

`c`	A linear constraint
`v`	A decision variable
`n`	Name given to the constraint or variable

Further information

1. When exporting a problem to a matrix file, constraint/variable names are deduced from the global public symbols: anonymous and local entities are usually named after their row/column number in the matrix. This procedure makes it possible to give a name to these entities.
2. If the given name starts with the `'#'` character, the generated matrix name will include the order number of the constraint or variable in the matrix.

Related topics

`exportprob`.

setparam

Purpose

Set the value of a control parameter.

Synopsis

```
procedure setparam(name:string,val:integer|string|real|boolean)
```

Arguments

`name` Name of a control parameter (case insensitive).

`val` New value for the control parameter

Example

See example of function `getparam`.

Further information

1. Control parameters include the settings of Mosel as well as those of any loaded module or package. The location of the parameter may be specified by prefixing its name with the name of the module or package defining it (*e.g.* `mmxprs.XPRS_verbose`). The type of the value must correspond to the type expected by the parameter.

2. This procedure can be applied only to control parameters the value of which can be modified.

3. The `name` argument must be a constant string: a model parameter, variable or string expression cannot be used as a control parameter name.

4. The following control parameters, supported by Mosel, can be altered with this procedure:
   `realfmt` Default C printing format for real numbers (string, default: `"%.10g"`)
   `zerotol` zero tolerance in comparisons between reals (non-negative real strictly smaller than 1, default: `1.0e-13`), see Section 2.7.7. This parameter is also used when displaying reals if the parameter `txtztol` is `true`: any value smaller than the zero tolerance is handled like the zero constant
   `txtztol` decide whether values smaller than the zero tolerance must be reported as the zero constant when converting a real value to its textual representation (Boolean, default: `true`)
   `ioctrl` specify whether the interpreter ignores IO errors (Boolean, default: `false`). When `ioctrl` is enabled it is required to get (and reset) the `iostatus` parameter (see `getparam`) after every IO operation. Not doing so may result in undefined behavior
   `mathctrl` specify whether the interpreter ignores Maths errors (Boolean, default: `false`)
   `readcnt` generate per label counting when executing 'initializations from' blocks (Boolean, default: `false`)
   `UTC` indicate whether the time functions return time expressed in local (false) or UTC (true) time (Boolean, default: `false`)
   `autofinal` indicate whether initialisation from blocks are finalizing sets (Boolean, default: `true` or `false` if compiler option `noautofinal` is used)
   `workdir` specify the current working directory of the model (string, initialised with the current working directory of the Mosel instance). The provided value can be a relative path (*e.g.* `"../somedir"`)
   `recloc` enable (or disable) automatic recording of source location of constraints definitions (Boolean, default: `false`). This parameter can be set to `true` only if the model has been compiled with option `-G`; it makes it possible the creation of meaningful constraint names when exporting a matrix (see `exportprob`)
   `localedir` directory where message catalogs are stored (string, default: `"./locale"`)
   `bimprefix` list of bim file prefixes (string). This parameter is used to locate packages when compiling a model (`compile`) and loading a bim file (`load`), see Section 2.3.1.

5. The parameter `realfmt` requires a format of the form `%[f][w][.p]c` where `f` (flags) is an optional string of 1 to 3 characters from the list `'#0 -+'`; `w` (width) an optional string of 1 to 3 digits (the first one cannot be `0`); `p` (precision) an optional string of 1 to 2 digits and `c` (conversion specifier) a character from the list `'eEfgGaAjy'` (see `formattext` for further details). The conversion specifiers `j` and `y` are Mosel extensions to the C standard that support flags `'0 -+'` and the optional width: they produce a reversible textual representation of the real number (*i.e.* converting the string back to real restores the exact original value). The format `'j'` generates a decimal notation similar to the specification ECMA-262 (*e.g.* `"123.456"`) while the format `'y'` produces a scientific notation in all cases (*e.g.* `"1.2345e2"`).

Related topics

`getparam`, `setdsoparam`, `localsetparam`, `restoreparam`.

setrandseed

Purpose

Initialize the random number generator.

Synopsis

```
procedure setrandseed(s:integer)
```

Argument

`s` Seed value

Further information

This procedure sets its argument as the seed for a new sequence of pseudo-random numbers to be returned by the function `random`.

Related topics

`random`.

setrange

Purpose

Set the domain range of a constraint.

Synopsis

```
procedure setrange(c:linctr, lb:real, ub:real)
```

Arguments

`c`	A linear constraint expression
`lb`	Lower bound
`ub`	Upper bound

Example

The following sets the domain of the `x` variable and defines `c` as a range constraint.

```
declarations
 x,y,z: mpvar
 c: linctr
end-declarations

c:= 2*y+4*z+5
setrange(x,3,10)    ! 3<=x<=10
setrange(c,1,30)    ! -4<=2*y+4*z<=25
```

Further information

1. If the parameter `c` is a linear expression a new anonymous range constraint is added to the problem. Otherwise, the provided constraint is turned into a range constraint (and added to the problem if required).
2. This procedure changes the type of the provided constraint to `CT_RNG`, stores the provided lower bound as an external information and records the upper bound as the constant term of the constraint. As a consequence defining the range of a constraint modifies its constant term, this has to be taken into account if a range constraint is converted to another type or used as part of a linear expression.

settype

Purpose

Set the type of a constraint.

Synopsis

```
procedure settype(c:linctr, type:integer)
```

Arguments

`c` A linear constraint

`type` Constraint type

Further information

The type (`type`) of a linear constraint may be set to one of:

`CT_EQ` Equality, '='

`CT_GEQ` Greater than or equal to, '$\geq$'

`CT_LEQ` Less than or equal to, '$\leq$'

`CT_UNB` Non-binding constraint

`CT_SOS1` Special ordered set of type 1

`CT_SOS2` Special ordered set of type 2

Values applicable for unary constraints only are:

`CT_CONT` Continuous

`CT_INT` Integer

`CT_BIN` Binary

`CT_PINT` Partial integer

`CT_SEC` Semi-continuous

`CT_SINT` Semi-continuous integer

`CT_FREE` Free

Related topics

`gettype`

sin

Purpose

Get the sine of a value.

Synopsis

```
function sin(r:real):real
```

Argument

`r` Real number to which to apply the trigonometric function

Return value

Sine value of the argument.

Related topics

`arctan`, `cos`.

splithead

Purpose

Split a list returning the first elements.

Synopsis

```
function splithead(l:list, o:integer):list
```

Arguments

`l`	A list
`o`	Number of elements to remove if >0 or number of elements to keep if <0

Return value

The list of elements removed.

Example

```
L:=[1,2,3,4,5]
L2:=splithead(L,2)     ! => L=[3,4,5] L2=[1,2]
L2:=splithead(L,-1)    ! => L=[5] L2=[3,4]
```

Further information

If the second parameter is 0, the list is unchanged and an empty list is returned. If the same parameter is larger than the size of the list, all elements are deleted and the function returns a copy of the original list.

Related topics

splittail

splittail

Purpose

Split a list returning the last elements.

Synopsis

```
function splittail(l:list, o:integer):list
```

Arguments

`l`	A list
`o`	Number of elements to remove if >0 or number of elements to keep if <0

Return value

The list of elements removed.

Example

```
L:=[1,2,3,4,5]
L2:=splittail(L,2)     ! => L=[1,2,3] L2=[4,5]
L2:=splittail(L,-1)    ! => L=[1] L2=[2,3]
```

Further information

If the second parameter is 0, the list is unchanged and an empty list is returned. If the same parameter is larger than the size of the list, all elements are deleted and the function returns a copy of the original list.

Related topics

`splithead`

sqrt

Purpose

Get the positive square root of a value.

Synopsis

```
function sqrt(r:real):real
```

Argument

`r` Real value the function is applied to. This value must be non-negative.

Return value

Square root of the argument.

Related topics

`abs`, `exp`, `ln`, `log`.

strfmt

Purpose

Create a formatted string from a string or a number.

Synopsis

```
function strfmt(str:string,len:integer):string
function strfmt(i:integer, len:integer):string
function strfmt(r:real, len:integer):string
function strfmt(r:real, len:integer, dec:integer):string
```

Arguments

`str` String to be formatted

`i` Integer to be formatted

`r` Real to be formatted

`len` Reserved length (may be exceeded if given string is longer, in this case the string is always left justified).

- `<0` Left justified within reserved space
- `>0` Right justified within reserved space
- `0` Use defaults

`dec` Number of digits after the decimal point

Return value

Formatted string.

Example

The following:

```
writeln("text1", strfmt("text2",8), "text3")
writeln("text1", strfmt("text2",-8), "text3")
r:=789.123456
writeln(strfmt(r,0)," ", strfmt(r,4,2), strfmt(r,8,0))
```

produces this output:

```
text1     text2text3
text1text2     text3
789.123 789.12        789
```

Further information

1. This function creates a formatted string from a string or an integer or real number. It can be used at any place where strings may be used. Its most likely use is for generating printed output (in combination with `write` and `writeln`).
2. If the resulting string is longer than the reserved space it is not cut but printed in its entirety, overflowing the reserved space to the right.

Related topics

`write`, `writeln`.

substr

Purpose

Get a substring of a string.

Synopsis

```
function substr(str:string, i1:integer, i2:integer):string
```

Arguments

`str`	String
`i1`	Starting position of the substring
`i2`	End position of the substring

Return value

Substring of the given string.

Example

```
write(substr("Example text", 3, 10))
```

This outputs the text: `ample te`

Further information

This function returns the substring from the i1th to the i2th character of a given string (the counting starts from 1). This function returns an empty string if the bounds are not compatible with the string (*e.g.* starting position larger than the length of the string) or inconsistent (*e.g.* starting position after end position).

timestamp

Purpose

Generate a timestamp by combining the current UTC date and time.

Synopsis

```
function timestamp:real
```

Return value

The number of seconds since 1/1/1970 at midnight as a real.

Further information

1. This function corresponds to the expression (using UTC time):
   `real(currentdate)*86400+currenttime/1000`
2. A local time timestamp may be obtained using: `getasnumber(datetime(SYS_NOW))`
3. Refer to the module mmsystem for a set of dedicated types for handling date and time.

Related topics

`currenttime`,`currentdate`

unpublish

Purpose

Unpublish a symbol.

Synopsis

```
procedure unpublish(name:string)
```

Argument

`name` Symbol to be removed from the dictionary

Further information

This procedure has the opposite effect of `publish`. If the given `name` does not correspond to a previously published symbol no operation is performed.

Related topics

`publish`.

versionnum, versionstr

Purpose

Version of Mosel, a module or package.

Synopsis

```
function versionnum(what:string):integer
function versionstr(what:string):string
```

Argument

`what` A module name, a package name, the string `"xpress"` or an empty string

Return value

A version number as a string formatted as `"maj.min.rel"` (with `versionstr`) or as an integer (with `versionnum`). An empty string or -1 is returned if the requested library cannot be found.

Further information

With an empty string these routines return the version of Mosel currently running, with the string `"xpress"` they give the version of the current FICO Xpress installation. Otherwise the argument is expected to be the name of a module (no suffix or name ending with `".dso"`), or the name of a package (name ending with `".bim"`). In both cases the library must be currently used by the model. For a package both imported and loaded at runtime packages are considered.

write, writeln

Purpose

Send an expression or list of expressions to the active output stream.

Synopsis

```
procedure write(e1:expr[, e2:expr...])
procedure writeln
procedure writeln(e1:expr[, e2:expr...])
```

Argument

`e1, e2,...` Expression or list of expressions

Example

The following lines

```
Set1:={"first", "second", "fifth"}
write(Set1)                    ! Print set contents without return
writeln                        ! Print an empty line
b:=true
writeln("A real:", strfmt(7.1234, 4, 2), ", a Boolean:",b)
                          ! Output followed by return
```

produce this output:

```
{`first', `second', `fifth'}
A real:7.12, a Boolean:true
```

Further information

These procedures write the given expression or list of expressions to the active output stream. The procedure `writeln` adds the return character to the end of the output. Numbers may be formatted using function `strfmt` (default formatting relies on parameters `realfmt`, `zerotol` and `txtztol`, see `setparam`). Basic types are printed "as is". For elementary but non-basic types (`linctr`, `mpvar`) only the address is printed. If the expression is a set or array, all its elements are printed.

Related topics

`fwrite`, `fwriteln`, `read`, `readln`, `strfmt`, `formattext`.

II. Modules

CHAPTER 4

deploy

This module defines two I/O drivers, *deploy.csrc* and *deploy.exe* for generating an executable program from a BIM file, along with two utility routines for accessing the program arguments with the Mosel model. Its use is discussed in Section 2.19.

4.1 Procedures and functions

argc

Purpose

Retrieve the number of arguments passed to a model executable.

Synopsis

```
function argc: integer
```

Return value

Number of parameters passed to the command used for executing a model (counting the command itself as the first).

Further information

This function makes it possible to access the program arguments when a model is run as an executable that has been generated via the *deploy.exe* I/O driver (see Section 4.2.2). If the model is not run as an executable but has instead been compiled to a standard BIM file then the returned value is always 1.

Example

See examples in Section 2.19.

Related topics

`argv`

Module

deploy

argv

Purpose

Retrieve an argument passed to a model executable.

Synopsis

```
function argv(ind: integer):string
```

Argument

`ind` index of the argument (positive integer)

Return value

Returns as a string the i^{th} argument passed to the command used for executing a model.

Further information

This function makes it possible to access the program arguments when a model is run as an executable that has been generated via the *deploy.exe* I/O driver (see Section 4.2.2). The number of arguments can be retrieved via `argc`. If the model is not run as an executable but has instead been compiled to a standard BIM file then there will be a single argument with the value `mosel`.

Example

See examples in Section 2.19.

Related topics

`argc`

Module

deploy

4.2 I/O drivers

The two I/O drivers provided by this module are designed to be used in combination with a Mosel command compiling a model by applying them to the output filename. They are not intended to be used in any other contexts.

```
deploy.*:filename[,p1[-z]=fp1[,...]]
```

4.2.1 Driver csrc

```
csrc:filename[,p1[-z]=fp1[,...]]
```

The *csrc* driver takes the following options:

`filename` Destination file name

`p1[-z]=fp1` list of labels and filenames, the optional `-z` flag indicates that compression is to be used

Example:

```
mosel comp mymodel.mos -o deploy.csrc:runmymod
```

This command produces a file `runmymod.c` that contains the model `mymodel.mos` in compiled (BIM) form and a complete C program for executing it via the Mosel C Library API. The generated code needs to be compiled into an executable for the targeted platform (see the `makefile` provided with the Mosel Library API examples).

4.2.2 Driver exe

```
exe:filename[,p1[-z]=fp1[,...]]
```

The *exe* driver takes the following options:

`filename` Destination file name

`p1[-z]=fp1` list of labels and filenames, the optional `-z` flag indicates that compression is to be used

Example:

```
mosel comp mymodel.mos -o deploy.exe:runmymod,MYFILE-z=otherfile.txt
```

Provided that a C compiler is available on the system, this command produces an executable for the platform in which it is invoked (resulting in a file named `runmymod` on Unix platforms or `runmymod.exe` under Windows). The executable serves for running the specified model, it also includes a second file `otherfile.txt` in compressed form, identified via the model parameter `MYFILE`.

The generation of this executable is obtained by producing a C source using the `deploy.csrc` driver that is compiled using the C-compiler installed on the system. This compiler can be specified by means of the `CC` environment variable (default value: `cl` on Windows and `cc` on Posix systems) and its default parameters can be selected with the environment variable `CFLAGS`. The location of the Xpress libraries is automatically deduced from the running program that is expected to be part of a standard Xpress installation.

For a full example, the reader is refered to the source of the *moseldoc* tool that is provided among the Mosel examples of the Xpress distribution.

Note that the generated executable only includes the compiled model and the specified additional files, it requires the same Xpress runtime dependencies (see the chapter *Creating runtime distributions* of the Xpress Installation Guide) for its execution as what would be required for running the model after compiling it into a standard BIM file.

CHAPTER 5

mmetc

This compatibility module just defines the *diskdata* procedure required to use data files formatted for mp-model from Mosel and provides a commercial discounting function. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmetc'
```

5.1 Procedures and functions

disc

Purpose

Annual discount.

Synopsis

```
function disc(a:real, t:real)
```

Arguments

`a`	Discount factor, real number greater than -1
`t`	Time, real number

Return value

Annual discount value: $1/(1 + a)^{t-1}$.

Further information

This function calculates the annual discount for the given period of time and discount factor.

Module

mmetc

diskdata

Purpose

Read in or write an array or set of strings to a file.

Synopsis

```
procedure diskdata(format:integer, file:string, a:array)
procedure diskdata(format:integer, file:string, s:set)
procedure diskdata(format:integer, file:string, l:list)
```

Arguments

`format` Format options:

`ETC_DENSE`	dense data format
`ETC_SPARSE`	sparse data format
`ETC_SGLQ`	strings quoted with single quotes
`ETC_NOQ`	strings are not quoted in the file
`ETC_OUT`	write to a file
`ETC_APPEND`	append output to the end of an existing file
`ETC_TRANS`	tables are transposed
`ETC_IN`	read from file (default)
`ETC_NOZEROS`	skip zero values
`ETC_CSV`	use CSV format
`ETC_SKIPH`	skip first line (header) of the file
`ETC_AUTONDX`	similar to sparse format but indices are not read or written (only applies to 1-dimension arrays indiced by ranges)
`ETC_EMPTYNDX`	missing indices are replaced by a default value
`ETC_DATAFRAME`	dense data format for a 2-dimension array and first index as a range (for the line numbers)

Several options may be combined using '+'.

`file` Extended file name

`a` Array to export or initialize

`s` Set to export or initialize

`l` List to export or initialize

Example

The following example declares two sets and two dynamic arrays. The array `ar1` is read in from the file `in.dat`. Then both arrays, `ar1` and `ar2`, are saved to the file `out.dat` (in sparse format) and finally the contents of the set `Set1` is appended to the file `out.dat`.

```
declarations
 Set1: set of string
 R: range
 ar1,ar2: array(Set1,R) of real
end-declarations

diskdata(ETC_SPARSE, "in.dat", ar1)
diskdata(ETC_OUT, "out.dat", [ar1, ar2])
diskdata(ETC_OUT+ETC_APPEND, "out.dat", Set1)
```

Further information

1. This procedure reads in data from a file or writes to a file, depending on the parameter settings. The file format used is compatible with the command DISKDATA of the modeler mp-model (unless the option `ETC_CSV` is specified).
2. Only arrays lists and sets of basic and native types (including `mpvar` and `linctr` for writing) can be used with this procedure, in particular records are not supported.
3. If option `"dataframe"` is combined with `"skiph"` the array to be processed must be indiced by a range and a set of strings. The second index is automatically populated with the column names of the header row when reading (the same line is generated when writing).
4. In case of error the procedure raises an IO error.

Module

mmetc

5.2 I/O drivers

This module provides the *diskdata* IO driver designed to be used as an interface for `initializations` blocks for both reading and writing files formated for the `diskdata` procedure.

5.2.1 Driver `diskdata`

```
diskdata:[dense|sparse|autondx|dataframe;][sglq|noq|csv;][cols();]
         [skiph;emptyndx;append;trans;nozeros;fsep=c;dsep=c]
```

The driver can only be used in 'initializations' blocks. In the opening part of the block, no file name has to be provided, but general options can be stated at this point: they will be applied to all labels. In the block, each label entry is understood as the file name to use for the actual processing. Note that, before the file name, one can add further options separated by comas or semicolons, that are effective to the particular entry. Here, the `csv` option might be followed by a list of columns separated by commas and enclosed in parenthesis. This selection may also be achieved using the `cols` option. The columns are identified by their number (first column has index 1) and must be given in ascending order without duplicate. If the last column number is suffixed by the plus sign, the following columns will also be included in the selection (*e.g.* `"csv(1,3+)"` skips the second column). To use names, the option `skiph` must be used and the column names are taken from the *header row* that is skipped through this option. When using `skiph`, column numbers need to be stated by prefixing the column number by # (even in this case columns must be given in ascending order).This column selection is ignored for a writing operation. The file name given can use extended notation.

The *diskdata* driver takes the following options:

`dense`	dense data format
`sparse`	sparse data format
`autondx`	sparse data format with automatic indexation (applies only to 1-dimension arrays indiced by ranges)
`autondx=st`	same as `autondx` but starting index is set to `st` (instead of 1)
`dataframe`	dense data format for a 2-dimension array and first index as a range (for the line numbers)
`sglq`	strings quoted with single quotes
`noq`	strings are not quoted in the file
`csv`	use CSV format: quoting and escaping with double quotes, all lines are processed (*i.e.* characters `'!'` and `'&'` are ordinary symbols), all columns are interpreted as text
`cols(c1[,c2,...])`	select a list of columns
`skiph`	When reading, the first line of the file is skipped, when writing, the first line of the file is preserved (or a comment line is inserted if the file does not already exist)
`emptyndx`	When reading array indices an empty cell causes a failure. With this option empty cells are replaced by the default value of the corresponding type (*e.g.* 0 for a numerical value)
`append`	append output to the end of an existing file
`trans`	tables are transposed
`nozeros`	skip zero values
`fsep=c`	character used to separate fields. The default value is `","`; tabulation or `";"` are also often employed

`dsep=c` character used as decimal separator (default: `"."`)

Example:

```
declarations
 Set1: set of string                 ! Declare a set of strings
 ar1,ar2: array(Set1,range) of real  ! Declare two dynamic arrays
 r: real                             ! Declare a real value
end-declarations

initializations from "diskdata:"     ! Use 'diskdata' format for reading
 ar1 as "sparse;csv(1,3,4);ind.dat"  ! Read `ar1' from 'in.dat' in sparse format
                                     ! using CSV conventions and selecting columns 1,3 and 4
 r as "r_init.dat"                   ! Initialize `r' from 'r_init.dat'
end-initializations

initializations to "diskdata:append" ! Use 'diskdata' format for output
 [ar1, ar2] as "out.dat"             ! Save two arrays in sparse format
 Set1 as "out.dat"                   ! Save set `Set1' to the same file
end-initializations
```

CHAPTER 6

mmhttp

The module *mmhttp* makes it possible to communicate with external components via HTTP requests. Both modes, client or server side, can be used in a Mosel model: the *client* routines allow a Mosel model to send the HTTP requests GET, POST, PUT, PATCH or DELETE to a web service. A model may also act as a *web service* by starting the integrated HTTP server. In this mode, the model gets notified about connections from remote clients via specific *mmjobs* events. The model can then reply to these requests using a set of dedicated routines.
To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmhttp'
```

6.1 New functionality for the Mosel language

6.1.1 The type `reqqueue`

The type `reqqueue` can be used to implement multithreaded HTTP servers: it represents a queue of pending HTTP requests to be processed by the server. A queue of this type must be declared as a global shared entity such that each cloned submodel of the master model can access it. A submodel ready to handle a new request has to call `httpreqpop` in order to warn the queue manager of its availability and then wait for an event. When the server receives a request that has to be processed by one of these submodels it moves this request to the queue using `httpreqpushlim` or `httpreqpush`, as a result the request is sent to one of the available submodels that is notified as if the request had been directly received from the network (see Section 6.4.2). If no submodel is ready, the request is recorded in the queue until a model becomes available for processing it.

6.2 Control parameters

The following parameters are defined by *mmhttp*:

`http_async`	HTTP requests processing mode.	p. 195
`http_browser`	Path to the web browser.	p. 195
`http_cookies`	Handling of cookies.	p. 196
`http_defpage`	Default page of the web server.	p. 196
`http_defport`	Default server TCP port.	p. 196
`http_expire`	Expiration delay of open connections.	p. 196
`http_freeasync`	Number of available asynchronous connections.	p. 197

http_async

Description This parameter selects the processing mode of the HTTP request functions (httpget|put|post|del). These functions return immediately after the connection to the server has been established (without waiting for the reply by the server) when this parameter is set to `true`. The model is notified about the completion of the request via an event of class `EVENT_HTTPEND`.

Type Boolean, read/write

Default value false

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

See also `http_maxasync`.

Module mmhttp

http_browser

Description The path to a web browser to be executed when the parameter `http_startwb` is active.

Type String, read/write

Values Path to a web browser

Affects routines `httpstartsrv`.

See also `http_startwb`.

Module mmhttp

http_cookies

Description Decides whether cookie management is enabled: when this parameter is set to `true` the cookie store is updated according to server replies and request headers are completed with the relevant cookies. Changing the value of this parameter does not affect the cookie store (*i.e.* existing cookies are not modified).

Type Boolean, read/write

Default value false

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

Module mmhttp

http_defpage

Description The default page is selected when the server receives a request not specifying any path (*e.g.* `"http://server/"`).

Type String, read/write

Values The label to be used as the default page. Selecting an empty string restores the default value

Default value "index.html"

Affects routines `httpstartsrv`.

Module mmhttp

http_defport

Description This is the port number used by the web server upon its startup. If this parameter is `0`, the port number is selected automatically by the operating system (the actual port number can be retrieved through parameter `http_port`).

Type Integer, read/write

Values Between 0 and 65535

Default value 0

Affects routines `httpstartsrv`.

See also `http_port`.

Module mmhttp

http_expire

Description Connections held in the connection pool are automatically closed if they are not used for more than the amount of time (in seconds) defined by this parameter.

Type Integer, read/write

Values Between 5 and 60 by steps of 5 seconds

Default value 5

See also `http_maxconn`.

Module mmhttp

http_freeasync

Description Up to `http_maxasync` asynchronous requests can be used concurrently. This parameter reports the current number of asynchronous requests that can still be initiated.

Type Integer, read only

See also `http_maxasync`.

Module mmhttp

http_keephdr

Description By default results of HTTP queries do not include the HTTP header lines. This parameter can be used to retrieve these header lines in addition to the result document (use `httpgetheader` to separate the header from the effective result document).

Type Boolean, read/write

Default value false

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

Module mmhttp

http_listen

Description This is the interface used by the web server upon its startup. The default value implies binding to all available interfaces.

Type String, read/write

Default value 0.0.0.0

Affects routines `httpstartsrv`.

Module mmhttp

http_maxconn

Description This parameter defines the size of the connection pool: whenever an HTTP request is emitted *mmhttp* tries to use one of the already open connections. After the end of the operation the connection is saved into the pool (if the server supports this functionality). Setting this parameter to 0 disables the pool (*i.e.* each query is executed on a new connection). When this parameter is changed all connections of the pool are closed.

Type Integer, read/write

Values Between 0 and 8

Default value 4

See also `http_expire`.

Module mmhttp

http_maxcontime

Description Maximum amount of time (in seconds) allowed for connecting to a HTTP server and send a request. If the operation is longer than the specified duration the request is cancelled and the procedure results in an IO error. A value of `0` disables this time limit.

Type Integer, read/write

Default value 0

See also `http_maxreqtime`.

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

Module mmhttp

http_maxreq

Description The maximum number of active concurrent connections the server is maintaining. Above this limit, connections are rejected and clients are notified with the HTTP code 500.

Type Integer, read/write

Values At least 1

Default value 16

Affects routines `httpstartsrv`.

Module mmhttp

http_maxreqtime

Description Maximum amount of time (in seconds) allowed for processing a request. If the operation is longer than the specified duration the request is cancelled and the procedure results in an IO error. A value of `0` disables this time limit.

Type Integer, read/write

Default value 0

See also `http_maxcontime`.

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

Module mmhttp

http_maxasync

Description This parameter defines the maximum number of active asynchronous requests that can be sent by a Mosel model. This parameter can only be changed if asynchronous mode is not active and there is no active request.

Type Integer, read/write

Values Between 4 and 58

Default value 8

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

See also `http_async`, `http_freeasync`.

Module mmhttp

http_port

Description This parameter reports the port number currently used by the web server.

Type Integer, read only

Affects routines `httpstartsrv`.

See also `http_defport`.

Module mmhttp

http_proxy

Description When this parameter is defined, HTTP connections are sent through this proxy server (instead of establishing direct connections).

Type Integer, read/write

Default value ""

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

See also `http_proxyport`.

Module mmhttp

http_proxyport

Description The value of this parameter corresponds to the connection port of the proxy server (when defined).

Type Integer, read/write

Values Between 1 and 65535

Default value 80

Affects routines `httpdel`, `httpget`, `httppost`, `httpput`, `httppatch`.

See also `http_proxy`.

Module mmhttp

http_srvconfig

Description This parameter specifies which request types are accepted by the HTTP server started from a Mosel model. For instance, if the application will only process HTTP GET queries the value of this parameter should be `HTTP_GET`. Moreover, if the flag `HTTP_SSL` is set, the server will also listen for HTTPS connections and, if the flag `HTTP_SSLONLY` is used, only the HTTPS server will be started (*i.e.* normal HTTP queries will be rejected). When an HTTPS server is started, the flag `HTTP_CLTAUTH` enables client authentication: clients are accepted only if they present a known certificate.

Type Integer, read/write

Default value HTTP_DELETE+HTTP_GET+HTTP_POST+HTTP_PUT

Affects routines `httpstartsrv`.

Module mmhttp

http_startwb

Description If this parameter is `true` a web browser pointing to the default page is launched just after the web server starts.

Type Boolean, read/write

Default value false

Affects routines `httpstartsrv`.

See also `http_browser`.

Module mmhttp

https_defport

Description This is the port number used by the web secure server upon its startup. If this parameter is `0`, the port number is selected automatically by the operating system (the actual port number can be retrieved through parameter `https_port`).

Type Integer, read/write

Values Between 0 and 65535

Default value 0

Affects routines `httpstartsrv`.

See also `https_port`.

Module mmhttp

https_listen

Description This is the interface used by the secure web server upon its startup. The default value implies binding to all available interfaces.

Type String, read/write

Default value 0.0.0.0

Affects routines `httpstartsrv`.

Module mmhttp

https_port

Description This parameter reports the port number currently used by the secure web server.

Type Integer, read only

Affects routines `httpstartsrv`.

See also `https_defport`.

Module mmhttp

6.3 Constants

mmhttp defines the following constants for frequently used HTTP status codes (the codes of the 200 series indicate success, the 400 series are error codes, according to the RFC 2616 specification). Note that the textual representations of HTTP status codes can be obtained via function `httpreason`.

- `HTTP_OK`: 200
- `HTTP_CREATED`: 201
- `HTTP_ACCEPTED`: 202
- `HTTP_NO_CONTENT`: 204
- `HTTP_RESET_CONTENT`: 205
- `HTTP_BAD_REQUEST`: 400
- `HTTP_UNAUTHORIZED`: 401
- `HTTP_PAYMENT_REQUIRED`: 402
- `HTTP_FORBIDDEN`: 403
- `HTTP_NOT_FOUND`: 404
- `HTTP_METHOD_NOT_ALLOWED`: 405
- `HTTP_NOT_ACCEPTABLE`: 406
- `HTTP_PROXY_AUTHENTICATION_REQUIRED`: 407
- `HTTP_REQUEST_TIMEOUT`: 408

6.4 Procedures and functions

6.4.1 HTTP client

The HTTP requests GET, HEAD, POST, PUT, PATCH and DELETE can be sent to a web service using functions `httpget`, `httphead`, `httppost`, `httpput`, `httppatch` and `httpdel` respectively. Each of these functions takes at least two parameters: the URL of the resource and a file name where to store the result of the operation. POST, PUT and PATCH requests require an additional file, namely the data source to be sent to the web service.
HTTP requests are either processed synchronously or asynchronously.

When a request is sent in *synchronous mode* (the default), the HTTP function call returns after the processing has completed and the return value corresponds to the status of the request (a successful request will have a status value between 200 and 299). The following example uses `www.bing.com` to search for 'FICO' using a synchronous request:

```
status:=httpget("http://www.bing.com/search?q=FICO", "result.html")
if status div 100=2 then
 writeln("Found FICO!")
else
 writeln("Request failed with code :", status, " (", httpreason(status), ")")
end-if
```

If the *asynchronous mode* is active (that is, the parameter `http_async` is set to `true`) the HTTP functions return just after the request has been sent, without waiting for the reply by the server. The processing continues in a separate thread of execution (up to `http_maxasync` requests can be handled at the same time) and the function returns a request identifier (or an error code in case of failure during the connection phase). Once the request has completed (*i.e.* the server has replied) an event of class `EVENT_HTTPEND` is raised (please refer to the documentation of the module `mmjobs` for further explanation on how to handle events). The associated value of this event is `request_id+status/1000`. For instance if request number 1300 succeeded with status 204 ('no data') the corresponding event value is `1300.204`. An asynchronous request can be cancelled using `httpcancel`: in this case an event is still generated but its status is 998.
In the following example, search for 'FICO' is sent to BING, Yahoo and Ask at the same time. A loop is then started to wait for answers from each of the search engines.

```
setparam("http_async",true)                ! Switch to asynchronous mode
reqyahoo:=httpget("http://us.search.yahoo.com/search/?p=FICO", "resyahoo.html")
writeln("Request ", reqyahoo, " sent to Yahoo")
reqbing:=httpget("http://www.bing.com/search?q=FICO", "resbing.html")
writeln("Request ", reqbing, " sent to BING")
reqask:=httpget("http://uk.ask.com/web?q=FICO", "resask.html")
writeln("Request ", reqask, " sent to Ask")
if reqbing<1000 or reqyahoo<1000 or reqask<1000 then
 writeln("A request has failed!")
else
 nbdone:=0
 repeat
  wait                                      ! Wait for an event
  evt:=getnextevent
  if evt.class = EVENT_HTTPEND then         ! One of the requests completed
   reqnum:=floor(evt.value)                 ! Get request number
   write("Request ", reqnum, " done: ")
   status:=round((evt.value-reqnum)*1000)   ! Get HTTP status
   if status div 100=2 then                 ! 200<=status<300 is success
    writeln("Found FICO!")
   else                                     ! Any other value is an error code
    writeln("Failed with code :", status, " (", httpreason(status), ")")
   end-if
   nbdone+=1
  end-if
```

```
 until nbdone=3                          ! Finished when all requests are done
end-if
```

By default the module performs direct TCP connections to the servers but a proxy may be specified using the `http_proxy` and `http_proxyport` parameters.

It is possible to set a limit on the time spent for connecting to a server by using `http_maxcontime`. The parameter `http_maxreqtime` defines a time limit on the entire request (*i.e.* connection and retrieval of result). *mmhttp* will wait undefinitely for each request if none of these parameters is defined.

When requests are sent to a secure server (*i.e.* URL starting with `"https://"`) the trusted certificates file `https_cacerts` must be available such that authenticity of servers can be verified. If this verification is not required, the control parameter `https_trustsrv` has to be set to `true`. If the requested secure server requires client authentication, client certificate `https_cltcrt` and associated private key `https_cltkey` must be defined. Note that these parameters are published by *mmssl*: this module has to be used when a secure requests have to be sent.

HTTP client functions:

delcookies

Purpose

Delete cookies from the cookie store.

Synopsis

```
procedure delcookies(domain:text|string)
```

Argument

`domain` Domain filter of the cookies to be deleted or an empty string to select all cookies

Related topics

`setcookie`.

Module

mmhttp

findcookie

Purpose

Get the value of a cookie from the cookie store.

Synopsis

```
function findcookie(name:string, domain:text, path:text, strict:boolean,
      val:text)
```

Arguments

`name`	Cookie name
`domain`	Domain of the cookie
`path`	Path in the domain
`strict`	If `true` perfect matching is required for `name`, `domain` and `path` (like for `setcookie`), otherwise any cookie of the requested name with a compatible domain and path is returned
`val`	Returned value when a corresponding cookie is found

Return value

`true` if the cookie was found (its value is saved in `val`), `false` otherwise

Related topics

`delcookies`, `findcookie`.

Module

mmhttp

httpcancel

Purpose

Cancel an asynchronous request.

Synopsis

```
procedure httpcancel(id: integer)
```

Argument

`id` Number of the request to cancel

Further information

This procedure has no effect if the request number cannot be found (*e.g.* the request has completed in the meantime). If the request is effectively cancelled an event of class `EVENT_HTTPEND` is raised with a request status of value 998.

Related topics

`httppost`, `httpput`, `httpget`, `httphead`, `httpdel`, `httppatch`.

Module

mmhttp

httpdel

Purpose

Perform an HTTP DELETE request.

Synopsis

```
function httpdel(url:string|text, result:string):integer
function httpdel(url:string|text, result:string, xhdr:string|text):integer
```

Arguments

`url`	URL to process
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if the asynchronous mode is active

Further information

1. The function returns after the request has been processed when synchronous mode is active (see `http_async`). Otherwise, using asynchronous mode, the function returns immediately after having sent the request and the model is notified about the completion of the operation by an event of class `EVENT_HTTPEND`. In this mode the result file `result` must be a physical file (although drivers `"tmp:"` and `"null:"` can still be used).
2. When cookie management is enabled (see `http_cookies`) an additional header `"Cookie:"` is inserted into the request if the cookie store contains compatible cookies. This behaviour is disabled if this optional header is already specified via the parameter `xhdr`.
3. An IO error will be raised if the destination file cannot be accessed.

Related topics

`httppost`, `httpput`, `httppatch`, `httpget`, `httphead`, `httpcancel`.

Module

mmhttp

httpget

Purpose

Perform an HTTP GET request.

Synopsis

```
function httpget(url:string|text, result:string):integer
function httpget(url:string|text, result:string, xhdr:string|text):integer
```

Arguments

`url`	URL to process
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if asynchronous mode is active

Example

Retrieve the default entry page of the FICO website in French and store it in the file `"fico.html"`:

```
status:=httpget('http://www.fico.com/fr/Pages/default.aspx', 'fico.html')
```

Further information

1. The function returns after the request has been processed when synchronous mode is active (see `http_async`). Otherwise, using asynchronous mode, the function returns immediately after having sent the request and the model is notified about the completion of the operation by an event of class `EVENT_HTTPEND`. In this mode the result file `result` must be a physical file (although drivers `"tmp:"` and `"null:"` can still be used).
2. When building a query it is important to encode data to be sent using `urlencode`
3. By default the header `"Accept-Encoding: gzip"` is inserted into the request and the result data is automatically decompressed if the server supports compression. This behaviour is disabled if this optional header is already specified (*e.g.* the parameter `xhdr` includes `"Accept-Encoding: identity"`).
4. When cookie management is enabled (see `http_cookies`) an additional header `"Cookie:"` is inserted into the request if the cookie store contains compatible cookies. This behaviour is disabled if this optional header is already specified via the parameter `xhdr`.
5. An IO error will be raised if the destination file cannot be accessed.

Related topics

`httppost`, `httpput`, `httppatch`, `httpdel`, `httphead`, `urlencode`, `httpcancel`.

Module

mmhttp

httpgetheader

Purpose

Extract the HTTP header of a result file.

Synopsis

```
function httpgetheader(sfile:string|text):text
function httpgetheader(sfile:string|text, dfile:string|text):text
```

Arguments

`sfile`	Name of the file to process
`dfile`	Destination file (can be the same as `sfile`)

Return value

Header of the result document

Further information

1. Result files of queries inlude the HTTP header when the parameter `http_keephdr` is set to `true`: this function returns the header of a result file when this setting is active.
2. The optional destination file `dfile` receives a copy of the original result file after the header has been removed.
3. An IO error will be raised in case of failure during a file operation.

Related topics

`httpget`, `httppost`, `httpput`, `httppatch`, `httpdel`.

Module

mmhttp

httphead

Purpose

Perform an HTTP HEAD request.

Synopsis

```
function httphead(url:string|text, result:string):integer
function httphead(url:string|text, result:string, xhdr:string|text):integer
```

Arguments

`url`	URL to process
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if asynchronous mode is active

Further information

1. The HEAD request is equivalent to a GET request except that no result is returned by the server, only the header can be retrieved (see `httpgetheader`).
2. An IO error will be raised if the destination file cannot be accessed.

Related topics

`httppost`, `httpput`, `httppatch`, `httpdel`, `httpget`, `urlencode`, `httpcancel`.

Module

mmhttp

httppatch

Purpose

Perform an HTTP PATCH request.

Synopsis

```
function httppatch(url:string|text, data:string, result:string):integer
function httppatch(url:string|text, data:string, result:string,
      xhdr:string|text):integer
```

Arguments

`url`	URL to process
`data`	Data file to be sent to the server
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if asynchronous mode is active

Further information

1. The function returns after the request has been processed when synchronous mode is active (see `http_async`). Otherwise, using asynchronous mode, the function returns immediately after having sent the request and the model is notified about the completion of the operation by an event of class `EVENT_HTTPEND`. In this mode the result file `result` must be a physical file (although drivers `"tmp:"` and `"null:"` can still be used).

2. The parameter `xhdr` is typically used when the data type has to be specified. For instance, when the data sent is URL-encoded it may be necessary to use `"Content-Type: application/x-www-form-urlencoded"` as the value for `xhdr` in order to indicate to the server how to decode and process this data.

3. When cookie management is enabled (see `http_cookies`) an additional header `"Cookie:"` is inserted into the request if the cookie store contains compatible cookies. This behaviour is disabled if this optional header is already specified via the parameter `xhdr`.

4. An IO error will be raised in case of failure during a file operation.

Related topics

`httpget`, `httphead`, `httpput`, `httppost`, `httpdel`, `urlencode`, `httpcancel`.

Module

mmhttp

httppost

Purpose

Perform an HTTP POST request.

Synopsis

```
function httppost(url:string|text, data:string, result:string):integer
function httppost(url:string|text, data:string, result:string,
      xhdr:string|text):integer
```

Arguments

`url`	URL to process
`data`	Data file to be sent to the server
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if asynchronous mode is active

Further information

1. The function returns after the request has been processed when synchronous mode is active (see `http_async`). Otherwise, using asynchronous mode, the function returns immediately after having sent the request and the model is notified about the completion of the operation by an event of class `EVENT_HTTPEND`. In this mode the result file `result` must be a physical file (although drivers `"tmp:"` and `"null:"` can still be used).

2. The parameter `xhdr` is typically used when the data type has to be specified. For instance, when the data sent is URL-encoded it may be necessary to use `"Content-Type: application/x-www-form-urlencoded"` as the value for `xhdr` in order to indicate to the server how to decode and process the data.

3. By default the header `"Accept-Encoding: gzip"` is inserted into the request and the result data is automatically decompressed if the server supports compression. This behaviour is disabled if this optional header is already specified (*e.g.* the parameter `xhdr` includes `"Accept-Encoding: identity"`).

4. When cookie management is enabled (see `http_cookies`) an additional header `"Cookie:"` is inserted into the request if the cookie store contains compatible cookies. This behaviour is disabled if this optional header is already specified via the parameter `xhdr`.

5. An IO error will be raised in case of failure during a file operation.

Related topics

`httpget`, `httphead`, `httpput`, `httppatch`, `httpdel`, `urlencode`, `httpcancel`.

Module

mmhttp

httpput

Purpose

Perform an HTTP PUT request.

Synopsis

```
function httpput(url:string|text, data:string, result:string):integer
function httpput(url:string|text, data:string, result:string,
      xhdr:string|text):integer
```

Arguments

`url`	URL to process
`data`	Data file to be sent to the server
`result`	File to store the result of the request
`xhdr`	Additional headers to add to the request

Return value

HTTP status of the request (*e.g.* 200 for success, see Section 6.3 for a list of predefined status code constants; value 999 indicates that an I/O error occurred during the operation) or the request number ($\geq$ 1000) if asynchronous mode is active

Further information

1. The function returns after the request has been processed when synchronous mode is active (see `http_async`). Otherwise, using asynchronous mode, the function returns immediately after having sent the request and the model is notified about the completion of the operation by an event of class `EVENT_HTTPEND`. In this mode the result file `result` must be a physical file (although drivers `"tmp:"` and `"null:"` can still be used).

2. The parameter `xhdr` is typically used when the data type has to be specified. For instance, when the data sent is URL-encoded it may be necessary to use `"Content-Type: application/x-www-form-urlencoded"` as the value for `xhdr` in order to indicate to the server how to decode and process this data.

3. When cookie management is enabled (see `http_cookies`) an additional header `"Cookie:"` is inserted into the request if the cookie store contains compatible cookies. This behaviour is disabled if this optional header is already specified via the parameter `xhdr`.

4. An IO error will be raised in case of failure during a file operation.

Related topics

`httpget`, `httphead`, `httppost`, `httppatch`, `httpdel`, `urlencode`, `httpcancel`.

Module

mmhttp

httpreason

Purpose

Generate the text representation of an HTTP status code.

Synopsis

```
function httpreason(code:integer):string
```

Argument

`code` HTTP status code (see Section 6.3 for a list of predefined status code constants)

Return value

Text associated to the provided status code or an empty string if the code is unknown

Example

The following displays `"Bad Request"`:

```
writeln(httpreason(400))
```

Further information

The HTTP standard specifies a set of predefined status codes. This function returns the text associated with a given code. For instance, upon success a request will reply with code 200 (`"OK"`) or 204 (`"No Content"`).

Module

mmhttp

loadcookies

Purpose

Load cookies from a file.

Synopsis

```
function loadcookies(fname:string|text, host:string):integer
```

Arguments

`fname` Source file name

`host` If not empty only cookies compatible with this host name are recorded

Return value

Number of cookies added to the store

Further information

1. This function loads cookies from the specified file and record them into the cookie store. The file must be encoded as a HTTP header and only `"Set-Cookie"` headers are processed (other lines are silently ignored).
2. An IO error will be raised if the source file cannot be accessed.

Related topics

`savecookies`, `setcookie`.

Module

mmhttp

savecookies

Purpose

Save the cookie store into a file.

Synopsis

```
function savecookies(fname:string|text, domain:string):integer
```

Arguments

`fname`	Destination file name
`domain`	Domain filter of the cookies to be saved or an empty string to select all cookies

Return value

Number of records generated

Further information

1. This function saves the selected cookies into a text file. The cookies are encoded according to the standard `"Set-Cookie"` header (one record per line per cookie).
2. An IO error will be raised if the destination file cannot be accessed.

Related topics

`loadcookies`, `findcookie`.

Module

mmhttp

setcookie

Purpose

Define or update a cookie.

Synopsis

```
procedure setcookie(name:string, value:text, domain:text, path:text,
      exp:integer)
```

Arguments

`name`	Cookie name
`value`	Associated value
`domain`	Domain of the cookie: if it does not start with a dot the domain is interpreted as a host name and the cookie is a *host only cookie*
`path`	Path in the domain
`exp`	Expiration time: with a negative value the cookie is deleted; with `0` the cookie never expires (*session cookie*) and a positive value is interpreted as an amount of time in seconds after which the cookie will expire

Further information

This procedure adds a cookie to the cookie store. If an existing cookie has the same name, domain and path as those specified to the procedure its value and expiration information is updated.

Related topics

`delcookies`, `findcookie`.

Module

mmhttp

tcpping

Purpose

Test availability of a service on a server.

Synopsis

```
function tcpping(host:string|text,port:integer):integer
```

Arguments

`host`	Name of server to test
`port`	Service port

Return value

Test result:

`0`	Connection succeeded
`1`	Invalid parameters
`2`	Host name not found
`3`	Connection failed

Further information

This function opens a TCP connection to to the given host and port and closes it immediately in case of success.

Module

mmhttp

urlencode

Purpose

Encode a text string for a URL.

Synopsis

```
function urlencode(data:string|text):text
```

Argument

`data` Text to encode

Return value

Encoded text suitable for building a URL

Example

The following request sends query `"qry"` to the server `"srv"` requiring parameters `"a"` and `"b"`. The values associated with these parameters are URL-encoded:

```
status:=httpget("http://srv/qry?a="+urlencode(a)+
    "&b="+urlencode(b), "result.txt")
```

Further information

1. This function converts a text string into a format that is compatible with URL conventions. The conversion consists in replacing characters with a special meaning by a portable representation based on the character code. For example, the character `"&"` is replaced by `"%26"`.
2. Typically, query parameters have to be encoded when sending them via an HTTP GET request, data sent via POST may also have to be encoded.

Module

mmhttp

6.4.2 HTTP server

The *mmhttp* module integrates an HTTP server that is started using the procedure `httpstartsrv` and stopped with `httpstopsrv` (the server is stopped in any case when the execution of the model terminates). The server behaviour may be changed using these module parameters: `http_defport` defines the TCP port on which the server is listening (by default a random port is selected); `http_defpage` indicates which *page* or *label* the server has to consider when no path is specified in a request (by default this is `"index.html"`); `http_srvconfig` defines the set of request types supported by the model (for instance only GET and POST) as well as whether a secure server is to be started; `http_maxreq` sets a limit on the number of simultaneous connections that are kept active.

When a secure server (HTTPS) is requested (the server config includes flags `HTTP_SSL` or `HTTP_SSLONLY`) besides the optional basic settings similar to those used for the standard server (like `https_defport`) additional parameters have to be set. The server certificate `https_srvcrt` as well as its private key `https_srvkey` are required. Moreover, if the clients are requested to authenticate themselves (server option `HTTP_CLTAUTH`), the authorised certificate file `https_cacerts` must include the expected certificates. Note that these parameters are published by *mmssl*: this module has to be used when a secure server is started.

The server runs in the background and notifies the model of incoming connections through events of class `EVENT_HTTPNEW` (please refer to the documentation of `mmjobs` for further explanation on how to handle events). The value associated with this event is a request number: the connection to the client is kept open and the model has to reply to the request in order to complete the operation. Any data associated with the incoming request (query in the case of a GET or data sent via POST, PUT or PATCH) is saved into a temporary file before the event is sent. URL encoded information is automatically decoded and converted to a format compatible with `initialisations from` blocks. The function `httppending` may also be used to retrieve the list of requests currently waiting for a reply.

Request properties can be obtained through a set of dedicated routines: `httpreqfrom` is the IP address of the client; `httpreqtype` is the request type (*i.e.* GET, POST, PUT, PATCH or DELETE); `httpreqheader` is the request header; `httpreqstat` reports the status associated to a request number (for instance whether it is active, or has associated data); `httpreqlabel` is the *label* of the request; `httpreqcookies` returns the cookies found in the header. The label of a request is its URL after having removed server reference and the query data (for example, the label returned for `"http://srv/some/path?a=10"` is `"some/path"`); `httpreqfile` is the name of the temporary file holding data associated to the request. The connection status of a request might be inspected with `httpreqconstat` that indicates whether the cleint is still waiting for a reply.

Three different methods can be used to reply to a request: `httpreplycode` will only return a status code associated with a short (error) message; `httpreply` takes as input a file to be sent back to the client (with a *success* status code) and `httpreplyjson` converts its input parameter into JSON data that is sent back to the client.

The following example shows how to implement a simple file server. This program expects GET (download a file) and PUT (upload a file) requests sent to the port 2533. The URI of the request is interpreted as the file name: for example, the URL `"http://srv:2533/myfile.txt"` could be used to access file `"myfile.txt"` stored on host `"srv"` running this example.

```
setparam("http_defport", 2533)                ! Set server port (2533)
setparam("http_srvconfig",HTTP_GET+HTTP_PUT)  ! Only GET and PUT requests
setparam("workdir", getparam("tmpdir"))       ! Move to temporary directory
httpstartsrv                                  ! Server now running
repeat
 wait                                         ! Wait for an event
 ev:=getnextevent
 if ev.class=EVENT_HTTPNEW then               ! Request pending
  r:=integer(ev.value)                        ! Get request ID
  fname:=httpreqlabel(r)                      ! File name will be the URI
  if httpreqtype(r)=HTTP_GET then             ! Client wants to get the file
   if bittest(getfstat(fname), SYS_TYP) = SYS_REG then
```

```
    httpreply(r,fname)                          ! If available: send it
   else
    httpreplycode(r,404)                        ! Otherwise: reply "Not Found"
   end-if
  elif httpreqtype(r)=HTTP_PUT and              ! Client wants to put a file
       httpreqstat(r)>=2 then                   ! File must be non-empty
   fmove(httpreqfile(r), fname)                 ! Try to save it
   if getsysstat=0 then
    httpreplycode(r,204)                        ! If success: reply "No Content"
   else
    httpreplycode(r,403)                        ! Otherwise: reply "Forbidden"
   end-if
  else
    httpreplycode(r,400)                        ! Empty files are refused
  end-if
 end-if
until false
```

In the above example all requests are handled by the same model but it is also possible to dispatch the processing of the requests to several submodels running concurrently to improve the efficiency of the service. To implement a multithreaded server a queue of requests of type `reqqueue` (See Section 6.1) has to be declared as a global shared entity and each of the submodels must be clones of the server model (in order to have access to this shared queue). The master model can then start all of its submodels and initialise the HTTP server as in the preceding example but it can move the HTTP requests it receives to the queue using `httpreqpush`. The submodels enter a loop starting with a call to `httpreqpop` (to indicate that they are ready to handle a request) followed by a wait: requests coming from the master model are notified via an event of class `EVENT_HTTPNEW` and exposed just as in a single-model server. The general structure of the server looks like the following:

```
parameters
 MASTER=true                  ! Running the master or a worker?
 NBW=5                        ! Number of submodels to start
end-parameters

declarations
 queue: shared reqqueue       ! The shared queue of requests
 procedure run_master
 procedure run_worker
 procedure process_request(req:integer)
end-declarations

if MASTER then
 run_master
else
 run_worker
end-if

! The master model runs the HTTP server
procedure run_master
 declarations
  workers:array(1..NBW) of Model
 end-declarations
 forall(i in 1..NBW) do
  load(workers(i))                    ! Each worker is a clone of the server
  run(workers(i),"MASTER=false")
 end-do
 setparam("http_defport", 2533)                 ! Set server port (2533)
 setparam("http_srvconfig",HTTP_GET+HTTP_PUT)   ! Only GET and PUT requests
 setparam("workdir", getparam("tmpdir"))        ! Move to temporary directory
 httpstartsrv                                   ! Server now running
 repeat
  wait                                          ! Wait for an event
  ev:=getnextevent
  if ev.class=EVENT_HTTPNEW then                ! Request pending
   r:=integer(ev.value)                         ! Get request ID
   httpreqpush(r,queue)                         ! Move it to the queue
```

```
  end-if
 until false
end-procedure

! Each worker waits for requests sent by the master model and processes them
procedure run_worker
 setparam("workdir", getparam("tmpdir"))       ! Move to temporary directory
 repeat
  httpreqpop(queue)                            ! Model ready
  wait                                         ! Wait for an event
  ev:=getnextevent
  if ev.class=EVENT_HTTPNEW then               ! Request pending
   r:=integer(ev.value)                        ! Get request ID
   process_request(r)                          ! Actual processing
  end-if
 until false
end-procedure
```

HTTP server functions:

httppending	Get a list of requests waiting for a reply.	p. 223
httpqueueinfo	Get size information of a queue of requests.	p. 224
httpreply	Reply to an HTTP request with a file.	p. 225
httpreplycode	Reply to an HTTP request only with a status code.	p. 226
httpreplyjson	Reply to an HTTP request with JSON data.	p. 227
httpreqconstat	Check the connection status of a request.	p. 228
httpreqcookies	Retrieve the cookies of a request.	p. 229
httpreqfile	Get the data file associated to a request.	p. 230
httpreqfrom	Get the IP address of the sender of a request.	p. 231
httpreqheader	Get the header associated to a request.	p. 232
httpreqlabel	Get the label associated to a request.	p. 233
httpreqpop	Ask for a HTTP request from a queue.	p. 234
httpreqpush	Move a request to a queue.	p. 235
httpreqpushlim	Move a request to a queue with restriction.	p. 236
httpreqstat	Get the status associated with a request.	p. 237
httpreqtype	Get the type of a request.	p. 238
httpstartsrv	Start the HTTP server.	p. 239
httpstopsrv	Stop the HTTP server.	p. 240
jsonread	Initialise a Mosel entity from a JSON data file.	p. 241
jsonwrite	Generate a JSON representation of a Mosel entity.	p. 242
mksetcookie	Generate a set-cookie header line.	p. 243

httppending

Purpose

Get a list of requests waiting for a reply.

Synopsis

```
function httppending(lp:list of integer):integer
function httppending:integer
```

Argument

`lp` List of request numbers

Return value

Number of requests in the waiting queue

Further information

This function returns in `lp` the list of requests currently waiting for a reply in the server queue (the content of the list is replaced).

Module

mmhttp

httpqueueinfo

Purpose

Get size information of a queue of requests.

Synopsis

```
function httpqueueinfo(rq:reqqueue, what:integer):integer
```

Arguments

`rq` A queue of requests

`what` What information to retrieve:

- `0` Number of requests waiting in the queue
- `1` Number of models having access to the queue
- `2` Number of models ready for processing a request
- `3` The result of `httpqueueinfo(rq,2)-httpqueueinfo(rq,0)`

Return value

Requested information or `0` for an unknown code.

Related topics

`httpreqpushlim`.

Module

mmhttp

httpreply

Purpose

Reply to an HTTP request with a file.

Synopsis

```
procedure httpreply(reqid:integer)
procedure httpreply(reqid:integer, fname:string)
procedure httpreply(reqid:integer, fname:string|text, xhdr:string|text)
procedure httpreply(reqid:integer, code:integer, fname:string|text,
      xhdr:string|text)
```

Arguments

`reqid`	Request number
`code`	0 or HTTP status code to be returned (see Section 6.3 for a list of predefined status code constants)
`fname`	Name of the file holding the response data
`xhdr`	Additional headers to include in the response

Further information

1. This procedure replies to the specified request sending the provided file and using 200 (*'OK'*) as the HTTP status code (if no code is given or if its value is 0).
2. The first form of the procedure is the same as providing an empty file name with the second form: in this case no data is sent to the client and the returned status code becomes 204 (*'No Content'*).
3. If the specified request is of type HEAD (see `httphead`) this procedure sends only the header part of the result.
4. An IO error will be raised if the response file cannot be accessed.

Related topics

`httpreplycode`, `httpreplyjson`, `mksetcookie`.

Module

mmhttp

httpreplycode

Purpose

Reply to an HTTP request only with a status code.

Synopsis

```
procedure httpreplycode(reqid:integer, code:integer)
procedure httpreplycode(reqid:integer, code:integer, msg:string)
procedure httpreplycode(reqid:integer, code:integer, msg:string,
      xhdr:string|text)
```

Arguments

`reqid`	Request number
`code`	HTTP status code to be returned (see Section 6.3 for a list of predefined status code constants)
`msg`	Explanation text
`xhdr`	Additional headers to include in the response

Further information

1. This procedure replies to the specified request using the provided code that should be a valid HTTP status (*i.e.* 3 digit number).
2. Unless the provided code is 204 (*No Content*) a basic HTML page is generated as the data associated to the response including the standard reason (*e.g. Bad Request* for code 400) as well as the given explanation text.
3. If the specified request is of type HEAD (see `httphead`) this procedure sends only the header part of the result.

Related topics

`httpreply`, `httpreplyjson`, `mksetcookie`, Section 6.3.

Module

mmhttp

httpreplyjson

Purpose

Reply to an HTTP request with JSON data.

Synopsis

```
procedure httpreplyjson(reqid:integer)
procedure httpreplyjson(reqid:integer, mosobj:*)
```

Arguments

`reqid`	Request number
`mosobj`	Mosel object to use for the reply

Further information

1. This procedure replies to the specified request by sending the provided Mosel object encoded as a JSON object and a status code of 200.
2. When the first form is used, the returned data is the JSON constant `null`.
3. If the specified request is of type HEAD (see `httphead`) this procedure sends only the header part of the result.

Related topics

`httpreply`, `httpreplycode`.

Module

mmhttp

httpreqconstat

Purpose

Check the connection status of a request.

Synopsis

```
function httpreqconstat(reqid:integer):integer
```

Argument

`reqid` Request number

Return value

Request status:

`<0`	Invalid request number
`0`	Request not active
`1`	The client has closed the connection
`2`	The client is still waiting for a reply

Further information

1. A disconnection can only be reliably detected if the remote end of the link has performed an orderly shutdown. As a consequence a return status `2` is not the guarantee that the connection to the client is effectively still valid.
2. A request must always be released by a call to a reply routine (*e.g.* `httpreply`), even after a disconnection has been detected.

Related topics

`httpreqstat`.

Module

mmhttp

httpreqcookies

Purpose

Retrieve the cookies of a request.

Synopsis

```
procedure httpreqcookies(reqid:integer, cook:array(string) of text)
```

Arguments

`reqid` Request number

`cook` An array where cookie values are returned (indiced by the names of the cookies)

Further information

This procedure decodes the header `"Cookie"` of a request to populate the provided array.

Related topics

`httpreqfrom`, `httpreqlabel`, `httpreqstat`, `httpreqtype`, `httpreqheader`, `httpreqfile`, `mksetcookie`.

Module

mmhttp

httpreqfile

Purpose

Get the data file associated to a request.

Synopsis

```
function httpreqfile(reqid:integer):string
```

Argument

`reqid` Request number

Return value

Full path to the data file

Further information

1. Each request is associated with a data file located in the temporary directory. This function returns the full path to this file.
2. The data file is specific to the given request number and can be used (for instance, to store the response to the request) even if no data is associated with the request.

Related topics

`httpreqfrom`, `httpreqlabel`, `httpreqstat`, `httpreqtype`, `httpreqheader`, `httpreqcookies`.

Module

mmhttp

httpreqfrom

Purpose

Get the IP address of the sender of a request.

Synopsis

```
function httpreqfrom(reqid:integer):text
```

Argument

`reqid` Request number

Return value

IP of the sender of the request as a text string

Related topics

`httpreqtype`, `httpreqfile`, `httpreqstat`, `httpreqlabel`, `httpreqheader`, `httpreqcookies`.

Module

mmhttp

httpreqheader

Purpose

Get the header associated to a request.

Synopsis

```
function httpreqheader(reqid:integer):text
```

Argument

`reqid` Request number

Return value

Header of the request

Further information

The *header* of the request is a block of text consisting of lines of the form *fieldname*:*value* (*e.g.* `Content-Type: application/json`).

Related topics

`httpreqfrom`, `httpreqfile`, `httpreqstat`, `httpreqlabel`, `httpreqtype`, `httpreqcookies`.

Module

mmhttp

httpreqlabel

Purpose

Get the label associated to a request.

Synopsis

```
function httpreqlabel(reqid:integer):text
```

Argument

`reqid` Request number

Return value

Label of the request

Further information

1. The *label* of the GET or DELETE request is the URL after having removed server reference and query data (for instance the label returned for `"http://srv/some/path?a=10"` is `"some/path"`). Any query data is automatically saved into the associated request file (`httpreqfile`) in a format compatible with initialisations blocks. When such a file has been created the request status (`httpreqstat`) has value 3.
2. In the case of a POST, a PUT or a PATCH request the returned value also includes the undecoded data.

Related topics

`httpreqfrom`, `httpreqfile`, `httpreqstat`, `httpreqtype`, `httpreqheader`, `httpreqcookies`.

Module

mmhttp

httpreqpop

Purpose

Ask for a HTTP request from a queue.

Synopsis

```
procedure httpreqpop(rq:reqqueue)
```

Argument

`rq` A queue of requests

Further information

1. This procedure has to be used by a model to notify the manager of a queue of requests that it is ready for processing an HTTP request. After this call, as soon as a new request is available an event of class `EVENT_HTTPNEW` is sent to the model that can handle it as if it was running the HTTP server.
2. The model is flagged as *available* if no request is waiting in the queue. This flag is cleared when a request is passed to the model: it is therefore required to call the procedure again after a request has been processed.

Related topics

`httpreqpushlim`, `httpreqpush`, `httpqueueinfo`.

Module

mmhttp

httpreqpush

Purpose

Move a request to a queue.

Synopsis

```
procedure httpreqpush(reqid:integer,rq:reqqueue)
```

Arguments

`reqid` Request number or `-1`

`rq` A queue of requests

Further information

1. This routine moves the selected request to a queue of requests in order to make it available to other server models. The request can no longer be accessed by the calling model after it has been passed to this procedure.
2. If the provided request is `-1` this routine only clears the availability flag of the model (*i.e.* it is no longer ready to process a request).

Related topics

`httpreqpushlim`, `httpreqpop`, `httpqueueinfo`.

Module

mmhttp

httpreqpushlim

Purpose

Move a request to a queue with restriction.

Synopsis

```
function httpreqpushlim(reqid:integer,rq:reqqueue,lim:integer):boolean
```

Arguments

`reqid`	Request number or `-1`
`rq`	A queue of requests
`lim`	Maximum number of waiting requests or `-1` for no limit

Return value

`true` if the operation succeeded, `false` otherwise.

Further information

1. This function moves the selected request to a queue of requests in order to make it available to other server models. The operation is canceled if the current number of elements in the queue exceeds the given limit `lim` and `false` is returned. Otherwise, `true` is returned and the request can no longer be accessed by the calling model.

2. If the provided request is `-1` this routine only clears the availability flag of the model (*i.e.* it is no longer ready to process a request). In this case the return value indicates whether the flag was reset or not: with a `false` result the flag was already cleared before the function call.

Related topics

`httpreqpush`, `httpreqpop`, `httpqueueinfo`.

Module

mmhttp

httpreqstat

Purpose

Get the status associated with a request.

Synopsis

```
function httpreqstat(reqid:integer):integer
```

Argument

`reqid` Request number

Return value

Request status:

`<0`	Invalid request number
`0`	Request not active
`1`	No associated data
`2`	Raw data available
`3`	'initialisations from' data available

Further information

1. If the return value is `2` or `3` a data file is available (see `httpreqfile`). If this function returns `3` then the file can be read using an *initialisations from* block: data that was originally URL-encoded has been decoded by the server and stored using Mosel's *initialisations* format.

2. The status 3 will be produced when the request is of type GET or DELETE and has associated data. This will also be the case with a query of type POST or DELETE if the content type is `"application/x-www-form-urlencoded"`.

Related topics

`httpreqfrom`, `httpreqfile`, `httpreqlabel`, `httpreqtype`, `httpreqheader`, `httpreqcookies`, `httpreqconstat`.

Module

mmhttp

httpreqtype

Purpose

Get the type of a request.

Synopsis

```
function httpreqtype(reqid:integer):integer
```

Argument

`reqid` Request number

Return value

Request type:

`<0`	Invalid request number
`0`	Request not active
`HTTP_GET`	GET (`1`)
`HTTP_POST`	POST (`2`)
`HTTP_PUT`	PUT (`4`)
`HTTP_DELETE`	DELETE (`8`)
`HTTP_HEAD`	HEAD (`128`)
`HTTP_PATCH`	PATCH (`256`)

Related topics

`httpreqfrom`, `httpreqfile`, `httpreqstat`, `httpreqlabel`, `httpreqheader`, `httpreqcookies`.

Module

mmhttp

httpstartsrv

Purpose

Start the HTTP server.

Synopsis

```
procedure httpstartsrv
procedure httpstartsrv(srvdir:string, moslab:string)
```

Arguments

`srvdir`	Server directory
`moslab`	Label identifying commands

Further information

1. The server takes its configuration from the parameters `http_defport`, `http_srvconfig`, `http_listen`, `http_maxreq` and `http_defpage`.
2. Only one server can be run by a model: if the server is already running, no operation is performed.
3. The server processes only authorised request types (see `http_srvconfig`): the model is notified of every valid request by an event of class `EVENT_HTTPNEW`. Malformed or unauthorised requests are automatically rejected.
4. When the function is used with arguments, `srvdir` designates a directory: *mmhttp* will act as a file server for the files stored in this directory (via `GET` queries). The argument `moslab` is a prefix that identifies requests that are to be handled by the model.
5. An IO error is raised if the server cannot start because of a network setting (typically the TCP port is already used or requires higher privileges).
6. If the parameter `http_startwb` is set to `true` a web browser (as defined by `http_browser`) is launched just after the server has started.

Related topics

`httpstopsrv`.

Module

mmhttp

httpstopsrv

Purpose

Stop the HTTP server.

Synopsis

```
procedure httpstopsrv
```

Further information

1. This procedure has no effect if no server is running.
2. During its shutting down procedure the server closes all waiting requests (with a response code 410) such that it is no longer possible for the model to reply to these requests (however, events corresponding to these requests may still be in the event queue).

Related topics

`httpstartsrv`.

Module

mmhttp

jsonread

Purpose

Initialise a Mosel entity from a JSON data file.

Synopsis

```
procedure jsonread(fname:text|string, mosobj:*)
```

Arguments

`fname` Name of a JSON file

`mosobj` A Mosel entity

Further information

1. This procedure accepts basic types (`integer`, `real`, `boolean`, `string`), native types compatible with from/tostring (*e.g.* `text` or `date`, they are initialised from json strings), records (only public fields of supported types are populated from the corresponding json object members), lists of compatible types (populated from json arrays) and unions. Unsupported entities are silently ignored (*e.g.* sets and arrays) and entries in the JSON document that do not correspond to an expected entry are also ignored.
2. Unions have a special handling: they can be initialised with a scalar (number, boolean or string) or an object if the union itself is already a field of a record (in this case the union takes the type of the structure that includes it).
3. Although basic types are supported the routine cannot initialise a scalar of a basic type: its input parameter must be a record, a union, a variable of a native type (supporting serialisation) or a list.
4. The procedure does not reset its input parameter: in particular when initialising a list, the values from the JSON file will be appended to the existing content. Note that the special value `null` from the JSON data might be applied to lists, records and unions to reset these entities.
5. An IO error will be raised if the source file cannot be accessed or if a parsing error occurs.

Related topics

`jsonwrite`.

Module

mmhttp

jsonwrite

Purpose

Generate a JSON representation of a Mosel entity.

Synopsis

```
procedure jsonwrite(fname:text|string, mosobj:*)
procedure jsonwrite(fname:text|string, mosobj:*, flags:integer)
```

Arguments

`fname` Name of a file to store the generated text

`mosobj` A Mosel entity

`flags` Option flags (can be combined with '+'):

`HTTP_SKIP_EMPTYCOL`	Skip empty collections in records
`HTTP_SKIP_EMPTYUNION`	Skip empty unions in records

Further information

1. This procedure generates a JSON representation of a Mosel entity: records are exposed as json objects; lists and sets are represented by json arrays; arrays result in either json objects or arrays depending on their structure and scalar values are output as json numbers, Booleans or strings. Types not supporting serialisation (*i.e.* conversion from/to some textual representation) are reported as the `null` json value.

2. When exporting a record, only public fields of types supporting serialisation are output: for instance a field of type `mpvar` will be silently ignored. With the flag `HTTP_SKIP_EMPTYCOL` empty collections (list,set or array) will also be skipped, and with the option `HTTP_SKIP_EMPTYUNION` undefined unions will be ignored.

3. If the file name is an empty string, the generated text is sent to the current output stream (by default this is the console). An IO error will be raised if the destination file cannot be accessed.

Related topics

`jsonread`.

Module

mmhttp

mksetcookie

Purpose

Generate a set-cookie header line.

Synopsis

```
function mksetcookie(name:string, value:text, domain:text, path:text,
      exp:integer):text
```

Arguments

`name`	Cookie name
`value`	Associated value
`domain`	Domain of the cookie: if it does not start with a dot the domain is interpreted as a host name and the cookie is a *host only cookie*
`path`	Path in the domain
`exp`	Expiration time: with a negative value the cookie will be deleted; with `0` the cookie never expires (*session cookie*) and a positive value is interpreted as an amount of time in seconds after which the cookie will expire

Return value

A text string of the form `"Set-Cookie: name=value\n"`

Further information

This function may be used to send cookies to a client by generating a set-cookie header that can be directly appended to the additional headers string of `httpreply` or `httpreplycode`. The returned string is terminated by an end of line.

Related topics

`httpreply`, `httpreplycode`, `httpreqcookies`.

Module

mmhttp

6.5 I/O drivers

The *mmhttp* module publishes the `url` driver with which a URL can be used as a file. Thanks to this facility it is possible to use files stored on an HTTP enabled file server just as if they were located on the local file system. For example, the following command downloads and executes the Mosel file `"hello.mos"` stored on the web server `mysrv`:

```
> mosel exec mmhttp.url:http://mysrv/hello.mos
```

6.5.1 Driver *url*

```
url:URL
```

The file name for this driver is a *URL*. Currently only HTTP URLs are supported (*i.e.* the name must begin with `"http://"`). The behaviour of the driver depends on the file operation:

`reading` A GET request is sent to the specified URL at the time of opening the file. The following *read* operations are executed directly from the result stream generated by the server.

`writing` The written data is first saved into a temporary file and then sent to the specified URL via a PUT request when the file is closed.

`deleting` When deleting a file (*e.g.*, using `fdelete`) through this driver a DELETE request is sent to the specified URL.

CHAPTER 7

mmjava

The *mmjava* module for Mosel is intended for users who integrate their Mosel models into Java applications. This module can only be used from a Java enabled application.

7.1 I/O drivers

This module provides the *java* and *jraw* IO drivers. The first one can be used to link a Mosel output (input) stream to a Java `OutputStream` (`InputStream`) or a Java `ByteBuffer`. The second driver is a modified version of the *raw* driver suitable for Java: instead of an address, this driver takes as input a reference to an object.

For both drivers, file names are replaced by references to objects. These references are of two kinds: direct references to public static objects (*e.g.* `"java.lang.Sytem.out"`) and names defined using the `XPRM.bind` method. The second technique will be used with non static objects: the method `XPRM.bind` establishes a link between a name and an object. This name can then be used as an object reference for *mmjava* drivers.

When using Java object from Mosel, it is important to make sure objects and related fields can be accessed: in particular the class and its fields must be public.

7.1.1 Driver `java`

```
java:[rewind,]static object|named object
```

With this driver a Java stream (`OutputStream` or `InputStream`) as well as a `ByteBuffer` can be used in place of a file in Mosel. This facility is specially useful for redirecting default Mosel streams to Java objects. Note that the Mosel Java interface uses this driver for redirecting default streams (in, out, and error) to the corresponding Java streams (`System.in`, `System.out` and `System.err`).
When the file is open for reading and the referenced object is a ByteBuffer, the option `rewind` can be used in order to rewind the buffer before starting to read.

Example:

```
mosel=new XPRM();
mosel.bind("out", myout);   /* Associate 'myout' object with string "out" */
                    /* Redirect default output to 'myout' */
mosel.setDefaultStream(XPRM.F_OUTPUT|XPRM.F_LINBUF, "java:out")
                    /* Redirect error stream to Java output stream */
mosel.setDefaultStream(XPRM.F_ERROR, "java:java.lang.System.out"
```

If the driver is used in an `initializations from` block (resp. `initializations to` block) and the provided object implements interface `XPRMInitializationFrom` (resp. `XPRMInitializationTo`) then the corresponding Java methods are used to process the initialization (refer to the *Mosel Library JavaDoc* for further explanation).

This driver supports the *delete* operation: deleting a java file name from the Mosel code (*e.g.* `fdelete("java:out")`) corresponds to executing `unbind` on the corresponding identifier. The operator first tries to unbind the identifier associated to the running model (`XPRMModel.unbind`) and then uses the global reference (`XPRM.unbind`) if the first attempt fails.

7.1.2 Driver *jraw*

```
jraw:[noindex,all]
```

The driver can only be used in 'initializations' blocks. In the opening part of the block, no file name has to be provided, but general options can be stated at this point: they will be applied to all labels. Two options are supported:

`all` forces output of all cells of an array even if it is dynamic (by default only existing cells are considered).

`noindex` indicates that only data (no indices) are transfered between the Java objects and Mosel. By default, the first fields of each object are interpreted as index values for the array to be transfered. This behavior is changed by this option.

In the block, each label entry is understood as an object reference to use for the actual processing. Note that, before the object reference, one can add further options separated by comas, that are effective to the particular entry.

If the Model object to be initialized (or saved) is a scalar or an array with option `noindex`, the driver expects a Java object of a corresponding type (*i.e.* same basic type and scalar or one dimension array). If the option `noindex` is not used and the Mosel object is an array, the label must specify which fields of the class have to be taken into account for the mapping. This is indicated by a list of field names separated by commas and noted in brackets (*e.g.* `"myobj(fi1,fi2,fi3)"`).

In the following example the *jraw* driver is used to initialize an array of reals, `a`, and an array of integers, `ia`, with data held in the Java application that executes the model.

Java part:

```
public class MyData {   /* A class to store an `array(string, int) of real' */
 public String s; public int r; public double v;
 MyData(String i1, int i2, double v0) { s=i1; r=i2; v=v0; }
}
...
MyData[] data;
int[] intarr;
...
mosel=new XPRM();
mosel.bind("data", data);   /* Associate `data' object with string "data" */
mosel.bind("ia", intarr);   /* Associate `intarr' object with string "ia" */
```

Mosel part:

```
declarations
 a:array(string, range) of real
 ia:array(range) of integer
end-declarations
...
initializations from "jraw:"
 aa as "data(s,r,v)" ! Initialize `aa' with fields s,r,v of object `data'
 ia as "noindex,ia"  ! Initialize `ia' with array `ia'; no index (only values)
end-initializations
```

CHAPTER 8

mmjobs

Thanks to this module it is possible to load several models in memory and execute them concurrently. In addition, other instances of Mosel might be started (either locally to the running system or remotely on another machine through the network) and used to run additional models controlled by the model that has started them. This means that the computing capacity of the running model is not restricted to the executing process. A general synchronization mechanism based on *event queues* as well as two specialized IO drivers are also provided in order to ease the implementation of parallel algorithms in Mosel.
To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmjobs'
```

8.1 Example

The following example shows how to compile, load, and then run a model from another model. After having started the execution, it waits for 60 seconds before stopping the secondary model if the latter has not yet finished.

```
model "mmjobs example"
uses "mmjobs","mmsystem"

declarations
 mymod: Model
 event: Event
end-declarations

                              ! Compile 'mymod.mos' to memory
 if compile("","mymod.mos","shmem:bim")<>0
 then
  exit(1)
 end-if

 load(mymod,"shmem:bim")      ! Load bim file from memory...
 fdelete("shmem:bim")         ! ... and release the memory block

                              ! Disable model output
 setdefstream(mymod,"","null:","null:")
 run(mymod)                   ! Start execution and
 wait(60)                     ! wait 1 min for an event

 if waitexpired then          ! No event has been sent...
  writeln("Model too long: stopping it!")
  stop(mymod)                 ! ... stop the model then wait
  wait
 end-if
                              ! An event is available: model finished
 event:=getnextevent
 writeln("Exit status: ", getvalue(event))
```

```
 writeln("Exit code  : ", getexitcode(mymod))

 unload(mymod)
end-model
```

8.2 Data sharing between models

A model may *share* data with its submodels under certain conditions: any initialisation performed by the master model on these shared entities is available to the submodels at their startup and any modification carried out by both the master model and its submodels are effective for all models.

Entities to be shared must be global and identified by the declaration qualifier `shared` (they do not need to be public). Only scalars of basic types and native types supporting sharing, as well as sets, lists and arrays of basic types can be shared. For the arrays, index sets must be either shared or constants of basic types, shared hashmap arrays cannot have more than 1 dimension.

```
declarations
 sci: shared integer
 ss: shared set of string
 sa: shared dynamic array(ss,1..2) of real
end-declarations
```

Data sharing is possible only between a model (the *master model*) and its *clones* (*i.e.* submodels loaded from the running model see `load`). The master model can manipulate its shared entities just like any other data structure as long as no compatible submodel is running. However, as soon as a submodel using shared data is started the *sharing mode* is enabled and access to shared entities is altered as follows: sets and lists behave as if they were constant, the structure of arrays is locked (*i.e.* it is no longer possible to add or remove cells of sparse arrays). Normal access to shared entities is restored when all submodels using them are reset (`reset`) or unloaded (`unload`). The current status of the sharing mode can be obtained from the `sharingstatus` control parameter (`getparam`).

```
model "shared example"
uses 'mmjobs'

declarations
 a: shared array(1..3) of integer
 m: Model
end-declarations

if getparam("sharingstatus")<>2 then
                            ! in master model ('a' is empty)
 forall(i in 1..3) a(i):=i  ! initialise 'a'
 writeln("master:",a)       ! output: master:[1,2,3]
 load(m)                    ! clone master then run it
 run(m)
 waitforend(m)              ! wait for its termination
 writeln("aftersub:",a)     ! output: aftersub:[2,3,4]
else
                            ! in submodel ('a' is already initialised)
 writeln("sub:",a)          ! output: sub:[1,2,3]
 forall(i in 1..3) a(i)+=1  ! modify 'a'
end-if

end-model
```

8.3 Control parameters

The following parameters are defined by *mmjobs*:

`conntmpl`	Default connection template.	p. 249

conntmpl

Description The connection template is used by the `connect` function to generate a valid host specification from an identifier (typically corresponding to a host name). The generation is performed by replacing in the template each occurrence of the `%h` marker by the original identifier.

Type String, read/write

Values A string containing `"%h"` at least once

Default value "xsrv:%h"

Affects routines `connect`.

Module mmjobs

nodenumber

Description The ID (or node number) of the current instance as returned by the function `getid` applied to this instance. The ID of the initial (root) instance is `0`

Type Integer, read only

Module mmjobs

defaultnode

Description This parameter is used by the IO driver `"rmt:"` when it is not given any node reference (see Section 8.5.6). By default its value is `0` (the initial node) but it may be changed by a parent model using the instance parameter `defaultnode` (see Annex B).

Type Integer, read only

Module mmjobs

jobid

Description The ID of the current model as returned by the function `getid` applied to this model. The ID of the initial (root) model is `0`

Type Integer, read only

Module mmjobs

parentnumber

Description The ID (or node number) of the parent (*i.e.*, creator) of the current instance. The ID of the initial instance is `0` and its parent is `-1`.

Type Integer, read only

Module mmjobs

keepalive

Description When using a Mosel remote instance (see `connect`), the server sends to its client a *keepalive* message at fixed `interval`. A connection is considered broken if more than `maxfail*interval` seconds have elapsed since the last message received. Setting 0 for `maxfail` disables this mechanism. This parameter can only be changed if no remote Mosel instance is connected.

Type String, read/write

Values A string of the form `"maxfail/interval"`

Default value "2/60"

Module mmjobs

fsrvport

Description This parameter defines the UDP port to be used by the `findxsrvs` routine for its broadcast messages.

Type Integer, read/write

Default value 2514

Affects routines `findxsrvs`.

See also `fsrvnbiter`, `fsrvdelay`.

Module mmjobs

fsrvdelay

Description After it has sent its broadcast message, the `findxsrvs` routine waits for up to `fsrvdelay` milliseconds for answers before aborting.

Type Integer, read/write

Default value 1000

Affects routines `findxsrvs`.

See also `fsrvnbiter`, `fsrvport`.

Module mmjobs

fsrvnbiter

Description This control parameter specifies the number of times the procedure `findxsrvs` sends a broadcast message.

Type Integer, read/write

Default value 1

Affects routines `findxsrvs`.

See also `fsrvdelay`, `fsrvport`.

Module mmjobs

sshcmd

Description When connecting to a remote host via the `"xssh:"` I/O driver, an external program is used to establish the SSH tunnel: this parameter specifies which program to use. The arguments of the program are identified with the symbol `"%h"` for the target host, `"%p"` for the TCP port and `"%f"` for the known host file (which is `"-"` when no file is provided). For instance the following string will select `ssh` as the program to handle the secure tunnel: `"ssh -q -p %p -s %h xprmsrv"`.

Note that this control parameter is read-only when Mosel is running under restriction `NoExec` (see Section 1.3.4).

Type String, read/write

Affects routines `connect`.

Values A string including at least `"%h"`

Default value "xprmsrv -sshclt %h -p %p -kh %f"

Module mmjobs

8.4 Procedures and functions

8.4.1 Mosel instance management

The type *Mosel* is used to reference a Mosel instance. Before an instance can execute commands (like loading or running a model), it must be *connected*. Connecting an instance consists in starting an additional operating system process running Mosel: this is done by the `connect` function. To improve readability of the model source, one can use host aliases (defined by means of the `sethostalias` routine) to designate connection targets. Once work with a particular instance has been finished, the instance can be disconnected (`disconnect`): this terminates the process running Mosel (and releases all associated resources).

`clearaliases`	Delete all defined aliases.	p. 255
`connect`	Connect a Mosel instance.	p. 253
`disconnect`	Disconnect a Mosel instance.	p. 254
`findxsrvs`	Search xprmsrv servers on the local network.	p. 260
`getaliases`	Retrieve the list of all defined aliases.	p. 258
`getbanner`	Get the banner displayed by an instance on startup.	p. 256
`gethostalias`	Get the value of a host alias.	p. 257
`sethostalias`	Define a host alias.	p. 259

connect

Purpose

Connect a Mosel instance.

Synopsis

```
function connect(mi:Mosel, host:string|text):integer
```

Arguments

`mi`	The instance to connect
`host`	A host specification

Return value

`0` if successful, a positive value otherwise

Example

Start instance `inst1` on a separate process:

```
r:=connect(ins1,"")
```

With default settings, the 2 following statements are equivalent:

```
r:=connect(ins2,"ariane")
r:=connect(ins3,"xsrv:ariane")
```

Further information

1. Any Mosel instance has to be connected before it can be used for executing commands.
2. If the `host` provided is an empty string (`""`), it is replaced by `"rcmd:"` (instance started on the same machine in a separate process). Otherwise, the string `host` is searched in the list of defined aliases (see `sethostalias`) and, if found, it is replaced by the associated text. If the resulting specification does not contain any IO driver reference, a valid specification is generated using the current connection template (see `conntmpl`): each occurrence of the `%h` marker in the template is replaced by the value of `host`.
3. The `host` argument (or the string resulting from the transformations described above) is expected to be an extended file name using an IO driver the task of which is to start a process running the `mosel` program in remote mode and create/manage the communication streams between the processes. The *mmjobs* module provides three drivers supporting this service (see Section 8.5): `"rcmd:"` to start a Mosel instance on a separate process on the same machine, `"xsrv:"` to start a Mosel instance on a host running the Mosel Remote Launcher (see Section 8.6) and `"xssh:"` to use a secure connection with an xprmsrv server.

Related topics

`sethostalias`, `findxsrvs`, `disconnect`, *Driver rcmd*, *Driver xsrv*, *Driver xssh*

Module

mmjobs

disconnect

Purpose

Disconnect a Mosel instance.

Synopsis

```
procedure disconnect(mi:Mosel)
```

Argument

`mi` The instance to disconnect

Further information

This routine should be used to terminate a Mosel instance started by `connect`.

Related topics

`connect`.

Module

mmjobs

clearaliases

Purpose

Delete all defined aliases.

Synopsis

```
procedure clearaliases
```

Further information

This routine deletes all host aliases previously defined by `sethostalias`.

Related topics

`sethostalias`,`getaliases`,`gethostalias`,`connect`.

Module

mmjobs

getbanner

Purpose

Get the banner displayed by an instance on startup.

Synopsis

```
function getbanner(mi:Mosel):string
```

Argument

`mi` A connected instance

Return value

The text displayed by Mosel when it started the instance

Further information

When a new instance is started, the text displayed by Mosel is saved (this includes typically copyright notice and version information): this function returns this startup banner.

Related topics

`connect`.

Module

mmjobs

gethostalias

Purpose

Get the value of a host alias.

Synopsis

```
function gethostalias(alias:string):string
```

Argument

`alias` Internal identifier

Return value

The host specification corresponding to the alias or an empty string if the alias is not defined

Related topics

`sethostalias`,`clearaliases`,`getaliases`, `connect`.

Module

mmjobs

getaliases

Purpose

Retrieve the list of all defined aliases.

Synopsis

```
procedure getaliases(aliases:list of string)
```

Argument

`aliases` A list to return the aliases

Example

The following procedure displays all aliases:

```
procedure showaliases
 declarations
  l:list of string
 end-declarations

 getaliases(l)
 forall(h in l)
  writeln(h,"->",gethostalias(h))
end-procedure
```

Further information

This procedure resets its `aliases` argument.

Related topics

`sethostalias`,`clearaliases`,`gethostalias`, `connect`.

Module

mmjobs

sethostalias

Purpose

Define a host alias.

Synopsis

```
procedure sethostalias(alias:string,host:string)
```

Arguments

`alias` Internal identifier

`host` Corresponding host specification

Example

The first statement defines `"localhost"` as a separate process on the same machine and `"win"` for a remote access to the machine `"winpc"`:

```
sethostalias("localhost","rcmd:")
sethostalias("win","xsrv:winpc")
```

Further information

Host aliases are used by `connect` to start Mosel instances. If the argument `host` is the empty string, the corresponding alias is removed from the list (or nothing is done if the alias was not defined before).

Related topics

`gethostalias`,`clearaliases`,`getaliases`, `connect`.

Module

mmjobs

findxsrvs

Purpose

Search xprmsrv servers on the local network.

Synopsis

```
procedure findxsrvs(group:integer,maxip:integer,addrs:set of string)
```

Arguments

`group`	Group number of the request
`maxip`	Maximum number of addresses to collect
`addrs`	Set to store the addresses found

Further information

1. This procedure sends a broadcast message over the local network and waits for replies from running `xprmsrv` servers (see Section 8.6). A given server will reply only to selected *group* numbers: the `group` argument specifies this property.
2. The IP addresses of the hosts having replied to the request are returned via the last argument of the procedure in the form of strings. The maximum size of this set is fixed by `maxip`. Note that the provided set is not cleared: if it already contains `maxip` elements the routine returns immediately.
3. Control parameters `fsrvnbiter`, `fsrvdelay` and `fsrvport` can be used to tune the behaviour of `findxsrvs`. This routine repeats `fsrvnbiter` times the following procedure: it sends a broadcast message to the `fsrvport` UDP port and then waits for up to `fsrvdelay` milliseconds for replies.

Related topics

`connect`, `disconnect`.

Module

mmjobs

8.4.2 Model management

The type *Model* is used to reference a Mosel model. This section describes the procedures and functions available for model management: compilation of source model files, loading of bim files, execution and retrieval of model information. Note that before it can be used, a model has to be initialized by loading a bim file (`load`).

compile

Purpose

Compile a source model.

Synopsis

```
function compile(src:string|text):integer
function compile(opt:string|text, src:string|text):integer
function compile(opt:string|text, src:string|text, dst:
      string|text):integer
function compile(opt:string|text, src:string|text, dst: string|text,
      com:string|text, pass:string|text, pke:string|text,
      kls:string|text):integer
function compile(mi:Mosel, opt:string|text, src:string|text, dst:
      string|text):integer
function compile(mi:Mosel, opt:string|text, src:string|text, dst:
      string|text, com:string|text, pass:string|text, pke:string|text,
      kls:string|text):integer
```

Arguments

`opt` Compilation options (may be separated by spaces or `'-'` symbols):
- `"g"` Include debugging information
- `"G"` Include tracing information
- `"s"` Strip symbols
- `"p"` parse only: stop after the syntax analysis of the source file, do not compile (no file generated)
- `"bx=prefix"` Package prefix list (can be quoted with single or double quotes)
- `"ix=prefix"` Include source prefix (can be quoted with single or double quotes)
- `"S"` Sign the bim file
- `"E"` Encrypt the bim file
- `"F"` The argument `pass` is a file name (not the password itself)
- `"V"` Accept to load signed packages only if their signature can be verified
- `"T"` Accept to load only signed packages with a valid signature

`src` Source file name

`dst` Destination file name

`com` Comment to store in the bim file

`mi` The Mosel instance to perform the compilation

`pass` Password or password file (for encryption with a password)

`pke` Private key file (for bim file signing)

`kls` File of public keys (for encryption with public keys)

Return value

`0` Function executed successfully

`1` Parsing phase has failed (syntax error or file access error)

`2` Error in compilation phase (a semantic error has been detected)

`3` Error writing the output file

`4` License error (compiler not authorized)

Example

Compile the local file `"src.mos"` stored on the current directory using the instance `inst1` and store the resulting BIM file on the current directory of this instance:

```
r:=compile(ins1,"","rmt:src.mos","dst.bim")
```

Further information

1. This function compiles a given model source file into a binary model file (bim file) that is required as input to function `load` for executing the model.
2. If no destination file name is provided, the output file takes the same name as the source file with the extension `.bim`.
3. When sending a compilation request to a separate Mosel instance, it is important to keep in mind that the operation is performed in the environment of this instance (in particular its current working directory) and file names should be specified appropriately (the `rmt:` IO driver can be particularly helpful in this context). An IO error will be raised in case of network failure.
4. The argument `kls` is a list of public key files (*i.e.* each line of the file is a key file name): when encrypting a file, the encryption is performed for each of the listed public keys such that the bim file can be decrypted by any of the corresponding private keys.
5. When prefixes provided via `bx` or `ix` are quoted with double quotes, backslashes are interpreted such that special characters can be included in the string. It is therefore required to double this symbol when it has to be included (*e.g.* `'bx="C:\\mydir"'`).
6. If the option `bx` is not stated, the current value of the control parameter `bimprefix` will be used instead during the compilation for loading packages (See section 2.3.1).

Related topics

`load`.

Module

mmjobs

detach

Purpose

Detach the current model from its parent node.

Synopsis

```
procedure detach
```

Further information

1. This procedure *detaches* the model calling it from its parent model such that it becomes a *master* model running on a *root node*. As a consequence the connection to its parent model is closed, its model number is set to 0 and the node number of its instance becomes 0 (root node). The parent node is notified of the detachment by means of a termination event for the model which gets the status `RT_DETACHED`.
2. The operation is possible only if the hosting intance is running exclusively this model (*i.e.* no submodel is loaded at the time of calling `detach`) and no file is open between the hosting instance or the model and its parent (in particular the default streams have to be set to `"null:"`).
3. After a model is detached, it can no longer communicate with its parent using events or access files through the `"rmt:"` driver. The HTTP protocol (available through the module `mmhttp`) might be used as an alternative to the facilities provided by `mmjobs` in this case.
4. The instance running the detached model terminates automatically after the end of execution of the model.
5. This routine can only be called by a submodel running on a remote instance. It has no effect if used by a master model.

Related topics

`getstatus`, `run`.

Module

mmjobs

load

Purpose

Load a Binary Model file.

Synopsis

```
procedure load(mo:Model)
procedure load(mo:Model, bimf:string|text)
procedure load(mo:Model, mr:Model)
procedure load(mo:Model, bimf:string|text, opt:string|text,
      pass:string|text, pke:string|text, kls:string|text)
procedure load(mi:Mosel, mo:Model, bimf:string|text)
procedure load(mi:Mosel, mo:Model, bimf:string|text, opt:string|text,
      pass:string|text, pke:string|text, kls:string|text)
```

Arguments

`mo` Model object to be initialized

`mr` Model object used as a reference

`bimf` Bim file name

`mi` The instance on which the model will be run

`opt` Loading options (may be separated by spaces or `'-'` symbols):
- `"c"` Check signature (if the file is signed)
- `"V"` If the file is signed, load it only if the signature is valid
- `"T"` Load only signed files with a valid signature
- `"F"` The argument `pass` is a file name (not the password itself)
- `"l"` Do not load required packages

`pass` Password or password file (for encrypted bim files)

`pke` Private key file (for encrypted bim files)

`kls` File of public keys

Further information

1. This procedure initializes the model `mo` with the bim file `bimf`. If `mo` has already been initialized, the model it references is unloaded before trying to load the new file (note that this operations fails if the model is running). If the file `bimf` cannot be accessed or one of the required modules cannot be loaded, the procedure generates an IO error (which may be intercepted if the control parameter `ioctrl` is true).

2. When loading a model from a separate Mosel instance, it is important to keep in mind that the operation is performed in the environment of this instance (in particular its current working directory) and file names should be specified appropriately (the `rmt:` IO driver can be particularly helpful in this context).

3. The argument `kls` is a list of public key files (*i.e.* each line of the file is a key file name): when a signed bim file is loaded, its signature is checked with the keys listed in this file. If this argument is not specified, the signing key is searched in the default public keys directory located at `getparam("ssl_dir")+"/pubkeys"`.

4. Packages required for the loading of a model are located using the list of prefixes defined by the control parameter `bimprefix` (See section 2.3.1).

5. When invoked with a single argument this routine creates a new model from the one being executed (without using any bim file): this *clone* can access data shared by its master model (see Section 8.2). Similarly, when a model is used in place of a bim file the new generated model is a copy of the provided reference model. Note that all copies of a given model share the constant information (like constant strings or the code segment) of the reference model. As a consequence, during a debugging session, setting a breakpoint in a model loaded this way also installs the same breakpoint in all other models coming from the same source (including the reference model).

Related topics

`compile`, `setdefstream`, `run`, `unload`.

Module

mmjobs

setdefstream

Purpose

Set default input/output streams of a model.

Synopsis

```
procedure setdefstream(mo:Model, wmd:integer, fname:string)
procedure setdefstream(mo:Model, input:string, output:string, error:string)
procedure setdefstream(mi:Mosel, wmd:integer, fname:string)
procedure setdefstream(mi:Mosel, input:string, output:string, error:string)
```

Arguments

`mo` A Model

`mi` A Mosel instance

`wmd` Stream to set. Possible values:

`F_INPUT`	Default input stream
`F_OUTPUT`	Default output stream
`F_ERROR`	Default error stream
`F_LINBUF`	Use line buffering

`fname` Extended file name to be used for the stream.

`input` Extended file name to be used for the input stream.

`output` Extended file name to be used for the output stream.

`error` Extended file name to be used for the error stream.

Further information

1. This function sets default IO streams to be used by a model. Model streams can be changed only when the model is not running. Each stream is associated to an extended file name (*i.e.* IO drivers can be used). For output streams, `F_LINBUF` may be specified (*e.g.*`F_OUTPUT+F_LINBUF`) in order to enable line buffering for the corresponding stream (the error stream is always open using line buffering).
2. For input and output streams, the filename is stored and streams are actually open when execution of the model starts: in case of an invalid file name, the error is not reported by this function. The error stream is immediately opened so in the case of an invalid file name it is detected by this function.
3. Using an empty string as the file name implies resetting to the original default stream.
4. When applied to a Mosel instance, this routine sets the default streams for this instance. These streams can only be changed if the instance has not yet loaded any model.
5. When using this routine on a separate Mosel instance or on a model loaded on a separate Mosel instance, it is important to keep in mind that the operation is performed in the environment of this instance (in particular its current working directory) and file names should be specified appropriately (the `rmt:` IO driver can be particularly helpful in this context).
6. An IO error will be raised in case of failure during a file operation.

Related topics

`getfname`.

Module

mmjobs

resetmodpar

Purpose

Remove a parameter from a model parameter string.

Synopsis

```
procedure resetmodpar(plist:text, pname:string|text)
```

Arguments

`plist`	Text object storing the parameters
`pname`	Parameter name

Further information

1. This function helps in building the model parameter string to be passed to the `run` procedure by removing a parameter definition (previously set with `setmodpar`) from a parameter string. The `plist` text is left unchanged if the requested parameter cannot be found.
2. It is expected that the provided text string is either empty or composed of a list of assignments of the form `"pname=val,pname2=val2..."`.

Related topics

`setmodpar`, `run`.

Module

mmjobs

setcontrol

Purpose

Set an instance control parameter on a remote instance.

Synopsis

```
procedure setcontrol(mi:Mosel, ctrl:string, val:string)
procedure setcontrol(mo:Model, ctrl:string, val:string)
```

Arguments

`mi`	A Mosel instance
`mo`	A model reference (it must be loaded onto a remote instance)
`ctrl`	Control name
`val`	Control value

Further information

1. This procedure is used to change an instance control parameter in the context of the Remote Invocation Protocol (see Annex B).
2. An IO error is raised in case of error.

Module

mmjobs

setmodpar

Purpose

Add or change the value of a parameter in a model parameter string.

Synopsis

```
procedure setmodpar(plist:text, pname:string|text,
      val:integer|real|boolean|string|text)
```

Arguments

`plist`	Text object storing the parameters
`pname`	Parameter name
`val`	Value assigned to the parameter.

Further information

1. This function helps in building the model parameter string to be passed to the `run` procedure. As input it takes a `text` object that it modifies by either adding an assignment of the form `pname=val` or by replacing an existing assignment. The routine adds the necessary quoting as necessary.
2. It is expected that the provided text string is either empty or composed of a list of assignments of the form `"pname=val,pname2=val2..."`.

Related topics

`resetmodpar`, `run`.

Module

mmjobs

setworkdir

Purpose

Set the initial working directory of a model.

Synopsis

```
procedure setworkdir(mo:Model, cwd:string)
```

Arguments

`mo`	A model reference
`cwd`	Initial working directory

Example

The following statement sets the initial working directory of submodel `sub` to the current directory of its master model:

```
setworkdir(sub,'.')
```

Further information

1. This procedure defines the initial working directory to be used when the execution of the model (re)starts. As a consequence it cannot be used to change the environment of a running model.
2. For a local execution the provided path is expanded just before the beginning of the execution relatively to the current working directory of the caller. For a remote execution the path is relative to the directory of the instance running the model.

Related topics

`run`.

Module

mmjobs

run

Purpose

Run a model.

Synopsis

```
procedure run(mo:Model)
procedure run(mo:Model, plist:string|text)
```

Arguments

`mo`	Model to be executed
`plist`	String composed of model parameter initializations separated by commas

Further information

1. This procedure starts the execution of a model in a new thread: when the procedure returns, the model is not necessarily started (this may be delayed depending on the operating system load) and not necessarily terminated (the second model is executing concurrently to the caller).
2. By default the execution starts in the working directory of the Mosel instance (that might be different from the working directory of the calling model). A different initial path can be setup using `setworkdir`.
3. When the execution of the model is completed (normal termination, interruption after calling `stop`, or runtime error) or could not be started, an event of class `EVENT_END` is sent to the caller. The execution status is returned via the event value but it may also be obtained using `getstatus`. The exit code related to the last execution may be retrieved using `getexitcode`.
4. An event `EVENT_END` is also received after a model has detached itself although its execution may continue (see `detach`). In this case the model status is `RT_DETACHED` and its associated instance is disconnected.
5. The specified model must have been previously initialized with `load` and must not be running. If the same model has to be executed several times concurrently, it must be loaded several times in different model objects.
6. The parameter string `plist` may be built and modified using `setmodpar` and `resetmodpar`. These routines handle transparently the protection of parameter values by adding the appropriate quotes when required.

Related topics

`load`, `wait`, `waitforend`, `setmodpar`, `stop`, `getstatus`, `getexitcode`, `reset`.

Module

mmjobs

getdsoprop, getdsopropnum

Purpose

Get module information.

Synopsis

```
function getdsoprop(dso:string, prop:integer):string
function getdsopropnum(dso:string, prop:integer):real
```

Arguments

`dso` The name of a module currently loaded into memory

`prop` The property to retrieve. Possible values:

`PROP_NAME`	Module name
`PROP_VERSION`	Module version
`PROP_PATH`	Path to the module file

Return value

The property as a string (real for `getdsopropnum`) or an empty string (`-1` for `getdsopropnum`) in case of error (invalid property or the module was not found)

Related topics

`getmodprop`

Module

mmjobs

getgid

Purpose

Get the group ID of a model.

Synopsis

```
function getgid(mo:Model):integer
```

Argument

`mo` A model

Return value

Group ID of the model

Further information

A model can be associated with a *group ID* using `setgid`. This group ID may be used to identify the origin of an event (see `getfromgid`) or as a filter for a wait (see `waitfor`).

Related topics

`getuid`, `getid`, `setgid`

Module

mmjobs

getid

Purpose

Get the ID of a model or Mosel instance.

Synopsis

```
function getid(mo:Model):integer
function getid(mi:Mosel):integer
```

Arguments

`mo` A model

`mi` A Mosel instance

Return value

ID of the model or instance as an integer

Further information

1. Each model object has a unique ID number that can be obtained with this function. This ID may be used to identify the origin of an event (see `getfromid`) or as a filter for a wait (see `waitfor`).
2. The ID number of a Mosel instance is its node number. The initial instance has node number 0.

Related topics

`getuid`, `getgid`, `jobid`

Module

mmjobs

getmodprop, getmodpropnum

Purpose

Get model information.

Synopsis

```
function getmodprop(mo:Model, prop:integer):string
function getmodprop(prop: integer):string
function getmodpropnum(mo:Model, prop:integer):real
function getmodpropnum(prop: integer):real
```

Arguments

`mo` A model

`prop` The property to retrieve. Possible values:

`PROP_NAME`	Model name (*cf.* `model` statement)
`PROP_ID`	Order number
`PROP_VERSION`	Model version
`PROP_SYSCOM`	System comment
`PROP_USRCOM`	User comment
`PROP_SIZE`	Amount of memory (in bytes) used by the model
`PROP_DATE`	Compilation date
`PROP_UNAME`	Unique model name

Return value

The property as a string (real for `getmodpropnum`) or an empty string (`-1` for `getmodpropnum`) in case of error

Further information

The second form of the function reports information for the calling model.

Related topics

`getdsoprop`, `memoryuse`

Module

mmjobs

getnode

Purpose

Get the ID (node number) of the Mosel instance of a model.

Synopsis

```
function getnode(mo:Model):integer
function getnode(mi:Mosel):integer
```

Arguments

`mo` A model

`mi` A Mosel instance

Return value

ID of the instance on which the model is loaded as an integer or `-1` if the model has not been loaded

Further information

1. This function returns the node number of the current instance if the provided model is local.
2. When applied to a Mosel instance this function returns the same information as `getid`.

Module

mmjobs

getrmtid

Purpose

Get the ID of a model on a remote instance.

Synopsis

```
function getrmtid(mo:Model):integer
```

Argument

`mo` A model

Return value

ID of the model on the remote instance as an integer or -1 if the model has not been loaded or is local to the running instance.

Further information

This ID corresponds to the model number assigned to the model by Mosel when it is loaded (*i.e.* the value of the control parameter `modelnumber`). This function can only be used on models handled by remote instances.

Module

mmjobs

getstatus

Purpose

Get the status of a model or of an instance.

Synopsis

```
function getstatus(mo:Model):integer
function getstatus(mi:Mosel):integer
```

Arguments

`mo`	A model
`mi`	A Mosel instance

Return value

The status of a Mosel instance is `0` if it is connected, any other value indicates that it is not ready. The model status can be:

`RT_NOTINIT`	Model has not been initialized or has been unloaded
`RT_RUNNING`	Model is running
`RT_OK`	Model is ready for execution and/or no error occurred during last execution
`RT_MATHERR`	A mathematical error occurred
`RT_ERROR`	A runtime error occurred
`RT_IOERR`	An IO error occurred
`RT_NULL`	A NULL reference error occurred
`RT_LICERR`	Execution could not start because no license was available
`RT_FDCLOSED`	Execution on a separate instance has been interrupted
`RT_DETACHED`	Execution on a separate instance continues although the instance has been disconnected (see `detach`)
`RT_STOP`	Execution has been interrupted by a call to `stop`

Related topics

`connect`, `stop`, `getexitcode`.

Module

mmjobs

getuid

Purpose

Get the user ID of a model.

Synopsis

```
function getuid(mo:Model):integer
```

Argument

`mo` A model

Return value

User ID of the model

Further information

A model can be associated with a *user ID* using `setuid`. This user ID may be used to identify the origin of an event (see `getfromuid`) or as a filter for a wait (see `waitfor`).

Related topics

`getgid`, `getid`, `setuid`

Module

mmjobs

getexitcode

Purpose

Get the exit code of a model.

Synopsis

```
function getexitcode(mo:Model):integer
```

Argument

`mo` A model

Return value

Exit code of the last execution or 0

Further information

1. The exit code of the last execution corresponds to the value stated via a call to the procedure `exit`. The default exit value (*i.e.* procedure `exit` has not been called) is 0.
2. The value of the exit code is defined only when the execution of the model succeeded (*i.e.* its status is `RT_OK`). This function will return `0` before the model is executed or after a runtime error.

Related topics

`getstatus`.

Module

mmjobs

stop

Purpose

Stop a running model.

Synopsis

```
procedure stop(mo:Model)
```

Argument

`mo` Model to interrupt

Further information

If the model is not currently running, no operation is performed. Note that the effect of this call may not be immediate and the corresponding model may continue running a few seconds before its effective interruption (for instance the time required to complete an IO operation).

Related topics

`run`.

Module

mmjobs

reset

Purpose

Reset a model.

Synopsis

```
procedure reset(mo:Model)
```

Argument

`mo` Model to reset

Further information

This procedure resets a model after its execution: all resources it has allocated are released. The model returns to its state just after it has been loaded into memory. Note that this function is automatically called before a model is unloaded or run.

Related topics

`run`, `unload`.

Module

mmjobs

unload

Purpose

Unload a model.

Synopsis

```
procedure unload(mo:Model)
```

Argument

`mo` Model to unload

Further information

1. This procedure unloads the given model. All resources used by this model, including modules, are released. The function fails if the model is running.
2. An IO error will be raised in case of network failure while unloading a model from a remote instance.

Related topics

`load`.

Module

mmjobs

getannidents

Purpose

Get model identitifiers for which annotations are available.

Synopsis

```
procedure getannidents(mo:Model, si:set of string)
```

Arguments

`mo`	A model reference
`si`	Set receiving the identifiers

Further information

This routine cannot be used with remote models.

Related topics

`getannotations`, applied to the model itself: `getannidents`.

Module

mmjobs

getannotations

Purpose

Get model annotations associated to a given symbol.

Synopsis

```
procedure getannotations(mo:Model, id:string, prefix:string, si:set of
      string, ann:array(string) of string)
procedure getannotations(mo:Model, id:string, prefix:string, lsa:list of
      string)
```

Arguments

`mo`	A model reference
`id`	Symbol for which annotations are requested (an empty string will report global declarations)
`prefix`	Prefix filter: only annotations with a name starting by the specified prefix will be returned
`si`	Set receiving the annotation names
`ann`	Array receiving the annotation values (indiced by names)
`lsa`	List receiving the annotation names and values

Example

The following code snippet implements a function to retrieve a specific annotation for the specified model entity (if several matching annotations are found the value of the first is returned):

```
public function getannot(mo:Model, symb:string, aname:string):string
  declarations
    l:list of string
  end-declarations
  getannotations(mo,symb,aname,l)
  if l.size>=2 and l(1)=aname then
    returned:=l(2)
  end-if
end-function

writeln("Value of first annotation 'my.annot' for entity 'x': ",
        getannot(mo,"x","my.annot"))
writeln("Value of first global annotation 'my.annot': ",
        getannot(mo,"","my.annot"))
```

Further information

1. With the version taking a list, each annotation is represented by 2 entries: the first one is the annotation name and the second one its value. Note that the version returning information via an array will only report partial information in the case of annotations defined several times.
2. These routines cannot be used with remote models.

Related topics

`getannidents`, applied to the model itself: `getannotations`.

Module

mmjobs

8.4.3 Synchronization

Synchronization between running models can be implemented using *events*. Events are characterized by a *class* and a *value* and may be exchanged between a model and its *parent* model. The model from which an event has been sent is identified by its unique ID, its user ID and its group ID. An event queue is attached to each model to collect all events sent to this model and is managed with a FIFO policy (First In – First Out). Depending on the needs, a model may check whether its queue is empty or simply suspend its execution until it has been sent an event.

The type *Event* represents an event in the Mosel language. Objects of type Event may be compared with = or <> and assigned with :=. The function `nullevent` returns an event without class and value: this is the initial value of a newly created event and no model can send an event of this kind (*i.e.* the class is necessarily not null).

`canceltimer`	Cancel an active timer.	p. 288
`dropnextevent`	Drop the next event in the event queue of the model.	p. 299
`getclass`	Get the class of an event.	p. 305
`getfromgid`	Get the group ID of the sender of an event.	p. 303
`getfromid`	Get the ID of the sender of an event.	p. 302
`getfromuid`	Get the user ID of the sender of an event.	p. 304
`getnextevent`	Get the next event in the event queue of the model.	p. 298
`gettimer`	Get the amount of time remaining before a timer expires.	p. 306
`getvalue`	Get the value associated with an event.	p. 307
`isqueueempty`	Check whether there are events waiting in the event queue.	p. 300
`nullevent`	Return a 'null' event.	p. 301
`peeknextevent`	Peek the next event in the event queue of the model.	p. 308
`pipeflush`	Clears the internal buffer of a memory pipe.	p. 309
`pipenotify`	Register for a notification associated to a memory pipe.	p. 310
`send`	Send an event to a running model.	p. 289
`setgid`	Set the group ID of a model.	p. 292
`settimer`	Create or update a timer.	p. 290
`setuid`	Set the user ID of a model.	p. 291
`wait`	Wait for an event.	p. 293
`waitexpired`	Indicate whether the previous 'wait' or 'waitfor' expired.	p. 294
`waitfor`	Wait for specific events.	p. 295
`waitforend`	Wait for the end of execution of a model.	p. 297

canceltimer

Purpose

Cancel an active timer.

Synopsis

```
procedure canceltimer(tid:integer)
```

Argument

`tid` A timer identifier

Further information

1. This procedure has no effect if it cannot find the requested timer. However it will delete from the event queue the event `EVENT_TIMER` coresponding to a timer that is no longer active.
2. If the provided timer identifier `tid` is negative or null all timers are cancelled.

Related topics

`settimer`, `gettimer`.

Module

mmjobs

send

Purpose

Send an event to a running model.

Synopsis

```
procedure send(mo:Model, class:integer, value:real)
procedure send(class:integer, value:real)
```

Arguments

`mo`	Model to send the event to
`class`	Event class (must be >1)
`value`	Event value

Further information

1. Events can be sent to models started by the caller (the *child models*) by using the first form of the procedure and to the model having started the caller (the *parent model*) with the second form of the procedure. An event can be received only by a running model using the *mmjobs* module: sending an event to a model that is not running or not using *mmjobs* is a no-operation.
2. Events are characterized by a `class` and a `value`. Event class values can be used to indicate the cause of the event (for instance, 2 could mean 'a new solution has been found') and the associated value may specify a property of the given instance (for example an objective value). Except for the special value 1 (`EVENT_END`) class values have no predefined meaning.
3. An event of class `EVENT_END` (=1) and model status as the event value is automatically sent by each model to its parent model when it terminates its execution.

Related topics

`wait`, `waitfor`.

Module

mmjobs

settimer

Purpose

Create or update a timer.

Synopsis

```
function settimer(tid:integer, dur:integer, rep:boolean):integer
function settimer(dur:integer, rep:boolean):integer
```

Arguments

`tid`	A timer identifier
`dur`	A duration in milliseconds
`rep`	Decides whether the timer will be armed one time only or automatically repeated

Return value

Timer identifier as a positive integer

Further information

1. This function creates or updates an *interval timer*: after a timer has been armed by a call to this routine an event of class `EVENT_TIMER` is scheduled for being sent to the model after the specified amount of time has elapsed. The value of such an event is the timer identifier `tid`. Note that the system will not emit a new event if an identical event is already in the queue.
2. If the option `rep` is set to `false` the timer is released after its termination, otherwise it is immediately re-armed with the same interval after each expiration until it is explicitly cancelled (see `canceltimer`).
3. If the provided identifier `tid` is not positive a new timer is created with a newly generated identifier, this corresponds to the behaviour of the second form of this function.
4. When the provided identifier corresponds to an existing timer, this one is first cancelled with a call to `canceltimer` before being re-created with the new properties.

Related topics

`canceltimer`, `gettimer`.

Module

mmjobs

setuid

Purpose

Set the user ID of a model.

Synopsis

```
procedure setuid(mo:Model,uid:integer)
```

Arguments

`mo`	A model
`uid`	New user ID

Further information

This function defines the *user ID* associated to a model (by default it is 0). This user ID may be used to identify the origin of an event (see `getfromuid`).

Related topics

`setgid`, `getuid`

Module

mmjobs

setgid

Purpose

Set the group ID of a model.

Synopsis

```
procedure setgid(mo:Model,gid:integer)
```

Arguments

`mo`	A model
`gid`	New group ID

Further information

This function defines the *group ID* associated to a model (by default it is 0). This group ID may be used to identify the origin of an event (see `getfromgid`).

Related topics

`setuid`, `getgid`

Module

mmjobs

wait

Purpose

Wait for an event.

Synopsis

```
procedure wait
procedure wait(dur:integer)
```

Argument

`dur` A duration in seconds or the constant `WAIT_INFINITE`

Further information

This procedure suspends the execution of the caller until an event is available. The second form specifies a time limit: the processing is suspended for at most `dur` seconds, the special value `WAIT_INFINITE` is interpreted as an infinite duration. The behaviour of the procedure is undefined if the specified duration is smaller than 1 second.

Related topics

`send`, `waitfor`, `waitforend`, `waitexpired`, `isqueueempty`, `getnextevent`, `dropnextevent`.

Module

mmjobs

waitexpired

Purpose

Indicate whether the previous 'wait' or 'waitfor' expired.

Synopsis

```
function waitexpired:boolean
```

Return value

`true` if the last call to `wait` or `waitfor` terminated after expiration of a time limit

Related topics

`wait`, `waitfor`.

Module

mmjobs

waitfor

Purpose

Wait for specific events.

Synopsis

```
procedure waitfor(mask:integer)
procedure waitfor(mask:integer,dur:integer)
procedure waitfor(mask:integer,dur:integer,opt:integer)
procedure waitfor(mask:integer,id:integer,dur:integer,opt:integer)
```

Arguments

`mask`	Bit mask of expected events
`id`	ID of model for which events are expected
`dur`	A duration in seconds, the constant `WAIT_INFINITE` or a timer identifier as a negative integer
`opt`	Options: `WAIT_EXACT` Mask must be exactly matched `WAIT_KEEP` Keep unexpected events `WAIT_UID` Wait for a particular user ID `WAIT_GID` Wait for a particular group ID

Example

The following statement waits for an event of class 3 coming from a model of group 100 without dropping any event:

```
waitfor(3,100,WAIT_INFINITE,WAIT_KEEP+WAIT_EXACT+WAIT_GID)
```

Further information

1. This procedure suspends the execution of the caller until an event of a particular class is available. The second form specifies a time limit: the processing is suspended for at most `dur` seconds, the special value `WAIT_INFINITE` is interpreted as an infinite duration.

2. If the time limit is `0` the execution is not suspended but the queue of events is processed once and a subsequent call to `waitexpired` will return `true` if no valid event was found.

3. The parameter `dur` may also take a negative value: in this case it is interpreted as the opposite of a timer identifier (see `settimer`) and the function will wait until this timer expires if no valid event arrives. When the routine interrupts its monitoring due to the expiration of a timer the first event in the queue is the event `EVENT_TIMER` associated to this timer. Note that if no timer corresponds to the given value the routine will terminate only when an expected event is available as if `WAIT_INFINITE` had been used.

4. By default, the parameter `mask` is interpreted as a bit mask to select the expected events: all events sent to the model are automatically dropped until an event `ev` satisfies the following condition:

   ```
   bittest(getclass(ev),mask)<>0
   ```

5. If the parameter `opt` includes option `WAIT_EXACT`, the parameter `mask` becomes the target event class: the wait will end when an event of a class equal to `mask` is found.

6. If the parameter `opt` includes option `WAIT_KEEP`, unexpected events are not dropped but the first event satisfying the condition is moved to the top of the queue such that it is returned by the next call to `getnextevent`.

7. With the last form of the function an *ID* is specified: it characterises events coming from a particular model or a group of models. By default the argument `id` is interpreted as the unique model ID (see `getid`), if option `WAIT_UID` is used, the ID is interpreted as a user ID (see `getuid`) and with option `WAIT_GID` the argument is a group ID (see `getgid`).

Related topics

`send`, `wait`, `waitexpired`, `isqueueempty`, `getnextevent`, `dropnextevent`.

Module

mmjobs

waitforend

Purpose

Wait for the end of execution of a model.

Synopsis

```
procedure waitforend(mo:Model)
procedure waitforend(mo:Model,dur:integer)
```

Arguments

`mo`	A model
`dur`	A duration in seconds, the constant `WAIT_INFINITE` or a timer identifier as a negative integer

Further information

1. This procedure suspends the execution of the caller until a given model has terminated its execution. The second form specifies a time limit: the processing is suspended for at most `dur` seconds, the special value `WAIT_INFINITE` is interpreted as an infinite duration.
2. Before the procedure returns all events received from the model to monitor are removed from the event queue (including the `EVENT_END` event) unless the time limit has been reached. In this case some of the events of the submodel may have been removed from the event queue.
3. If the time limit is `0` the execution is not suspended but the queue of events is processed once and a subsequent call to `waitexpired` will return `true` if the model was still running when the procedure was called (the event queue is not modified in this case).
4. The parameter `dur` may also take a negative value: in this case it is interpreted as the opposite of a timer identifier (see `settimer`) and the function will wait until this timer expires if no valid event arrives. When the routine interrupts its monitoring due to the expiration of a timer the first event in the queue is the event `EVENT_TIMER` associated to this timer. Note that if no timer corresponds to the given value the routine will terminate only when an expected event is available as if `WAIT_INFINITE` had been used.

Related topics

`wait`, `waitexpired`.

Module

mmjobs

getnextevent

Purpose

Get the next event in the event queue of the model.

Synopsis

```
function getnextevent:Event
```

Return value

The next event or `nullevent` if the queue is empty

Further information

The returned event is removed from the queue after it has been retrieved with this function.

Related topics

`peeknextevent`, `dropnextevent`, `isqueueempty`.

Module

mmjobs

dropnextevent

Purpose

Drop the next event in the event queue of the model.

Synopsis

```
procedure dropnextevent
```

Further information

This procedure has no effect if the event queue is empty.

Related topics

`peeknextevent`, `getnextevent`, `isqueueempty`.

Module

mmjobs

isqueueempty

Purpose

Check whether there are events waiting in the event queue.

Synopsis

```
function isqueueempty:boolean
```

Return value

`false` if at least one event is available in the queue, `true` otherwise.

Related topics

`dropnextevent`, `peeknextevent`, `getnextevent`.

Module

mmjobs

nullevent

Purpose

Return a ‘null’ event.

Synopsis

```
function nullevent:Event
```

Return value

An event of class and value equal to 0

Further information

Variables of type `Event` are initialized with this function.

Related topics

`getnextevent`.

Module

mmjobs

getfromid

Purpose

Get the ID of the sender of an event.

Synopsis

```
function getfromid(ev:Event):integer
```

Argument

`ev` An event

Return value

The ID of the sender of the event. 0 is returned for a `nullevent`

Further information

1. Each model has a unique ID that is attached to each event it sends. With this function one can identify the sender of a given event.
2. The ID of an event sent from the parent model is always 0.

Related topics

`getid`, `getfromgid`, `getfromuid`, `getvalue`, `getclass`.

Module

mmjobs

getfromgid

Purpose

Get the group ID of the sender of an event.

Synopsis

```
function getfromgid(ev:Event):integer
```

Argument

`ev` An event

Return value

The group ID of the sender of the event. 0 is returned for a `nullevent`

Further information

1. Each model can be associated with a group ID that is attached to each event it sends. With this function one can identify the sender of a given event.
2. The group ID of an event sent from the parent model is always 0.

Related topics

`getgid`, `setgid`, `getvalue`, `getfromid`, `getfromuid`, `getclass`.

Module

mmjobs

getfromuid

Purpose

Get the user ID of the sender of an event.

Synopsis

```
function getfromuid(ev:Event):integer
```

Argument

`ev` An event

Return value

The user ID of the sender of the event. 0 is returned for a `nullevent`

Further information

1. Each model can be associated with a user ID that is attached to each event it sends. With this function one can identify the sender of a given event.
2. The user ID of an event sent from the parent model is always 0.

Related topics

`getuid`, `setuid`, `getvalue`, `getfromid`, `getfromgid`, `getclass`.

Module

mmjobs

getclass

Purpose

Get the class of an event.

Synopsis

```
function getclass(ev:Event):integer
```

Argument

`ev` An event

Return value

The class of the event (>0) or 0 for a `nullevent`

Further information

A model sends automatically an event of class `EVENT_END`(=1) when it terminates its processing. Other values are application specific.

Related topics

`getvalue`, `getfromid`, `getfromgid`, `getfromuid`.

Module

mmjobs

gettimer

Purpose

Get the amount of time remaining before a timer expires.

Synopsis

```
function gettimer(tid:integer):integer
```

Argument

`tid` A timer identifier

Return value

Remaining time in milliseconds before the timer expires or `0` if the corresponding event is already available in the queue or `-1` if no timer corresponds to the provided identifier

Further information

This function will return `0` if an event corresponding to the specified timer is waiting in the queue of event even if this timer has been automatically re-armed.

Related topics

`canceltimer`, `settimer`.

Module

mmjobs

getvalue

Purpose

Get the value associated with an event.

Synopsis

```
function getvalue(ev:Event):real
```

Argument

`ev` An event

Return value

The value of the event

Further information

In the case of an event of class `EVENT_END`(=1), this value corresponds to the model status.

Related topics

`getclass`, `getfromid`, `getfromgid`, `getfromuid`.

Module

mmjobs

peeknextevent

Purpose

Peek the next event in the event queue of the model.

Synopsis

```
function peeknextevent:Event
```

Return value

A copy of the next event or `nullevent` if the queue is empty

Further information

The returned event is a copy of the first available event of the queue. The event queue is not changed by this function.

Related topics

`getnextevent`, `dropnextevent`, `isqueueempty`.

Module

mmjobs

pipeflush

Purpose

Clears the internal buffer of a memory pipe.

Synopsis

```
function pipeflush(pname:string):boolean
```

Argument

`pname` Name of the pipe to clear

Return value

`true` if the operation was successful

Further information

This function can be called only if the caller is the model that has opened the pipe for reading or if no model is reading from this pipe.

Module

mmjobs

pipenotify

Purpose

Register for a notification associated to a memory pipe.

Synopsis

```
function pipenotify(pname:string,class:integer,value:real):boolean
```

Arguments

`pname`	Name of the pipe to monitor
`class`	Event class (0 or must be >1)
`value`	Event value

Return value

`true` if the operation was successful

Further information

1. This function sets up a monitor on a memory pipe (See section 8.5.2) such that an event (with the specified class and value) is sent to the model when some data is available for reading from the pipe. The event is sent immediately and no monitor is installed if the pipe is already non-empty.
2. The mechanism is effective for one notification only: after the event has been sent the monitor is removed, the function must be called again if the program requires further notifications.
3. It is not possible to install several monitors on a given pipe (the function returns `false` if a monitor is already active), however a model can remove a monitor that it has previously requested through this function by calling it again with a class set to 0.

Module

mmjobs

8.5 I/O drivers

The *mmjobs* module provides a modified version of the `mem` IO driver designed to be used in a multithreaded environment: memory blocks allocated by the `shmem` IO driver are *persistent* (*i.e.* they are not released after the model terminates) and can be used by several models. Thanks to this facility, models running concurrently may exchange data through memory by means of initialization blocks for instance.

The driver `mempipe` offers another communication mechanism between models: a *memory pipe* may be open by two models simultaneously. One of them for writing and the other one for reading. This driver also supports *initialization blocks*.

The drivers `rcmd`, `xsrv` and `xssh` allow to start additional Mosel instances: they have to be used to build host specifications as expected by the `connect` function. Finally, thanks to the `rmt` driver a Mosel instance can access files available from the environment of another instance.

8.5.1 Driver *shmem*

```
shmem:label[/minsize[/incstep]]
```

The file name for this driver is a *label*: this is the identifier (the first character must be a letter) of the memory block. A label is not local to a particular model and remains valid after the end of the execution of the model having created it. All memory blocks are released when the module *mmjobs* is unloaded but a given memory block may also be deleted explicitly by calling the `fdelete` procedure of module `mmsystem` or by using the `fremove` C-function of the Native Interface. Note also that deleting the special file `"shmem:*"` has the effect of releasing all memory blocks handled by the driver.

Several models may open a given label at the same time and several read operations may be performed concurrently. However, writing to a memory block can be done by only one model at a time: if several models try to read and write from/to the same label, only one (it becomes the *owner* of the memory block) performs its IO operations for writing and the others are suspended until the owner closes its file descriptor to the specified label. Then, one of the waiting models is restarted and becomes the new owner: this process continues until all file descriptors to the label are closed.

The memory block is allocated dynamically and resized as necessary. By default the size of the memory block is increased by pages of 4 kilobytes: the optional parameter `incstep` may be used to change this page size (*i.e.* the default setting is `"label/0/4k"`). The special value 0 modifies the allocation policy: instead of being increased of a fixed amount, the block size is doubled. In all cases unused memory is released when the file is closed.

8.5.2 Driver *mempipe*

```
mempipe:name[/minsize]
```

A *memory pipe* is characterized by its *name*. Only one model may open a pipe for reading but several models may open the same pipe for writing. However, if several models try to write to the same pipe, only one (it becomes the *owner* of the memory pipe) performs its IO operations and the others are suspended until the owner closes its file descriptor to the specified pipe. Then, one of the waiting models is restarted and becomes the new owner: this process continues until all file descriptors to the pipe are closed.

Each pipe is associated with a buffer: a model can write to a pipe without blocking until this buffer is full. The default size of such a buffer is of 2 kilobytes but a different size may be specified by appending the required size to the pipe name (*e.g.* `"mempipe:mypipe/256"` sets the size of the pipe to 256 bytes). This setting will be ignored if the buffer has already been allocated and is larger than the requested size, the buffer will be reallocated anyway if it is not large enough to store a write operation.

There is no notion of 'end of file' in a pipe: if a model tries to read from an empty pipe (*i.e.* no model is

writing to the other end and the pipe buffer is empty) no error is raised and the model is suspended until something is available. Similarly trying to write to a pipe for which no model is reading from the other end might be a blocking operation if its buffer is full. In order to avoid lock ups, it is usually good practice to synchronize the models relying on events, for instance using the `pipenotify` function. Also, getting the size of a memory pipe with `getfsize` will return the amount of data currently available in the pipe internal buffer and deleting a pipe with `fdelete` will release the data structure allocated for the pipe. The content of a pipe may also be cleared thanks to function `pipeflush`.

8.5.3 Driver *rcmd*

```
rcmd:[command]
```

This driver starts the specified command in a new process and connects its standard input and output streams to the calling Mosel instance. The created process is executed in the same current working directory as the controlling model and inherits the environment variables defined using `setenv`. The default command is `"mosel -r"`. A typical use for this driver is to start an instance on the current machine or on a remote computer through an external program. For instance:

```
rcmd:rsh sunbox mosel -r
```

When Mosel is running in restricted mode (see Section 1.3.4), the restriction `NoExec` disables this driver.

8.5.4 Driver *xsrv*

```
xsrv:hostname[(port)][/ctx[/pass]][|var=val...]
```

This driver connects to the host `hostname` running the Mosel Remote Launcher (see Section 8.6) through a TCP socket on port `port` (default value: 2513) asking for the context `ctx` (default: `xpress`) using the password `pass` (default: no password). Additional environment variables can be specified: assignments of the form `var=val` must be separated by the symbol `|` and variable values may include variable references noted `${varname}` (expansion is performed on the remote host in the context of its environment). The special environment variable `MOSEL_CWD` defines the current working directory for the newly created instance.

```
xsrv:winbox(3211)/xpr64|MOSEL_CWD=C:\workdir|MYDATA=${MOSEL_CWD}\data
```

8.5.5 Driver *xssh*

```
xssh:hostname[(port,kwf)][/ctx[/pass]][|var=val...]
```

This driver is the secure version of the `xsrv` driver decribed above: it establishes the connection to the xprmsrv server through an encrypted SSH tunnel (using 2515 as the default TCP port number). In addition to the port number, the driver can also take a file name (`kwf`) used as the *known host file* for server authentication: this file contains the list of known hosts with their corresponding public keys. When the connection is established to the remote host, the public key stored in this file is compared with the key provided by the server. The connection is canceled if keys do not match. Generating this known hosts file requires running the command `xprmsrv -key public` on the remote server in order to retrieve its public key (see Section 8.6.1).

For instance, the following command will include the server `mysun` in the `knownhosts.txt` file (the command must be run on the server):

```
xprmsrv -key public -hn mysun >>knownhosts.txt
```

Then after having moved the file to the machine(s) from where connections are initiated, the following connection string may be used to open secure connections with server authentication:

```
xssh:mysun(knownhosts.txt)
```

The remote connection is handled by a separate process. By default the program `xprmsrv` is used as the helper program but it can be replaced by another SSH client by changing the control parameter `sshcmd`.

8.5.6 Driver *rmt*

```
rmt:[node,bs]filename
```

This driver can be used with any routine expecting a physical file for accessing files on remote instances. By default, the file is located on the instance running on the node identified by the parameter `defaultnode` but a particular instance may be specified by prefixing the file name by its node number enclosed in square brackets. The special node number `-1` designates the parent node of the current instance.

```
load(mi,mo,"rmt:[-1]model.bim")
```

By default the driver creates a buffer of 8 kilobytes for its communication operations. The size of this buffer might be changed by specifying the desired buffer size (in kilobytes) after the node number (for instance `"rmt:[0,4]filename"` to use a 4096 bytes buffer). If only the buffer size has to be stated the node number can be omitted (*e.g.* `"rmt:[,4]filename"`). Note that a buffer size must be between 2 and 63.

In addition to physical files, this driver also emulates the behaviour of drivers `cb`, `sysfd`, `tmp`, `shmem`, `mempipe` (for writing only) and `java` such that it can transfer streams from one instance to another. For instance, `"rmt:sysfd:2"` is the standard error stream of the process running the default node.

8.6 The Mosel Remote Launcher `xprmsrv`

The `xprmsrv` program is the server part of the `"xsrv:"` and `"xssh:"` IO drivers: it must be running on each computer on which instances will be started using these drivers. The communication between two Mosel instances is achieved through a single TCP stream. Mosel instances are started in the context of *execution environments*: such an environment consists in a set of environment variables as well as the name of the program to start with its initial working directory. The server can manage different execution environments which are identified by a name and optionally protected by a password. Thanks to this feature a single server can offer several versions of Xpress or dedicated settings for particular distributed applications.

This program is also used as an SSH client by `mmjob` and `XPRD` when connecting to an xprmsrv server through a secure tunnel. Therefore it must be available when using the `"xssh:"` IO driver even if no server is to be run on the host machine.

8.6.1 Running the *xprmsrv* command

8.6.1.1 Main command line options

The first argument of the command that is not identified as an option is used as the name for a configuration file. The following options are accepted:

`-h` Display a short help message and terminate.

`-V` Display the version number and terminate.

`-tc` Display the current configuration and terminate.

`-tm #` The server will terminate after # seconds of inactivity.

`-f` Force automatic setting of environment variable `XPRESSDIR` even if it is already defined.

`-v [#]` Set the verbosity level of the communication protocol. The default value is 1 (report only errors) when the server is running in background (service/daemon) and 2 (report activity) when the server is run from a console.

`-l fname` Set a logfile to record all messages.

`-li addr` Set the address of the interface to use (default: 0.0.0.0 for all interfaces).

`-p port` Set the TCP port to listen to (default port is 2513, -1 to disable).

`-bp port` Set the UDP port for broadcast (default port is 2514, -1 to disable).

`-pf pfname` Define a file name for recording the process number of the server. This file is removed when the server exits.

`-d` Start the server in background (or as a daemon on Posix systems).

The following options are used by the Windows version of the server:

`-service install` Install the server as a service. All other provided options (including configuration file) are recorded and will be used by the server. If the corresponding service has already been installed, its execution settings are updated with the provided options.

`-service remove` Remove the previously installed service.

`-service start` Start the previously installed service.

`-service reload` Reload configuration.

`-service stop` Stop the previously started service.

`-service status` Check whether the service is already running.

`-u user` This option is used only when installing the service: it selects the user running the service.

`-pwd pwd` This option specifies the password required for the user indicated by the `-u` option.

The following options are used by all other platforms:

`-u user` User that should be running the server.

`-g group` Group that should be running the server.

When the server is run as a service (under Windows) or as a daemon (on Posix systems) that are usually started by a privileged user, it is recommended to use the appropriate option to run the process as an unprivileged user for security reasons. For instance, under Windows, installing the service can be done using the following command in order to use the *network service account*:

```
xprmsrv -service install -u "NT AUTHORITY\NetworkService" conffile
```

Similarly on a Posix system, the server can be run as the *nobody* user:

```
xprmsrv -d -u nobody conffile
```

8.6.1.2 Secure server

xprmsrv can also accept secure connections through SSH tunnels: this is the protocol used by the `xssh` IO driver. The following options are used to setup the secure server:

`-sp port` Set the TCP port for SSH connections (default port is 2515, -1 to disable).

`-k fname` Private key file name.

`-sc cilst` Set the list of accepted ciphers in order of preference (default: `"aes256-ctr aes192-ctr aes128-ctr aes256-cbc aes192-cbc aes128-cbc blowfish-cbc 3des-cbc"`).

The secure server requires a private key to authenticate itself (see following section). By default it will use the file `"xprmsrv_rsa.pem"` located in the same directory as the xprmsrv executable. It is important to store this file in a secure location as it identifies the server, in particular it must not be readable by Mosel models started by the server. If this file is missing or the provided file name cannot be accessed the secure server will be disabled.

8.6.1.3 Private key management

A new private key can be generated with the following command:

```
xprmsrv -key new
```

Additionally, option `-k filename` can be specified to change the default key file location. Note that this procedure does not remove an existing key file.

The following command loads and check the validity of a key file:

```
xprmsrv -key check
```

When executed on a valid key file this command displays the fingerprint of the public part of the key as well as its properties.

The SSH protocol makes possible authentication of a server by a client. This optional feature, supported by the IO driver `xssh`, requires a *known host file* on the client side: this text file consists in a list of host server names with their associated public key. The command `xprmsrv -key public` generates the required data for such a file using the hostname reported by the operating system to identify the server. Often this hostname does not correspond to the public name of the machine. In such a case, it is possible to replace the label in the file or use the option `-hn name` to select a different name. For instance, the following command will append to the file `knownhosts.txt` the public data key for the server using keyfile `mykey.pem` with host name `srvname`:

```
xprmsrv -key public -k mykey.pem -hn srvname >>knownhosts.txt
```

8.6.1.4 Mode of operation

The server proceeds as follows:

1. If the environment variable `XPRESSDIR` is not defined or if the `-f` option is in use, the value of this environment variable is deduced from the location of the program itself. Under Posix operating systems, the environment variable `XPAUTH_PATH` is also set up.
2. The environment variables `MOSEL_DSO` and `MOSEL_BIM` (see Section 2.3.1), `MOSEL_TMP` (see Section 2.17), `MOSEL_EXECPATH` (see `system`), `MOSEL_RWPATH`, `MOSEL_ROPATH` (see Section

1.3.4) and XPRMSRV_ACCESS (see Section 8.6.2.1) are cleared and the environment variable MOSEL_RESTR is initialised with value "NoReadNoWriteNoExecNoDBWDOnly" (see Section 1.3.4).

3. The default execution environment xpress is created: it refers to the Xpress installation detected at the first step.
4. If available, the configuration file is read (see Section 8.6.2): it can be used to define global settings (*e.g.*, defining the logfile) or/and create and modify execution environments by defining environment variables.
5. The process then starts its main loop listening to the specified TCP and UDP ports.
6. When a connection is requested, a new session is started to process commands from the client. These commands are used to authenticate the client, select an environment and finally start the Mosel program in a separate process. This process inherits all the environment variables defined in the context and starts in the specified working directory (by default: the location pointed by XPRESSDIR). In addition, on Posix systems, the path ${XPRESSDIR}/lib is added to the dynamic library path of the operating system. Once the process is started, xprmsrv detaches itself from the client — the communication is established directly between the two Mosel instances.

8.6.2 Configuration file

The configuration file consists in a list of variable definitions of one of the following forms:

```
varname=value

varname?=value
```

Each statement is recorded in the *current environment*. The value may contain variable references noted ${varname}, the expansion is executed when the environment is processed except for self references that are expanded at the time of defining the variable (*e.g.*PATH=${PATH}:otherpath). When the first syntax is used, the variable cannot be changed by a remote host; the second syntax (using ?=) allows a remote host to modify the corresponding variable before starting the Mosel instance.

Switching to a different environment is done by giving the name of the environment enclosed in square brackets:

```
[newenv]
```

If the environment name has not yet been used, a new environment is created unless the line ends with the symbol '+' (*e.g.* [myenv]+). In this case the following definitions are included only if the environment already exists. If the line ends with the symbol '=' (*e.g.* [myenv]=) the previous definitions for this context are cleared. These markers can be combined (*e.g.* [myenv]+=) such that the definition block replaces the corresponding context only if it exists.

Upon startup, two environments are automatically created: "global" to store general configuration and settings shared by all environments and "xpress" (it can also be referred to as * or default) the default execution environment. When the reading of the configuration file begins, the *global* environment is selected: in this environment all variable definitions are processed immediatly and added to the xprmsrv process environment. In this context, some variables have a special meaning and are not handled as ordinary environment variables (all paths must be absolute):

LOGFILE — the file to be used for recording all messages. Messages are sent to the standard error stream when this parameter is not set.

LISTEN — address of the interface to use (default value: 0.0.0.0 for all interfaces).

`TCP_PORT` the port number to use for TCP connections (default value: 2513, -1 to disable).

`UDP_PORT` the port number to use for UDP connections (default value: 2514, -1 to disable). The server listen to this port for broadcast messages (see procedure `findxsrvs`).

`SSH_PORT` the port number to use for SSH connections (default value: 2515, -1 to disable).

`KEYFILE` private key file name used by the SSH protocol (default value: xprmsrv_rsa.pem located in the same directory as the xprmsrv executable).

`SSH_CIPHERS` the list of accepted ciphers in order of preference (default: `"aes256-ctr aes192-ctr aes128-ctr aes256-cbc aes192-cbc aes128-cbc blowfish-cbc 3des-cbc"`).

`VERBOSITY` verbosity level for the communication protocol (default value: 1 if the server is running in background and 2 if it is run from a console).

`GROUPMASK` Bit mask to select what broadcast requests to accept (default value: ANY). The server replies to a request of group `grp` only if bit test `grp&GROUPMASK` is not 0 (see procedure `findxsrvs`). The mask value can be given as an integer (*e.g.* `3` to allow groups `1` and `2`), an hexadecimal number (*e.g.* `0xFF` for groups `1` to `128`) or the special keyword `ANY` (all groups allowed).

`MAXAUTHTIME` a connection is closed if the authentication procedure takes more than the specified amount of time in seconds (default value:30).

`MAXSESSIONS` maximum number of concurrent sessions (the default value 0 disables this limitation).

`XPRMSRV_ACCESS` access control list (see Section 8.6.2.1).

`CONFDIR` a configuration directory path. The server includes each of the files stored in this directory (sorted in alphabetical order) after it has finished reading the main configuration file.

If the corresponding command line options are used (namely options `-l`, `-p`, `-bp`, `-sp`, `-k`, `-sc` and `-v`) the settings of the configuration file are ignored.

In other contexts, the following variables have a special meaning:

`MOSEL_CMD` the command to execute. The default value is `"${XPRESSDIR}/bin/mosel -r"`

`MOSEL_CWD` default working directory. The default value is `"${XPRESSDIR}"`

`RUN_BEFORE` command to be run before `MOSEL_CMD`. This command is executed in the same environment as `MOSEL_CMD` after all variables have been defined.

`RUN_AFTER` command to be run after `MOSEL_CMD`. This command is executed in the environment of the server but the variable itself is expanded in the context of `MOSEL_CMD` before its execution.

`PASS` password required to use this environment (empty by default). If this variable is set to the special value `"*"`, the associated environment is disabled.

`MAXSESSIONS` maximum number of concurrent sessions running under this context (by default there is no limit; a maximum of 0 or less disables the environment).

`XPRMSRV_ACCESS` context specific access control list (applied after the global access list).

`XPRMSRV_SID` session ID: if not explicitly defined this variable is automatically set by the server.

`XPRMSRV_PEER` IP address of the remote host: if not explicitly defined this variable is automatically set by the server.

For instance, the following configuration file sets the logfile to "/tmp/logfile.txt"; adds the password "hardone" to the default context and defines an additional context named xptest pointing to a different installation of xpress:

```
# simple xprmsrv config file
LOGFILE=/tmp/logfile.txt

[xpress]
PASS=hardone

[xptest]
XPRESSDIR=/opt/xpressmp/testing
XPAUTH_PATH=/opt/xpressmp/lic
MOSEL_RESTR=NoWriteNoDBNoExecWDOnly
MOSEL_CWD?=${XPRESSDIR}/workdir
```

Assuming the server using this configuration is running on the machine mypc, the following statements will create two instances on this machine, one for each of the defined execution environments:

```
r1:=connect(m1, "xsrv:mypc/xpress/hardone")
r2:=connect(m2, "xsrv:mypc/xptest")
```

Since MOSEL_CWD has been initialised with the ?= symbol, the remote host can change its working directory. For instance:

```
r2:=connect(m2, "xsrv:mypc/xptest|MOSEL_CWD=/tmp")
```

While the server is running it is possible to request a reload of its configuration: this procedure consists in reading again the configuration file(s) in order to update the definition of the contexts. During this operation only context specific definitions are processed (all global definitions are silently ignored). Under Windows configuration change can only be requested on a running service using the reload command:

```
xprmsrv -service reload
```

On a Unix system configuration change is performed after reception of a signal USR1. For instance if PID is the process ID of a running xprmsrv server:

```
kill -USR1 PID
```

The configuration update can only be executed when the server is not monitoring any Mosel instance. If a request cannot be processed immediately it is delayed until the server is idle. Moreover if an error is detected while reading the configuration an error is reported but the server continues running with its current settings.

8.6.2.1 Access control list

The environment variable XPRMSRV_ACCESS may be defined in each context of the configuration file. This variable defines which hosts are allowed to connect to the server or use a particular context. The restriction applies to the server itself when the variable is defined in the global context and as a supplementary restriction when it is included in any other context (*i.e.* a host cannot be allowed in a context if it is rejected by the global context).

The value of the variable must consist in a list of hosts and subnetworks separated by spaces. Each entry of this list can optionally be preceded by the + sign (for accepting the host; this is the default if no policy is specified) or – sign (to reject connection). Order of the list members is important: when checking authorisation for a given host the list is processed from left to right. The first matching entry will decide whether access is allowed or denied. A given host will be rejected if no matching entry can be found.

A host is identified by its name (*e.g.* `myhost`) or its IP address (*e.g.* `192.168.1.1`). A subnetwork is defined by a routing prefix that can be expressed as a partial address (*e.g.* `192.168.1`); or using the CIDR notation - the first address of the network followed by the bit-length of the prefix, separated by a slash `"/"` character (*e.g.* `192.168.1.0/24`). The subnet mask may also be used instead of the bit-length which is a quad-dotted decimal representation like an address (*e.g.* `192.168.1.0/255.255.255.0`). The special identifier `ALL` is replaced by the subnetwork definition `0.0.0.0/0` (any host) and the identifier `SELF` is replaced by the hostname of the server.

In the first example below, host `uranus` is rejected and subnetwork `192.168.1.0/24` is allowed to connect. Note that `uranus` will be rejected even if it is part of the autorised subnetwork because its reference appears first in the list. In the second example, all hosts are allowed except 2 subnetworks (`192.168.1.0/24` and `192.168.2.0/24`):

```
XPRMSRV_ACCESS=-uranus 192.168.1
XPRMSRV_ACCESS=-192.168.1.0/255.255.255.0 -192.168.2.0/24 +ALL
```

All defined control lists are preprocessed just after the configuration file has been read in order to resolve host names and check for syntax errors. Unresolved host names are ignored (although a warning is displayed in such a case) but a syntax error on a control list will cause the server to abort its processing.

CHAPTER 9

mmnl

The *mmnl* module extends the Mosel language with a new type for representing nonlinear expressions and constraints and also with some additional subroutines. To use this module the following line must be included in the header of the Mosel model file:

```
uses 'mmnl'
```

The first section presents the new functionality for the Mosel language provided by *mmnl*, namely the new type `nlctr` and a set of subroutines that may be applied to objects of this type.

The following sections give detailed documentation of the subroutines (other than mathematical operators) defined by this module.

9.1 New functionality for the Mosel language

9.1.1 The problem type `mpproblem.nl`

This module exposes its functionality through an extension to the `mpproblem` problem type. As a consequence, all routines presented here are executed in the context of the current problem.

9.1.2 The type `nlctr` and its operators

The module *mmnl* defines the type `nlctr` to represent nonlinear constraints in the Mosel Language. As shown in the following example (Section 9.1.4), *mmnl* also defines the standard arithmetic operations that are required for working with objects of this type. By and large, these are the same operations as for linear expressions (type `linctr` of the Mosel language) with additionally the possibility to multiply or divide by decision variables and to use the exponential notation `x^r` (assuming that `x` is of type `mpvar`). Nonlinear constraints may also be defined by using overloaded versions of Mosel's arithmetic and trigonometric functions on expressions involving decision variables (see Section 9.2 for a complete list).

9.1.3 Setting initial values

An important feature in Nonlinear Programming is the possibility to set initial values for decision variables. With *mmnl* this is done by the procedure `setinitval`. Nonlinear solvers use initial values as starting point for the search. The choice of the initial values may not only have an impact on the time spent by the solver but also, depending on the problem type, on the best (locally optimal) solution found by the solver.

The definitions of initial values can be removed with `clearinitvals`. It is also possible to employ the solution values obtained from the immediately preceding optimization run as initial values to the next by calling the procedure `copysoltoinit`.

9.1.4 *Example: using* mmnl *for QCQP*

The following example shows how to solve a QCQP (Quadratically Constrained Quadratic Programming) problem with the Xpress-MP QCQP solver. To use this solver we need to load the module *mmxprs* in addition to *mmnl* since the module *mmnl* does not include any solver.

The problem we wish to solve is a classical NLP test problem (source: http://www.orfe.princeton.edu/ rvdb/ampl/nlmodels/ that determines the shape of a hanging chain by minimizing its potential energy. The objective function is linear and the problem has convex quadratic constraints.

```
model "catenary"
 uses "mmxprs", "mmnl"

 parameters
  N = 100                       ! Number of chainlinks
  L = 1                         ! Difference in x-coordinates of endlinks
  H = 2*L/N                     ! Length of each link
 end-parameters

 declarations
  RN = 0..N
  x: array(RN) of mpvar         ! x-coordinates of endpoints of chainlinks
  y: array(RN) of mpvar         ! y-coordinates of endpoints of chainlinks
 end-declarations

 forall(i in RN) x(i) is_free
 forall(i in RN) y(i) is_free

! Objective: minimise the potential energy
 potential_energy:= sum(j in 1..N) (y(j-1)+y(j))/2

! Bounds: positions of endpoints
! Left anchor
  x(0) = 0; y(0) = 0
! Right anchor
  x(N) = L; y(N) = 0

! Constraints: positions of chainlinks
 forall(j in 1..N)
  Link_up(j):= (x(j)-x(j-1))^2+(y(j)-y(j-1))^2 <= H^2

! Setting start values
 forall(j in RN) setinitval(x(j), j*L/N)
 forall(j in RN) setinitval(y(j), 0)

 setparam("XPRS_verbose", true)
 minimise(potential_energy)

 writeln("Solution: ", getobjval)
 forall(j in RN)
  writeln(strfmt(getsol(x(j)),10,5), " ", strfmt(getsol(y(j)),10,5))
end-model
```

A QCQP matrix can be exported to a text file (in MPS or LP format) by adding the following lines to your model after the problem definition:

```
 setparam("XPRS_loadnames", true)    ! Enable loading of names
 loadprob(potential_energy)          ! Load the problem
 writeprob("catenary.mat", "")       ! Write an MPS matrix ("l" for LP format)
```

Not all problems with quadratic constraints conform with the properties required by QCQP solvers. Xpress-Optimizer therefore performs a convexity check before starting the optimization. This test takes some time and if you know that your problem is convex you may disable it by setting the following

parameter before starting the optimization.

```
setparam("XPRS_ifcheckconvexity", false)    ! Disable convexity check
```

9.2 Procedures and functions

The module *mmnl* overloads certain mathematical functions of the Mosel language, replacing an argument of type `real` by the types `linctr` and `nlctr`. The return value of these functions is of type `nlctr`. This means they can be used as operators in the definition of nonlinear constraints as shown in the example of Section 9.1.4. The relevant functions are:

- **Arithmetic functions:**

`abs`	absolute value
`ceil`	rounding to the next largest integer
`exp`	natural exponent of the argument
`floor`	rounding to the next smallest integer
`ln`	natural logarithm of the argument
`log`	base 10 logarithm of the argument
`round`	rounding to the nearset integer
`sqrt`	positive square root of the argument
`sign`	sign of an expression (-1 if negative, 1 if positive, 0 othewise)
`fmin`	Minimum value of a list of expressions (this function accepts a variable number of arguments or a list)
`fmax`	Maximum value of a list of expressions (this function accepts a variable number of arguments or a list)

- **Trigonometric functions:**

`arccos`	arccosine of the argument
`arcsin`	arcsine of the argument
`arctan`	arctangent of the argument
`cos`	cosine of the argument
`sin`	sine of the argument
`tan`	tangent of the argument

Since these mathematical operators are fairly self-explanatory, we shall forego any more detailed documentation of these functions.

The following list gives an overview of all other functions and procedures defined by *mmnl* for which we give detailed descriptions later.

`clearinitvals`	Delete all initial value definitions.	p. 324
`copysoltoinit`	Copy solution values to initial values.	p. 325
`getsol`	Get the solution value of a nonlinear constraint.	p. 327
`gettype`	Get the type of a nonlinear constraint.	p. 330
`ishidden`	Test whether a constraint is hidden.	p. 328

`pwlin`	Generate a piecewise linear function.	p. 331
`sethidden`	Hide or unhide a nonlinear constraint.	p. 329
`setinitval`	Set an initial value (start value) for a variable.	p. 326
`setname`	Associate a matrix name to a nonlinear constraint.	p. 332
`settype`	Set the type of a nonlinear constraint.	p. 333

clearinitvals

Purpose

Delete all initial value definitions.

Synopsis

```
procedure clearinitvals
```

Example

The following copies the solution values from an optimization run to the initial values of the variables involved. Later all initial value definitions are deleted and a new initial value is set for variable `x`.

```
uses "mmnl"
declarations
 x,y: mpvar
end-declarations
...
minimize(sin(x+y))
copysoltoinit
...
clearinitvals
setinitval(x, -1)
```

Further information

This procedure deletes all previously defined initial values for decision variables.

Related topics

`copysoltoinit`, `setinitval`.

Module

mmnl

copysoltoinit

Purpose

Copy solution values to initial values.

Synopsis

```
procedure copysoltoinit
```

Example

The following copies the solution values of all variables in an optimization run to their initial values and then sets a different initial value for variable `x(1)`.

```
uses "mmnl"
declarations
 x: array(1..10) of mpvar
 y,z: mpvar
end-declarations
...
maximize(x(1)*x(3) + ln(y+z))
copysoltoinit
setinitval(x(1), 0)
```

Further information

This procedure copies the solution values of decision variables in the immediately preceding optimization run to their initial values for the next run. Doing so it overrides any previously set initial values for the involved variables. However, the settings for decision variables that did not occur in the previously solved problem remain unchanged.

Related topics

`copysoltoinit`, `clearinitvals`, `setinitval`.

Module

mmnl

setinitval

Purpose

Set an initial value (start value) for a variable.

Synopsis

```
procedure setinitval(x:mpvar, val:real)
```

Arguments

`x`	A decision variable
`val`	A real number to be used as initial value

Example

The following sets an initial value of 0 for variable `x`. For `y` its solution from the preceding optimization is set as its new initial value.

```
uses "mmnl"
declarations
 x,y: mpvar
end-declarations
setinitval(x, 0)
setinitval(y, getsol(y))
```

Further information

This procedure sets an initial value for a decision variable. Initial values are used by nonlinear solvers as a (good) starting point for the search. It is in general not required that the initial values be part of a feasible solution to the optimization problem. All previously set initial values can be removed by calling `clearinitvals`. The procedure `copysoltoinit` can be used to turn the solution of a previous optimization run into initial values for the next run.

Related topics

`clearinitvals`, `copysoltoinit`.

Module

mmnl

getsol

Purpose

Get the solution value of a nonlinear constraint.

Synopsis

```
function getsol(c:nlctr):real
```

Argument

`c` A nonlinear constraint

Return value

Solution value or 0.

Example

The following prints the solution values of a nonlinear constraint and a nonlinear expression.

```
uses "mmnl"
declarations
 x,y,z: mpvar
 Ctr: nlctr
end-declarations
  ...                          ! (Define and solve the problem)
writeln("Evalution of Ctr: ", getsol(Ctr))
writeln("Evaluation of an expression: ", getsol(abs(x*y)+5*z^3))
```

Further information

This function returns the evaluation of a nonlinear constraint using the current solution values of its variables. Note that the solution value of a variable is 0 if the problem has not been solved or the variable is not contained in the problem that has been solved.

Related topics

`maximize`/`minimize`, `copysoltoinit`.

Module

mmnl

ishidden

Purpose

Test whether a constraint is hidden.

Synopsis

```
function ishidden(c:nlctr):boolean
```

Argument

`c` A nonlinear constraint

Return value

`true` if the constraint is hidden, `false` otherwise.

Example

The following tests whether a nonlinear constraint is hidden.

```
uses "mmnl"
declarations
 c: nlctr
end-declarations

if ishidden(c) then
 writeln("Constraint 'c' is currently hidden.")
end-if
```

Further information

This function tests the current status of a constraint. At its creation a constraint is added to the current problem, but using the function `sethidden` it may be hidden. This means, the constraint will not be contained in the problem that is solved by the nonlinear solver but it is not deleted from the definition of the problem in Mosel.

Related topics

`sethidden`.

Module

mmnl

sethidden

Purpose

Hide or unhide a nonlinear constraint.

Synopsis

```
procedure sethidden(c:nlctr, b:boolean)
```

Arguments

`c` A nonlinear constraint

`b` Constraint status:

`true`	Hide the constraint
`false`	Unhide the constraint

Example

The following defines a constraint and then sets it as hidden:

```
uses "mmnl"
declarations
 x,y,z: mpvar
end-declarations

c:= 4*cos(x) + y - z^2 <= 12
sethidden(c, true)
```

Further information

At its creation a constraint is added to the current problem, but using this procedure it may be hidden. This means that the constraint will not be contained in the problem that is solved by the nonlinear solver but it is not deleted from the definition of the problem in Mosel. Function `ishidden` can be used to test the current status of a constraint.

Related topics

`ishidden`.

Module

mmnl

gettype

Purpose

Get the type of a nonlinear constraint.

Synopsis

```
function gettype(c:nlctr):integer
```

Argument

`c` A nonlinear constraint

Return value

Constraint type. Applicable values for nonlinear constraints are:

`CT_EQ` Equality, '='

`CT_GEQ` Greater than or equal to, '$\geq$'

`CT_LEQ` Less than or equal to, '$\leq$'

`CT_UNB` Non-binding constraint, *i.e.* free

Related topics

`settype`.

Module

mmnl

pwlin

Purpose

Generate a piecewise linear function.

Synopsis

```
function pwlin(x:mpvar, points:list of real):nlctr
function pwlin(x:mpvar, brks:list of real, slopes:list of real):nlctr
function pwlin(fcts:list of pws):nlctr
```

Arguments

`x`	Input variable of the function
`points`	List of breakpoints; each point is defined by its coordinates (*i.e.* the size of the list must be even)
`brks`	List of x-values for the breakpoints
`slopes`	List of slopes to be applied between each breakpoint (there must be 1 more slope than breakpoints)
`fcts`	List of segments of the function by means of `pws` constructs

Return value

The piecewise linear expression as an `nlctr` entity

Example

The following code extract generates 3 identical piecewise linear functions using the different methods supported by this routine:

```
pwl1:=pwlin(x,[0.0,0, 1,10, 2,13, 3,15, 4,16])
pwl2:=pwlin(x,[1.0,2,3],[10.0,3,2,1])
pwl3:=pwlin([pws(0,10*x),pws(1,10+3*(x-1)),pws(2,13+2*(x-2)),
             pws(3,15+(x-3))])
```

Further information

1. The first form of the routine expects a list of coordinates: each point is defined by the value for the variable `x` and the value of the function on this point. With the second form the list `brks` specifies the points where the slope of the function changes and the list `slopes` gives the actual slopes. The first slope applies for values before the first breakpoint and the last one is for values after the last breakpoint. Note that with this syntax it is assumed that the evaluation of the function is 0 for `x=0`.
2. Using the last form of the routine makes it possible to describe the function by means of linear expressions. Each element of the list `fcts` must be a `pws` construct that is composed of a real (the first x-value of the segment) and a linear expression on the input variable (segments must depend on the same input variable).

Module

mmnl

setname

Purpose

Associate a matrix name to a nonlinear constraint.

Synopsis

```
procedure setname(c:nlctr, n:string)
```

Arguments

`c`	A nonlinear constraint
`n`	Name given to the constraint

Further information

1. When exporting a problem to a matrix file, constraint names are deduced from the global public symbols: anonymous and local constraints are usually named after their row number in the matrix. This procedure makes it possible to give a name to these constraints.
2. If the given name starts with the `'#'` character, the generated matrix name will include the row number of the constraint in the matrix.

settype

Purpose

Set the type of a nonlinear constraint.

Synopsis

```
procedure settype(c:nlctr, type:integer)
```

Arguments

`c` A nonlinear constraint

`type` Constraint type. Applicable values are:

`CT_EQ`	Equality, '='
`CT_GEQ`	Greater than or equal to, '$\geq$'
`CT_LEQ`	Less than or equal to, '$\leq$'
`CT_UNB`	Non-binding constraint

Further information

This procedure can be used to change the type of a nonlinear constraint, turning it into an equality or inequality or making it unbounded, *i.e.* free.

Related topics

`gettype`.

Module

mmnl

CHAPTER 10

mmoci

The Mosel OCI (Oracle Call Interface) interface provides a set of procedures and functions that may be used to access Oracle databases. To use the OCI interface, the following line must be included in the header of a Mosel model file:

```
uses 'mmoci'
```

This manual describes the Mosel OCI interface and shows how to use some standard PL/SQL commands, but it is not meant to serve as a manual for PL/SQL. The reader is referred to the documentation of Oracle for more detailed information on these topics.

10.1 Prerequisite

The Oracle interface defined by the module *mmoci* accesses Oracle databases via the Oracle Call Interface (OCI). Oracle's Instant Client package must be installed on the machine that runs the Mosel model.

10.2 Example

Assume that the Oracle database contains a table "pricelist" of the following form:

```
articlenum  color  price
1001        blue   10.49
1002        red    10.49
1003        black  5.99
1004        blue   3.99
   ...
```

The following small example shows how to logon to a database from an Mosel model file, read in data, and logoff from the database.

```
model 'OCIexample'
 uses 'mmoci'

 declarations
  prices: array (range) of real
 end-declarations

 setparam("OCIverbose", true)   ! Enable OCI message printing in case of error
 OCIlogon("scott","tiger","")   ! connect to Oracle as the user 'scott/tiger'
```

```
 writeln("Connection number: ", getparam("OCIconnection"))

 OCIexecute("select articlenum,price from pricelist", prices)
                                ! Get the entries of field `price' (indexed by
                                ! field `articlenum') in table `pricelist'

 OCIlogoff                      ! Disconnect from the database
end-model
```

Here the `OCIverbose` control parameter is set to `true` to enable OCI message printing in case of error. Following the connection, the procedure `OCIexecute` is called to retrieve entries from the field `price` (indexed by field `articlenum`) in the table `pricelist`. Finally, the connection is closed.

For further examples of working with databases and spreadsheets, the reader is referred to the Xpress whitepaper *Using ODBC and other database interfaces with Mosel*.

10.3 Data transfer between Mosel and Oracle

Data transfer beetween Mosel and Oracle is achieved by calls to the procedure `OCIexecute`. The value of the control parameter `OCIndxcol` and the type and structure of the second argument of the procedure decide how the data are transferred between the two systems.

10.3.1 From Oracle to Mosel

Information is moved from Oracle to Mosel when performing a `SELECT` command for instance. Assuming `mt` has been declared as follows:

```
mt: array(1..10,1..3) of integer
```

the execution of the call:

```
OCIexecute("SELECT c1,c2,c3 from T", mt)
```

behaves differently depending on the value of `OCIndxcol`. If this control parameter is `true`, the columns `c1` and `c2` are used as indices and `c3` is the value to be assigned. For each row (`i`,`j`,`k`) of the result set, the following assignment is performed by mmoci:

```
mt(i,j):=k
```

With a table T containing:

```
c1 c2 c3 c4
 1  2  5  7
 4  3  6  8
```

We obtain the initialization:

```
m2(1,2)=5, m(4,3)=6
```

If the control parameter `OCIndxcol` is `false`, all columns are treated as data. In this case, for each row (`i`,`j`,`k`) the following assignments are performed:

```
mt(r,1):=i; mt(r,2):=j; mt(r,3):=k
```

where `r` is the row number in the result set.

Here, the resulting initialization is:

```
mt(1,1)=1, mt(1,2)=2, mt(1,3)=5
```

```
mt(2,1)=4, mt(2,2)=3, mt(2,3)=6
```

If the SQL statement selects 4 columns (instead of 3) as in:

```
OCIexecute("SELECT c1,c2,c3,c4 from T", mt)
```

and the control parameter OCIndxcol is false, the first column is used as the first array index while the remaining columns are treated as data. As a consequence, for each row (i,j,k,l) the following assignments are performed:

```
mt(i,1):=j; mt(i,2):=k; mt(i,3):=l
```

The resulting initialization is therefore:

```
mt(1,1)=2, mt(1,2)=5, mt(1,3)=7
mt(4,1)=3, mt(4,2)=6, mt(4,3)=8
```

The second argument of OCIexecute may also be a list of arrays. When using this version, the value of OCIndxcol is ignored and the first column(s) of the result set are always considered as indices and the following ones as values for the corresponding arrays. For instance, assuming we have the following declarations:

```
m1, m2: array(1..10) of integer
```

With the statement:

```
OCIexecute("SELECT c1,c2,c3 from T", [m1,m2])
```

for each row (i,j,k) of the result set, the following assignments are performed:

```
m1(i):=j; m2(i):=k
```

So, if we use the table T of our previous example, we get the initialization:

```
m1(1)=2, m1(4)=5
m2(1)=3, m2(4)=6
```

10.3.2 From Mosel to Oracle

Information is transferred from Mosel to Oracle when performing an INSERT command for instance. In this case, the way to use the Mosel arrays has to be specified by using parameters in the SQL command. These parameters are identified by their name in the expression. For instance in the following expression 3 parameters (:1, :2 and :3) are used:

```
INSERT INTO T (c1,c2,c3) VALUES (:1,:2,:3)
```

mmoci expects that parameters are always named :n where n is the parameter number starting at 1 but does not impose any order (*i.e.* :3,:1,:2 is also valid) and a given parameter may be used several times in an expression. The command is then executed repeatedly as many times as the provided data allows to build new tuples of parameters. The initialization of parameters is similar to what is done for a SELECT statement.

Assuming mt has been declared as follows:

```
mt: array(1..2,1..3) of integer
```

and initialized with this assignment:

```
mt::[1,2,3,
```

```
    4,5,6]
```

the execution of the call:

```
OCIexecute("INSERT INTO T (c1,c2,c3) VALUES (:1,:2,:3)",mt)
```

behaves differently depending on the value of OCIndxcol. If this control parameter is true, for each execution of the command, the following assignments are performed by *mmoci*:

```
':1':= i, ':2':= j, ':3':= mt(i,j)
```

The execution is repeated for all possible values of i and j (in our example 6 times). The resulting table T is therefore:

```
c1 c2 c3
 1  1  1
 1  2  2
 1  3  3
 2  1  4
 2  2  5
 2  3  6
```

Note that *mmoci* uses the names of the parameters to perform an initialization and not their relative position. This property is particularly useful for UPDATE statements where the order of parameters needs to be changed. For instance, if we want to update the table T instead of inserting new rows, we can write:

```
OCIexecute("UPDATE T c3=:3 WHERE c1=:1, c2=:2",mt)
```

This command is executed exactly in the same way as the INSERT example above (*i.e.* we do not have ':3':=i, ':1':=j, ':2':=mt(i,j) as the order of appearance in the command suggests but ':1':=i, ':2':=j, ':3':=mt(i,j)).

The same functionality may also be used to reorder or repeat columns. With the same definition of the array mt as before and a 4-column table S in the database the execution of the command

```
OCIexecute("INSERT INTO S (c1,c2,c3,c4) VALUES (:1,:2,:3,:2)",mt)
```

results in the following contents of table S:

```
c1 c2 c3 c4
 1  1  1  1
 1  2  2  2
 1  3  3  3
 2  1  4  1
 2  2  5  2
 2  3  6  3
```

If the control parameter OCIndxcol is false, only the values of the Mosel array are used to initialize the parameters. So, for each execution of the command of our initial example (with 3 parameters), we have:

```
':1':=mt(i,1), ':2':=mt(i,2), ':3':=mt(i,3)
```

The execution is repeated for all possible values of i (in our example 2 times). The resulting table T is therefore:

```
c1 c2 c3
 1  2  3
 4  5  6
```

However if the SQL query defines 4 parameters (instead of 3) as in:

```
OCIexecute("INSERT INTO T (c1,c2,c3,c4) VALUES (:1,:2,:3,:4)",mt)
```

and the control parameter OCIndxcol is false, the first parameter is used as the first array index while the remaining parameters are populated with data. As a consequence, for each execution of the command, the following assignments are performed by *mmoci*:

```
':1':= i, ':2':= mt(i,1), ':3':= mt(i,2), ':4':=mf(i,3)
```

The execution is repeated for all possible values of i (in our example 2 times). The resulting table T is therefore:

```
c1 c2 c3 c4
 1  1  2  3
 2  4  5  6
```

When OCIexecute is used with a list of arrays, the behavior is again similar to what has been described earlier for the SELECT command: the first parameter(s) are assigned index values and the final ones the actual array values. For instance, assuming we have the following declarations:

```
m1,m2: array(1..3) of integer
```

And the arrays have been initialized as follows:

```
m1::[1,2,3]
m2::[4,5,6]
```

Then the following call:

```
OCIexecute("INSERT INTO T (c1,c2,c3) VALUES (:1,:2,:3)",[m1,m2])
```

executes 3 times the INSERT command. For each execution, the following parameter assignments are performed:

```
':1':=i, ':2':=m1(i), ':3':=m2(i)
```

The resulting table T is therefore:

```
c1 c2 c3
 1  1  4
 2  2  5
 3  3  6
```

10.4 Control parameters

The following parameters are defined by *mmoci*:

OCIndxcol	Indicate whether to use first columns as indices.	p. 341
OCIrowcnt	Number of lines affected by the last SQL command.	p. 341
OCIrowxfr	Number of lines transferred during the last SQL command.	p. 341
OCIsuccess	Indicate whether the last SQL command succeeded.	p. 342
OCItruncsize	Length of the largest string that has been truncated.	p. 342
OCIverbose	Enable/disable message printing by OCI.	p. 342

All parameters can be accessed with the Mosel function `getparam`, and those that are not marked read-only in the list below may be set using the procedure `setparam`.

Example:

```
setparam("OCIverbose", true)    ! Enable message printing by OCI
csize:=getparam("OCIcolsize")   ! Get the maximum string length
setparam("OCIconnection", 3)    ! Select the connection number 3
```

OCIautocommit

Description Enable/disable "commit on success" in OCI.

Type Boolean, read/write

Values
- `true` Changes to the database are committed automatically.
- `false` transactions have to be explicitly committed (or rolled back) using OCIcommit (or OCIrollback).

Default value `true`

Module mmoci

OCIautondx

Description Enable automatic indexation of arrays.

Type Boolean, read/write

Values
- `true` Enable automatic indexation.
- `false` Disable automatic indexation.

Default value `false`

Note Automatic indexation affects handling of arrays in SQL queries. It can be used only on 1-dimension arrays indiced by ranges: when this mode is enabled indices are not imported or exported, only array values are exchanged with the database. For reading, the initial index value is taken from the parameter OCIfirstndx and incremented at each iteration. When writing all cells of the arrays are exported.

Affects routines OCIexecute.

See also OCIfirstndx.

Module mmoci

OCIbufsize

Description Size in kilobytes of the buffer used for exchanging data between Mosel and Oracle.

Type Integer, read/write

Values At least 1

Default value 4

Affects routines `OCIexecute`, `OCIreadstring`.

Module mmoci

OCIcolsize

Description Maximum length of strings accepted to exchange data, anything exceeding this size is cut off.

Type Integer, read/write

Values At least 8

Default value 64

Note When exporting external type entities as text strings to the database and the column size is too small the resulting cells might be empty.

Affects routines `OCIexecute`, `OCIreadstring`.

See also `OCItruncsize`.

Module mmoci

OCIconnection

Description Identification number of the active OCI connection. By changing the value of this parameter, it is possible to work with several connections simultaneously.

Type Integer, read/write

Affects routines `OCIlogoff`, `OCIexecute`, `OCIreadinteger`.`OCIreadreal`, `OCIreadstring`.

Set by routines `OCIlogon`.

Module mmoci

OCIdebug

Description When this parameter is set to `true`, `OCIverbose` is also enabled and any SQL request sent to Oracle is displayed to the error stream before execution. This option is ignored if the model is not compiled with debug information.

Type Boolean, read/write

Values

`true` Enable debug mode.

`false` Disable debug mode.

Default value `false`

See also `OCIverbose`.

Module mmoci

OCIfirstndx

Description Initial index value for an automatic indexation.

Type Integer, read/write

Default value 1

Affects routines `OCIexecute`.

See also `OCIautondx`.

Module mmoci

OCIndxcol

Description Indicates whether the first columns of each row must be interpreted as indices in all cases. Setting it to the value `false` might be useful, for example, if one is trying to access a non-relational table, perhaps a dense table. Note this mode can be enabled only is at least the last dimension of each array is of fixed size.

Type Boolean, read/write

Values

`true` Interpret the first columns of each row as indices.

`false` Do not interpret the first columns of each row as indices.

Default value `true`

Affects routines `OCIexecute`, `OCIreadinteger`.`OCIreadreal`, `OCIreadstring`.

Module mmoci

OCIrowcnt

Description Number of lines affected by the last SQL command.

Type Integer, read only

Set by routines `OCIexecute`, `OCIreadinteger`.`OCIreadreal`, `OCIreadstring`.

See also `OCIrowxfr`.

Module mmoci

OCIrowxfr

Description Number of lines transferred during the last SQL command.

Type Integer, read only

Set by routines `OCIexecute`, `OCIreadinteger`.`OCIreadreal`, `OCIreadstring`.

See also `OCIrowcnt`.

Module mmoci

OCIsuccess

Description Indicate whether the last SQL command has been executed successfully.

Type Boolean, read only

Values
`true` Succes.
`false` Error.

Set by routines All OCI functions.

Module mmoci

OCItruncsize

Description Length of the largest string that has been truncated.

Type Integer, read only

Note When exporting text to the database all strings must fit into the predefined column size (`OCIcolsize`). If strings are truncated due to this limit the operation status is set to `false` (see `OCIsuccess`) and this parameter receives the size that should be used to avoid any truncation.

Set by routines `OCIexecute`.

See also `OCIsuccess`, `OCIcolsize`.

Module mmoci

OCIverbose

Description Enable/disable message printing by OCI.

Type Boolean, read/write

Values
`true` Enable message printing.
`false` Disable message printing.

Default value `true`

Module mmoci

10.5 Procedures and functions

This section lists in alphabetical order the functions and procedures that are provided by the *mmoci* module.

OCIlogon

Purpose

Connect to a database.

Synopsis

```
procedure OCIlogon(s:string|text)
procedure OCIlogon(u:string|text, p:string|text, db:string|text)
```

Arguments

`s`	Logon string as `"user/password@db"`
`n`	User name
`p`	Password
`db`	Database name (may be `""` for the default database)

Example

The following connects to the database 'test' as the user 'yves' with the password 'DaSH':

```
OCIlogon("yves/DaSH@test")
```

Open a connection to the default database the user 'scott' with the password 'tiger'

```
OCIlogon("scott","tiger","")
```

Further information

1. This procedure establishes a connection to the database `db` as user `n/p`. It is possible to open several connections but the connection established last becomes active. Each connection is assigned an identification number which can be obtained by getting the value of the parameter `OCIconnection` after this procedure has been executed. This parameter can also be used to change the active connection.
2. When Mosel is running in restricted mode (see Section 1.3.4), the restriction `NoDB` disables this routine.

Related topics

`OCIlogoff`.

Module

mmoci

OCIlogoff

Purpose

Terminate the active database connection.

Synopsis

```
procedure OCIlogoff
```

Further information

The active connection can be accessed or changed by setting the control parameter `OCIconnection`.

Related topics

`OCIlogon`.

Module

mmoci

OCIexecute

Purpose

Execute an SQL command.

Synopsis

```
procedure OCIexecute(s:string|text)
procedure OCIexecute(s:string|text, a:array)
procedure OCIexecute(s:string|text, l:list)
procedure OCIexecute(s:string|text, m:set)
```

Arguments

`s`	SQL command to be executed
`a`	An array
`l`	A list. May be a list of arrays
`m`	A set

Example

The following example contains four `OCIexecute` statements performing the following tasks:

- Get all different values of the column `color` in the table `pricelist`.
- Initialize the arrays `colors` and `prices` with the values of the columns `color` and `price` of the table `pricelist`.
- Create a new table `newtab` in the active database with 2 columns, `ndx` and `price`.
- Add data entries to table `newtab`.

```
declarations
 prices: array(1001..1004) of real
 colors: array(1001..1004) of string
 allcolors: set of string
end-declarations

OCIexecute("select color from pricelist", allcolors)
OCIexecute("select articlenum,color,price from pricelist",
                                                  [colors,prices])
OCIexecute("create table newtab (ndx integer, price double)")
OCIexecute("insert into newtab (ndx, price) values (:1,:2)", prices)
```

Further information

1. This procedure executes the given SQL command. The user is referred to the Oracle documentation for further information on PL/SQL.
2. For output commands (like `insert into`) this procedure accepts arrays, sets and lists of basic types (integer, real, string or Boolean) as well as module types for which from/to string conversions are available. Record types composed of scalars or other records can also be used (the fields that cannot be handled are silently ignored). It is also possible to use a list of arrays of basic types (all arrays must be indexed by the same sets) or a list of scalar elements of different basic or module types.
3. For input commands (like `select from`) the same restrictions apply for arrays,lists and list of arrays but sets must be of a basic type.

Related topics

`OCIreadinteger`, `OCIreadreal`, `OCIreadstring`.

Module

mmoci

OCIreadinteger

Purpose

Read an integer value from a database.

Synopsis

```
function OCIreadinteger(s:string|text):integer
```

Argument

`s` SQL command for selecting the value to be read

Return value

Integer value read or 0.

Example

The following gets the article number of the first data item in table `pricelist` for which the field `color` is set to `blue`:

```
i:=OCIreadinteger(
        "select articlenum from pricelist where color=blue")
```

Further information

1. `0` is returned if no integer value can be found.
2. If the given SQL selection command does not denote a single value, the first value to which the selection criterion applies is returned.

Related topics

`OCIexecute`, `OCIreadreal`, `OCIreadstring`.

Module

mmoci

OCIreadreal

Purpose

Read a real value from a database.

Synopsis

```
function OCIreadreal(s:string|text):real
```

Argument

`s` SQL command for selecting the value to be read

Return value

Real value read or 0.

Example

The following returns the price of the data item with index 2 in table `newtab`:

```
r:=OCIreadreal("select price from newtab where ndx=2")
```

Further information

1. `0` is returned if no real value can be found.
2. If the given SQL selection command does not denote a single value, the first value to which the selection criterion applies is returned.

Related topics

`OCIexecute`, `OCIreadinteger`, `OCIreadstring`.

Module

mmoci

OCIreadstring

Purpose

Read a string from a database.

Synopsis

```
function OCIreadstring(s:string|text):string
```

Argument

`s` SQL command for selecting the string to be read

Return value

String read or empty string.

Example

The following retrieves the color of the (first) data item in table `pricelist` with article number 1004:

```
s:=OCIreadstring(
       "select color from pricelist where articlenum=1004")
```

Further information

1. The empty string is returned if no real value can be found.
2. If the given SQL selection command does not denote a single entry, the first string to which the selection criterion applies is returned.

Related topics

`OCIexecute`, `OCIreadinteger`, `OCIreadreal`.

Module

mmoci

OCIcommit

Purpose

Commit the current transaction.

Synopsis

```
procedure OCIcommit
```

Further information

This procedure is required only if the control parameter `OCIautocommit` is set to `false`.

Related topics

`OCIrollback`.

Module

mmoci

OCIrollback

Purpose

Roll back the current transaction.

Synopsis

```
procedure OCIrollback
```

Further information

This procedure can be used only if the control parameter `OCIautocommit` is set to `false`.

Related topics

`OCIcommit`.

Module

mmoci

10.6 I/O drivers

This module provides a driver designed to be used in `initializations` blocks for both reading and writing data. The *oci* IO driver simplifies access to Oracle databases.

10.6.1 Driver `oci`

```
oci:[debug;][noindex;][colsize=#;][bufsize=#;]logstring
```

The driver can only be used in 'initializations' blocks. The database to use has to be given in the opening part of the block as `user/password@dbname`. Before this identifier, the following options may be stated:

`debug` to execute the block in debug mode (to display what SQL queries are produced). This option is ignored if the model is not compiled with debug information.

`noindex` to indicate that only data (no indices) are transferred between the data source and Mosel. By default, the first columns of each table are interpreted as index values for the array to be transferred. This behaviour is changed by this option.

`colsize=c` to set the size of a text column (default 64 characters).

`bufsize=c` to set the size of the data buffer in kilobytes (default 4).

In the block, each label entry is understood as a table name optionally followed by a list of column names in brackets (*e.g.* `"my_table(col1,col2)"`). All columns are used if no list of names is specified. Note that, before the table name, one can add option `noindex` to indicate that for this particular entry indices are not used.

Example:

```
initializations from "mmoci.oci:scott/tiger@orcl"
 NWeeks as "PARAMS(Weeks)"      ! Initialize `NWeeks' with column `Weeks'
                                ! of table `PARAMS'
 BPROF as "noindex;BPROFILE"    ! Initialize `BPROF' with table `BPROFILE'
                                ! all columns being data (no indices)
end-initializations
```

CHAPTER 11

mmodbc

The Mosel ODBC interface provides a set of procedures and functions that may be used to access databases for which an ODBC driver is available. This module also includes the SQLite database engine that can be directly run without the need for any additional software.
To use the ODBC interface, the following line must be included in the header of a Mosel model file:

```
uses 'mmodbc'
```

This manual describes the Mosel ODBC interface and shows how to use some standard SQL commands, but it is not meant to serve as a manual for SQL. The reader is referred to the documentation of the software he is using for more detailed information on these topics.

11.1 Prerequisite

The ODBC technology relies on a *driver manager* that is used as an interface between applications (like *mmodbc*) and a *data source* itself accessed through a dedicated driver. As a consequence, this module requires that both, a driver manager and the necessary drivers (one for each data source to be used), are installed and set up on the operating system.

Under Windows, usually the driver manager is part of the system and most data sources are provided with their ODBC driver (for instance Excel, Access or SQLServer).

On the other supported operating systems it may be necessary to install a driver manager (as well as the necessary drivers). The module *mmodbc* supports two driver managers: *iODBC* (http://www.iodbc.org) and *unixODBC* (http://www.unixodbc.org). Upon startup the module tries to load the dynamic library `"libiodbc.so"` then, if this fails, tries `"libodbc.so"`. If none of these libraries can be found only the SQLite integrated driver will be available, please make sure that one of the driver managers is installed and that the corresponding libraries can be accessed (in general this requires updating some environment variable).

11.2 Example

Assume that the data source “mydata” defines a database that contains a table “pricelist” of the following form:

```
articlenum  color  price
1001        blue   10.49
1002        red    10.49
1003        black  5.99
1004        blue   3.99
   ...
```

The following small example shows how to connect to a database from an Mosel model file, read in data, and disconnect from the data source.

```
model 'ODBCexample'
 uses 'mmodbc'

 declarations
  prices: array (range) of real
 end-declarations

 setparam("SQLverbose", true)   ! Enable ODBC message printing in case of error
 SQLconnect("DSN=mydata")       ! Connect to the database defined by `mydata'

 writeln("Connection number: ", getparam("SQLconnection"))

 SQLexecute("select articlenum,price from pricelist", prices)
                                ! Get the entries of field `price' (indexed by
                                ! field `articlenum') in table `pricelist'

 SQLdisconnect                  ! Disconnect from the database
end-model
```

Here the `SQLverbose` control parameter is set to `true` to enable ODBC message printing in case of error. Following the connection, the procedure `SQLexecute` is called to retrieve entries from the field `price` (indexed by field `articlenum`) in the table `pricelist`. Finally, the connection is closed.

For further examples of working with databases and spreadsheets, the reader is referred to the Xpress whitepaper *Using ODBC and other database interfaces with Mosel*.

11.3 Data transfer between Mosel and the database

Data transfer beetween Mosel and the database is achieved by calls to the procedure `SQLexecute`. The value of the control parameter `SQLndxcol` and the type and structure of the second argument of the procedure decide how the data are transferred between the two systems.

11.3.1 From the database to Mosel

Information is moved from the database to Mosel when performing a `SELECT` command for instance. Assuming `mt` has been declared as follows:

```
mt: array(1..10,1..3) of integer
```

the execution of the call:

```
SQLexecute("SELECT c1,c2,c3 from T", mt)
```

behaves differently depending on the value of `SQLndxcol`. If this control parameter is `true`, the columns `c1` and `c2` are used as indices and `c3` is the value to be assigned. For each row (`i`,`j`,`k`) of the result set, the following assignment is performed by mmodbc:

```
mt(i,j):=k
```

With a table T containing:

```
c1 c2 c3 c4
 1  2  5 7
 4  3  6 8
```

We obtain the initialization:

```
m2(1,2)=5, m(4,3)=6
```

If the control parameter SQLndxcol is false, all columns are treated as data. In this case, for each row (i,j,k) the following assignments are performed:

```
mt(r,1):=i; mt(r,2):=j; mt(r,3):=k
```

where r is the row number in the result set.

Here, the resulting initialization is:

```
mt(1,1)=1, mt(1,2)=2, mt(1,3)=5
mt(2,1)=4, mt(2,2)=3, mt(2,3)=6
```

If the SQL statement selects 4 columns (instead of 3) as in:

```
SQLexecute("SELECT c1,c2,c3,c4 from T", mt)
```

and the control parameter SQLndxcol is false, the first column is used as the first array index while the remaining columns are treated as data. As a consequence, for each row (i,j,k,l) the following assignments are performed:

```
mt(i,1):=j; mt(i,2):=k; mt(i,3):=l
```

The resulting initialization is therefore:

```
mt(1,1)=2, mt(1,2)=5, mt(1,3)=7
mt(4,1)=3, mt(4,2)=6, mt(4,3)=8
```

The second argument of SQLexecute may also be a list of arrays. When using this version, the value of SQLndxcol is ignored and the first column(s) of the result set are always considered as indices and the following ones as values for the corresponding arrays. For instance, assuming we have the following declarations:

```
m1, m2: array(1..10) of integer
```

With the statement:

```
SQLexecute("SELECT c1,c2,c3 from T", [m1,m2])
```

for each row (i,j,k) of the result set, the following assignments are performed:

```
m1(i):=j; m2(i):=k
```

So, if we use the table T of our previous example, we get the initialization:

```
m1(1)=2, m1(4)=5
m2(1)=3, m2(4)=6
```

11.3.2 From Mosel to the database

Information is transferred from Mosel to the database when performing an INSERT command for instance. In this case, the way to use the Mosel arrays has to be specified by using parameters in the SQL command. These parameters are identified by the symbol '?' in the expression. For instance in the following expression 3 parameters are used:

```
INSERT INTO T (c1,c2,c3) VALUES (?,?,?)
```

The command is then executed repeatedly as many times as the provided data allows to build new tuples of parameters. The initialization of parameters is similar to what is done for a SELECT statement.

Assuming `mt` has been declared as follows:

```
mt: array(1..2,1..3) of integer
```

and initialized with this assignment:

```
mt::[1,2,3,
     4,5,6]
```

the execution of the call:

```
SQLexecute("INSERT INTO T (c1,c2,c3) VALUES (?,?,?)",mt)
```

behaves differently depending on the value of `SQLndxcol`. If this control parameter is `true`, for each execution of the command, the following assignments are performed by *mmodbc* (`?1`,`?2`,`?3` denote respectively the first second and third parameter):

```
'?1':= i, '?2':= j, '?3':= mt(i,j)
```

The execution is repeated for all possible values of `i` and `j` (in our example 6 times). The resulting table `T` is therefore:

```
c1 c2 c3
 1  1  1
 1  2  2
 1  3  3
 2  1  4
 2  2  5
 2  3  6
```

If the control parameter `SQLndxcol` is `false`, only the values of the Mosel array are used to initialize the parameters. So, for each execution of the command, we have:

```
'?1':=mt(i,1), '?2':=mt(i,2), '?3':=mt(i,3)
```

The execution is repeated for all possible values of `i` (in our example 2 times). The resulting table `T` is therefore:

```
c1 c2 c3
 1  2  3
 4  5  6
```

However if the SQL query defines 4 parameters (instead of 3) as in:

```
SQLexecute("INSERT INTO T (c1,c2,c3,c4) VALUES (?,?,?,?)",mt)
```

and the control parameter `SQLndxcol` is `false`, the first parameter is used as the first array index while the remaining parameters are populated with data. As a consequence, for each execution of the command, the following assignments are performed by *mmodbc*:

```
'?1':= i, '?2':= mt(i,1), '?3':= mt(i,2), '?4':=mf(i,3)
```

The execution is repeated for all possible values of `i` (in our example 2 times). The resulting table `T` is therefore:

```
c1 c2 c3 c4
 1  1  2  3
 2  4  5  6
```

When `SQLexecute` is used with a list of arrays, the behavior is again similar to what has been described

earlier for the SELECT command: the first parameter(s) are assigned index values and the final ones the actual array values. For instance, assuming we have the following declarations:

```
m1,m2: array(1..3) of integer
```

And the arrays have been initialized as follows:

```
m1::[1,2,3]
m2::[4,5,6]
```

Then the following call:

```
SQLexecute("INSERT INTO T (c1,c2,c3) VALUES (?,?,?)",[m1,m2])
```

executes 3 times the INSERT command. For each execution, the following parameter assignments are performed:

```
'?1':=i, '?2':=m1(i), '?3':=m2(i)
```

The resulting table T is therefore:

```
c1 c2 c3
 1  1  4
 2  2  5
 3  3  6
```

11.4 ODBC and MS Excel

Microsoft Excel is a spreadsheet application. Since ODBC was primarily designed for databases special rules have to be followed to read and write Excel data using ODBC:

- A table of data is referred to as either a named range (*e.g.* MyRange), a worksheet name (*e.g.* [Sheet1$]) or an explicit range (*e.g.* [Sheet1$B2:C12]).
- By default, the first row of a range is used for naming the columns (to be used in SQL statements). The option FIRSTROWHASNAMES=0 disables this feature and columns are implicitly named F1, F2... However, even with this option, the first row is ignored and cannot contain data.
- The data type of columns is deduced by the Excel driver by scanning the first 8 rows. The number of rows analyzed can be changed using the option MAXSCANROWS=n (n between 1 and 8).

It is important to be aware that when writing to database tables specified by a named range in Excel, they will increase in size if new data is added using an *INSERT* statement. To overwrite existing data in the worksheet, the SQL statement *UPDATE* can be used in most cases (although this command is not fully supported). Now suppose that we wish to write further data over the top of data that has already been written to a range using an *INSERT* statement. Within Excel it is not sufficient to delete the previous data by selecting it and hitting the Delete key. If this is done, further data will be added after a blank rectangle where the deleted data used to reside. Instead, it is important to use Edit/Delete/Shift cells up within Excel, which will eliminate all traces of the previous data, and the enlarged range.

Microsoft Excel tables can be created and opened by only one user at a time. However, the "Read Only" option available in the Excel driver options allows multiple users to read from the same .xls files.

When first experimenting with acquiring or writing data via ODBC it is tempting to use short names for column headings. This can lead to horrible-to-diagnose errors if you inadvertently use an SQL keyword. We strongly recommend that you use names like “myParameters”, or “myParams”, or “myTime”, which will not clash with SQL reserved keywords.

11.5 Control parameters

The following parameters are defined by *mmodbc*:

All parameters can be accessed with the Mosel function `getparam`, and those that are not marked read-only in the list below may be set using the procedure `setparam`.

Example:

```
setparam("SQLverbose", true)    ! Enable message printing by the ODBC driver
csize:=getparam("SQLcolsize")   ! Get the maximum string length
setparam("SQLconnection", 3)    ! Select the connection number 3
```

SQLautocommit

Description When this parameter is set to `true` (the default), any change to the database is sent immediately. Otherwise, if transactions are supported by the database, changes are retained until a call to `SQLcommit` (commit changes) or `SQLrollback` (discard changes) is issued. The value of this parameter is used at the time the database is open with `SQLconnect`: once connection is established, changing this parameter has no impact on the existing connections (*i.e.* they remain in their initial transaction mode)

Type Boolean, read/write

Values
`true` Enable auto commit mode.
`false` Disable auto commit mode (*i.e.* transactions).

Default value `true`

Affects routines `SQLconnect`.

Module mmodbc

SQLautondx

Description Enable automatic indexation of arrays.

Type Boolean, read/write

Values
`true` Enable automatic indexation.
`false` Disable automatic indexation.

Default value `false`

Note Automatic indexation affects handling of arrays in SQL queries. It can be used only on 1-dimension arrays indiced by ranges: when this mode is enabled indices are not imported or exported, only array values are exchanged with the database. For reading, the initial index value is taken from the parameter `SQLfirstndx` and incremented at each iteration. When writing all cells of the arrays are exported.

Affects routines `SQLexecute`.

See also `SQLfirstndx`.

Module mmodbc

SQLbufsize

Description Size in kilobytes of the buffer used for exchanging data between Mosel and the ODBC driver.

Type Integer, read/write

Values At least 1

Default value 4 on Posix systems and 8 on Windows

Affects routines `SQLexecute`, `SQLreadstring`.

Module mmodbc

SQLcolsize

Description Maximum length of strings accepted to exchange data, anything exceeding this size is cut off.

Type Integer, read/write

Values At least 8

Default value 64

Affects routines `SQLexecute`, `SQLreadstring`.

Note The column size is expressed in bytes when using an ANSI interface (with a multibyte encoding a single character may occupy more than one byte) and in characters when using a Unicode interface. When exporting text strings to the database and the column size is significantly too small the resulting cells might be empty.

See also `SQLtruncsize`.

Module mmodbc

SQLconnection

Description Identification number of the active ODBC connection. By changing the value of this parameter, it is possible to work with several connections simultaneously.

Type Integer, read/write

Affects routines `SQLdisconnect`, `SQLexecute`, `SQLreadinteger`.`SQLreadreal`, `SQLreadstring`.

Set by routines `SQLconnect`.

Module mmodbc

SQLdebug

Description When this parameter is set to `true`, `SQLverbose` is also enabled and any SQL request sent to ODBC is displayed to the error stream before execution. This option is ignored if the model is not compiled with debug information.

Type Boolean, read/write

Values

`true`	Enable debug mode.
`false`	Disable debug mode.

Default value `false`

See also `SQLverbose`.

Module mmodbc

SQLdm

Description Driver manager currently used.

Type Integer, read only

Values

`<0`	No driver manager available (Unix/Linux).
`0`	Unspecified (manager not loaded dynamically).
`1`	iODBC.
`2`	unixODBC.

Note A negative value for this parameter indicates that no driver manager could be found on the system. As a consequence only the integrated SQLite driver can be accessed.

Module mmodbc

SQLextn

Description Enable/Disable extended syntax.

Type Boolean, read/write

Values

`true`	Enable extended syntax.
`false`	Disable extended syntax.

Default value `true`

Affects routines `SQLconnect`, `SQLexecute`.

Module mmodbc

SQLfirstndx

Description Initial index value for an automatic indexation.

Type Integer, read/write

Default value 1

Affects routines `SQLexecute`.

See also `SQLautondx`.

Module mmodbc

SQLndxcol

Description Indicates whether the first columns of each row must be interpreted as indices in all cases. Setting it to the value `false` might be useful, for example, if one is trying to access a non-relational table, perhaps a dense spreadsheet table. Note this mode can be enabled only if at least the last dimension of each array is of fixed size.

Type Boolean, read/write

Values

`true` Interpret the first columns of each row as indices.

`false` Do not interpret the first columns of each row as indices.

Default value `true`

Affects routines `SQLexecute`, `SQLreadinteger`.`SQLreadreal`, `SQLreadstring`.

Module mmodbc

SQLrowcnt

Description Number of lines affected by the last SQL command.

Type Integer, read only

Set by routines `SQLexecute`, `SQLreadinteger`.`SQLreadreal`, `SQLreadstring`.

See also `SQLrowxfr`.

Module mmodbc

SQLrowxfr

Description Number of lines transferred during the last SQL command.

Type Integer, read only

Set by routines `SQLexecute`, `SQLreadinteger`.`SQLreadreal`, `SQLreadstring`.

See also `SQLrowcnt`.

Module mmodbc

SQLsuccess

Description Indicate whether the last SQL command has been executed successfully.

Type Boolean, read only

Values
`true` Succes.
`false` Error.

Set by routines All ODBC functions.

Module mmodbc

SQLtruncsize

Description Length of the largest string that has been truncated.

Type Integer, read only

Note When exporting text to the database all strings must fit into the predefined column size (`SQLcolsize`). If strings are truncated due to this limit the operation status is set to `false` (see `SQLsuccess`) and this parameter receives the size that should be used to avoid any truncation.

Set by routines `SQLexecute`.

See also `SQLsuccess`, `SQLcolsize`.

Module mmodbc

SQLverbose

Description Enable/disable message printing by the ODBC driver.

Type Boolean, read/write

Values
`true` Enable message printing.
`false` Disable message printing.

Default value `true`

Module mmodbc

11.6 Procedures and functions

This section lists in alphabetical order the functions and procedures that are provided by the *mmodbc* module.

SQLcolumns

Purpose

Get the columns of a given table.

Synopsis

```
function SQLcolumns(t:string,cname:array(range) of
       string,cstype:array(range) of string):integer
function SQLcolumns(t:string,cname:array(range) of
       string,citype:array(range) of integer):integer
function SQLcolumns(t:string,cname:array(range) of string):integer
```

Arguments

`t`	The table name
`cname`	An array of strings to return the column names
`cstype`	An array of strings to return the column types (textual representation)
`citype`	An array of integers to return the column types (type codes)

Return value

Number of columns.

Example

The following example displays the names and types of columns of table 'dtt':

```
declarations
 CR:range
 cname:dynamic array(CR) of string
 ctype:dynamic array(CR) of string
end-declarations

nbc:=SQLcolumns("dtt",cname,ctype)
write("Table 'dtt' has columns:")
forall(c in 1..nbc) write(' ',cname(c),'(',ctype(c),')')
writeln
```

Related topics

SQLtables, SQLprimarykeys, SQLindices.

Module

mmodbc

SQLcommit

Purpose

Terminate the current transaction by committing any pending changes.

Synopsis

```
procedure SQLcommit
```

Further information

If the database supports transactions and the connection has been created in manual commit mode (see `SQLautocommit`), all changes to the database are recorded as a transaction. This procedure *commits* all pending changes corresponding to the current transaction and starts a new transaction.

Related topics

`SQLrollback`.

Module

mmodbc

SQLconnect

Purpose

Connect to a database.

Synopsis

```
procedure SQLconnect(s:string|text)
```

Argument

`s` Connection string

Example

The following connects to the MySQL database ‘test’ as the user ‘yves’ with the password ‘DaSH’:

```
SQLconnect("DSN=mysql;DB=test;UID=yves;PWD=DaSH")
```

Open the database `mydata.sqlite` with the integrated SQLite engine:

```
SQLconnect("mydata.sqlite")
```

Further information

1. This procedure establishes a connection to the database defined by the given connection string. If extended mode is in use (default) and the ODBC driver manager publishes its driver list, the connection string may be reduced to a file name as long as this name allows identification of the required driver (by using the filename extension).

2. Both *Unicode* and *ANSI* ODBC interfaces are supported. By default the Unicode interface is used on Windows and the ANSI interface is selected on Posix systems. It is possible to choose the interface by using the `"enc:"` file name prefix: any of the UTF encodings (except UTF-8) will enable the Unicode interface. Otherwise the ANSI interface is selected using the specified encoding. For instance for using the ANSI interface under Windows with an Access database: `"enc:sys,mydb.mdb"`. Similarly, to use the Unicode interface of MySQL on a Unix machine, the connection strings looks like: `"enc:wchar,DSN=mysql;DB=test"`.

3. It is possible to open several connections but the connection established last becomes active. Each connection is assigned an identification number which can be obtained by getting the value of the parameter `SQLconnection` after this procedure has been executed. This parameter can also be used to change the active connection.

4. ODBC drivers are not necessarily executed from the same working directory as the model. As a consequence, a driver expecting a file as data source may not be able to locate the file if its name is relative to the current directory (*e.g.* `"DSN=Microsoft Access Driver; DBQ=mydb.mdb"`). The use of the function `expandpath` from `mmsystem` allows to avoid this problem by generating an absolute path name for the given name (*e.g.* `"DSN=Microsoft Access Driver; DBQ="+expandpath("mydb.mdb")`).

5. When Mosel is running in restricted mode (see Section 1.3.4), connections using a file name are not possible if restriction `NoRead` or `NoWrite` is active and connections using a DSN are disabled by restriction `NoDB`.

6. The embedded SQLite database engine is selected when specifying a file name with extension `".db"`, `".db3"`, `".sqlite"` or `".sqlite3"`. The driver may also be selected with the help of an extended connection string starting with the `DRIVER` keyword and using `"mmsqlite"` as the driver name. In this case the option `DB` has to be set in order to select the database file and `READONLY` may also be added to open the database read-only. The option `TIMEOUT` will define the *busy timeout* for the connection: this is an amount of time (in milliseconds) indicating for how long SQLite will try to execute a query when the database is locked (by default the query fails if the database is already used by a concurrent connection). A typical connection string for this SQLite driver is therefore of the form: `"DRIVER=mmsqlite;READONLY=FALSE;TIMEOUT=0;DB=mydata.db"` (that is the same as `"mydata.db"`). When using this syntax a temporary database can be created by using an empty file name and an in-memory database is generated if the file name is `":memory:"`.

Related topics

`SQLdisconnect`.

Module

mmodbc

SQLdataframe

Purpose

Retrieve a dataframe of an SQL query.

Synopsis

```
procedure SQLdataframe(query: string|text, dfrm: array(R:range, C:set of
      string))
```

Arguments

`query` SQL query

`dfrm` An array to receive the dataframe

Example

The example shows how to populate an array of type *any* from a join of two tables.

```
declarations
  DFT:array(RT:range,CST:set of string) of text
  DFA:array(RA:range,CSA:set of string) of any
end-declarations
SQLdataframe("select * from mytesttable", DFT)
writeln("Field indices: ", CST)

SQLdataframe("select * from mytesttable inner join anothertable " +
             "on id=customer", DFA)
writeln("Field indices: ", CSA)
writeln("Number of data records (rows): ", RA.size)
```

Further information

1. This procedure retrieves the *dataframe* associated to an SQL query: lines of the result set are numbered starting from 1 (index set `R`) and columns (index set `C`) are named after the corresponding column names of the result set (if a column has no name a unique identifier is generated by the routine), the type of the output array is expected to be compatible with the columns of the result set.
2. The routine supports union types (like `any`), this will be the preferred approach when getting the dataframe from a query for which no type information is available. Otherwise the data received from the database is cast to the type of the provided array (this may lead to invalid data for instance if the database returns some textual information while the array if of a numerical type).

Related topics

`SQLexecute`

SQLdisconnect

Purpose

Terminate the active database connection.

Synopsis

```
procedure SQLdisconnect
```

Further information

The active connection can be accessed or changed by setting the control parameter `SQLconnection`.

Related topics

`SQLconnect`.

Module

mmodbc

SQLexecute

Purpose

Execute an SQL command.

Synopsis

```
procedure SQLexecute(s:string|text)
procedure SQLexecute(s:string|text, a:array)
procedure SQLexecute(s:string|text, l:list)
procedure SQLexecute(s:string|text, m:set)
procedure SQLexecute(s:string|text, lp:list, a:array)
procedure SQLexecute(s:string|text, lp:list, l:list)
procedure SQLexecute(s:string|text, lp:list, m:set)
```

Arguments

`s`	SQL command to be executed
`a`	An array
`l`	A list
`m`	A set
`lp`	A list of parameters

Example

The following example contains four `SQLexecute` statements performing the following tasks:

- Get all different values of the column `color` in the table `pricelist`.
- Initialize the arrays `colors` and `prices` with the values of the columns `color` and `price` of the table `pricelist`.
- Create a new table `newtab` in the active database with 2 columns, `ndx` and `price`.
- Add data entries to table `newtab`.

```
declarations
 prices: array(1001..1004) of real
 colors: array(1001..1004) of string
 allcolors: set of string
end-declarations

SQLexecute("select color from pricelist", allcolors)
SQLexecute("select articlenum,color,price from pricelist",
                                                  [colors,prices])
SQLexecute("create table newtab (ndx integer, price double)")
SQLexecute("insert into newtab (ndx, price) values (?,?)", prices)
```

Further information

1. This procedure executes the given SQL command. The user is referred to the documentation of the database driver he is using for more information about the commands that are supported by it. Note that if extended syntax is in use (default), parameters usually noted '?' in normal SQL queries may be numbered (like '?1','?2',...) in order to control in which order are mapped columns of data source table to Mosel arrays. This feature is especially useful when writing 'update' queries for which indices must appear after values (*e.g.* `"update mytable set datacol=?2 where ndxcol=?1"`).

2. For output commands (like `insert into`) this procedure accepts arrays, sets and lists of basic types (integer, real, string or Boolean) as well as module types for which from/to string conversions are available. Record types composed of scalars or other records can also be used (the fields that cannot be handled are silently ignored). It is also possible to use a list of arrays of basic types (all arrays must be indexed by the same sets) or a list of scalar elements of different basic or module types.

3. For input commands (like `select from`) the same restrictions apply for arrays,lists and list of arrays but sets must be of a basic type.

4. The form using an extra list argument will be used with input commands requiring parameters: the list defines the value of the parameters.

Related topics

`SQLupdate`, `SQLreadinteger`, `SQLreadreal`, `SQLreadstring`, `SQLdataframe`.

Module

mmodbc

SQLparam

Purpose

Generate an SQL parameter.

Synopsis

```
function SQLparam(i:integer):SQLparameter
function SQLparam(r:real):SQLparameter
function SQLparam(s:string):SQLparameter
```

Arguments

`i`	The initial value as an integer
`r`	The initial value as a real
`s`	The initial value as a string

Return value

SQL parameter suitable for SQL routines.

Example

The following calls a procedure named `myproc` using 3 parameters. The first one is an input string parameter (`'hello'`), the second is an input/output integer parameter (`10`) and the last one is an output string parameter. The procedure returns a result set that `mmodbc` will use to initialise `result`. After execution of the query, the new values of the 2 input/output parameters set by the procedure may be displayed using the appropriate SQLgetparam routines.

```
SQLexecute("CALL myproc(?,?,?)",
           ['hello',SQLparam(10),SQLparam("")],result)
writeln("P1=",SQLgetiparam(1))
writeln("P2=",SQLgetsparam(2))
```

Further information

1. This routine can only be used in a list of parameters for an SQL query: it defines an input/output parameter. The input value of the parameter is provided via the argument function (an integer, a real or a string) and the output value (set by the database during the execution of the query) can be retrieved using one of the `SQLgetparam` functions.
2. SQL parameters are typed: the type of the parameter is deduced from its initial values (passed to the `SQLparam` function).

Related topics

`SQLexecute`, `SQLreadreal`, `SQLreadstring`, `SQLreadinteger`, `SQLgetparam`.

Module

mmodbc

SQLgetparam

Purpose

Get the value of an SQL parameter.

Synopsis

```
function SQLgetiparam(n:integer):integer
function SQLgetrparam(n:integer):real
function SQLgetsparam(n:integer):string
```

Argument

`n` Parameter number (≥ 1)

Return value

The value of the corresponding parameter.

Further information

1. This routine can be used after a query using input/output SQL parameters has been executed to retrieve the values of the parameters.
2. Each of the 3 functions is associated to a specific type: for instance `SQLgetiparam` will return values only for integer parameters.

Related topics

`SQLparam`.

Module

mmodbc

SQLindices

Purpose

Get the list of indices of a given table.

Synopsis

```
procedure SQLindices(t:string,ls:list of string)
```

Arguments

`t`	The table name
`ls`	A list of strings to return the index names

Further information

The provided list is reset.

Related topics

`SQLtables`, `SQLcolumns`, `SQLprimarykeys`.

Module

mmodbc

SQLprimarykeys

Purpose

Get the list of primary keys of a given table.

Synopsis

```
procedure SQLprimarykeys(t:string,ls:list of string)
procedure SQLprimarykeys(t:string,li:list of integer)
```

Arguments

`t`	The table name
`ls`	A list of strings to return the column names
`li`	A list of strings to return the column numbers

Further information

The provided list is reset.

Related topics

`SQLtables`, `SQLcolumns`, `SQLindices`.

Module

mmodbc

SQLreadinteger

Purpose

Read an integer value from a database.

Synopsis

```
function SQLreadinteger(s:string|text):integer
function SQLreadinteger(s:string|text,p:list):integer
```

Arguments

`s`	SQL command for selecting the value to be read
`p`	A list of SQL parameters

Return value

Integer value read or 0.

Example

The following gets the article number of the first data item in table `pricelist` for which the field `color` is set to `blue`:

```
i:=SQLreadinteger(
       "select articlenum from pricelist where color=blue")
```

Further information

1. `0` is returned if no integer value can be found.
2. If the given SQL selection command does not denote a single value, the first value to which the selection criterion applies is returned.
3. The second argument can be used to specify SQL parameter values if the SQL query contains parameter markers.

Related topics

`SQLexecute`, `SQLreadreal`, `SQLreadstring`.

Module

mmodbc

SQLreadreal

Purpose

Read a real value from a database.

Synopsis

```
function SQLreadreal(s:string|text):real
function SQLreadreal(s:string|text,p:list):real
```

Arguments

`s`	SQL command for selecting the value to be read
`p`	A list of SQL parameters

Return value

Real value read or 0.

Example

The following returns the price of the data item with index 2 in table `newtab`:

```
r:=SQLreadreal("select price from newtab where ndx=2")
```

Further information

1. `0` is returned if no real value can be found.
2. If the given SQL selection command does not denote a single value, the first value to which the selection criterion applies is returned.
3. The second argument can be used to specify SQL parameter values if the SQL query contains parameter markers.

Related topics

`SQLexecute`, `SQLreadinteger`, `SQLreadstring`.

Module

mmodbc

SQLreadstring

Purpose

Read a string from a database.

Synopsis

```
function SQLreadstring(s:string|text):string
function SQLreadstring(s:string|text,p:list):string
```

Arguments

`s`	SQL command for selecting the string to be read
`p`	A list of SQL parameters

Return value

String read or empty string.

Example

The following retrieves the color of the (first) data item in table `pricelist` with article number 1004:

```
s:=SQLreadstring(
       "select color from pricelist where articlenum=1004")
```

Further information

1. The empty string is returned if no real value can be found.
2. If the given SQL selection command does not denote a single entry, the first string to which the selection criterion applies is returned.
3. The second argument can be used to specify SQL parameter values if the SQL query contains parameter markers.

Related topics

`SQLexecute`, `SQLreadinteger`, `SQLreadreal`.

Module

mmodbc

SQLrollback

Purpose

Terminate the current transaction by discarding any pending changes.

Synopsis

```
procedure SQLrollback
```

Further information

If the database supports transactions and the connection has been created in manual commit mode (see `SQLautocommit`), all changes to the database are recorded as a transaction. This procedure discards all pending changes corresponding to the current transaction and starts a new transaction.

Related topics

`SQLcommit`.

Module

mmodbc

SQLtables

Purpose

Get the list of tables available in the database.

Synopsis

```
procedure SQLtables(l:list of string)
```

Argument

`l` A list of strings to return the table names

Further information

This procedure retrieves the list of tables available in the current database. The provided list is reset.

Related topics

`SQLcolumns`, `SQLprimarykeys`, `SQLindices`.

Module

mmodbc

SQLupdate

Purpose

Update the selected data with the provided array(s).

Synopsis

```
procedure SQLupdate(s:string|text, a:array)
procedure SQLupdate(s:string|text, la:list)
```

Arguments

`s`	An SQL 'SELECT' command
`a`	An array of one of the basic types (integer, real, string or Boolean)
`la`	A list of arrays of basic types (integer, real string or Boolean)

Example

The following example initializes the array `prices` with the values of the table `pricelist`, changes some values in the array and finally, updates the date in the table `pricelist`.

```
declarations
 prices: array(1001..1004) of real
end-declarations
SQLexecute("select articlenum,price from pricelist", prices)
prices(1002):=prices(1002)*0.9; prices(1003):=prices(1003)*0.8
SQLupdate("select articlenum,price from pricelist", prices)
```

Further information

This procedure updates the data selected by an SQL command (usually 'SELECT') with an array or tuple of arrays. This procedure is available only if the data source supports positioned updates (for instance, MS Access does but MS Excel does not). An IO error will be raised if the required functionality is not available.

Related topics

`SQLexecute`.

Module

mmodbc

11.7 I/O drivers

In order to simplify access to ODBC enabled data sources, this module provides a driver designed to be used in `initializations` blocks for both reading and writing data.

11.7.1 Driver `odbc`

```
odbc:[debug;][noindex;][colsize=#;][bufsize=#;]DSN
```

The driver can only be used in 'initializations' blocks. The Data Source Name to use has to be given in the opening part of the block. Before the DSN, the following options may be stated:

`debug` to execute the block in debug mode (to display what SQL queries are produced). This option is ignored if the model is not compiled with debug information,

`noindex` to indicate that only data (no indices) are transferred between the data source and Mosel. By default, the first columns of each table are interpreted as index values for the array to be transferred. This behaviour is changed by this option,

`colsize=c` to set the size of a text column (default 64 characters),

`bufsize=c` to set the size of the data buffer in kilobytes (default 4).

In the block, each label entry is understood as a table name optionally followed by a list of column names in brackets (*e.g.* `"my_table(col1,col2)"`). All columns are used if no list of names is specified. Note that, before the table name, one can add option `noindex` to indicate that for this particular entry indices are not used.

Example:

```
initializations from "mmodbc.odbc:auction.db3"
 NWeeks as "PARAMS(Weeks)"      ! Initialize `NWeeks' with column `Weeks'
                                ! of table `PARAMS'
 BPROF as "noindex;BPROFILE"    ! Initialize `BPROF' with table `BPROFILE'
                                ! all columns being data (no indices)
end-initializations
```

CHAPTER 12

mmquad

The *mmquad* module extends the Mosel language with a new type for representing quadratic expressions.To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmquad'
```

The first section presents the new functionality for the Mosel language that is provided by *mmquad*, namely the new type `qexp` and a set of subroutines that may be applied to objects of this type.

Via the inter-module communication interface, the module *mmquad* publishes several of its library functions. These are documented in the second section. By means of an example it is shown how the functions published by *mmquad* can be used in another module for accessing quadratic expressions and working with them.

12.1 New functionality for the Mosel language

12.1.1 The type `qexp` and its operators

The module *mmquad* defines the type `qexp` to represent quadratic expressions in the Mosel Language. As shown in the following example, *mmquad* also defines the standard arithmetic operations that are required for working with objects of this type. By and large, these are the same operations as for linear expressions (type `linctr` of the Mosel language) with in addition the possibility to multiply two decision variables or one variable with itself. For the latter, the exponential notation `x^2` may be used (assuming that `x` is of type `mpvar`).

12.1.1.1 Example: using *mmquad* for Quadratic Programming

Quadratic expressions as defined with the help of *mmquad* may be used to define quadratic objective functions for Quadratic Programming (QP) or Mixed Integer Quadratic Programming (MIQP) problems. The Xpress-Optimizer module *mmxprs* for instance accepts expressions of type `qexp` as arguments for its optimization subroutines `minimize` and `maximize`, and for the procedure `loadprob` (see also the *mmxprs* Reference Manual). The following

```
model "Small MIQP example"
 uses "mmxprs", "mmquad"

 declarations
  x: array(1..4) of mpvar
  Obj: qexp
 end-declarations

! Define some linear constraints
 x(1) + 2*x(2) - 4*x(4) >= 0
 3*x(1) - 2*x(3) - x(4) <= 100
```

```
 x(1) + 3*x(2) + 3*x(3) - 2*x(4) >= 10
 x(1) + 3*x(2) + 3*x(3) - 2*x(4) <= 30

 2 <= x(1); x(1) <= 20
 x(2) is_integer; x(3) is_integer
 x(4) is_free

! The objective function is a quadratic expression
 Obj:= x(1) + x(1)^2 + 2*x(1)*x(2) + 2*x(2)^2 + x(4)^2

! Solve the problem and print its solution
 minimize(Obj)

 writeln("Solution: ", getobjval)
 forall(i in 1..4) writeln(getsol(x(i)))
end-model
```

12.1.2 Procedures and functions

The module *mmquad* overloads certain subroutines of the Mosel language, replacing an argument of type `linctr` by the type `qexp`.

`exportprob`	Export a quadratic problem to a file.	p. 385
`getsol`	Get the solution value of a quadratic expression.	p. 386

exportprob

Purpose

Export a quadratic problem to a file.

Synopsis

```
procedure exportprob(options:integer, filename:string, obj:qexp)
procedure exportprob(filename:string, obj:qexp)
```

Arguments

`options` File format options:

`EP_MIN`	LP format, minimization
`EP_MAX`	LP format, maximization
`EP_MPS`	MPS format
`EP_STRIP`	Use scrambled names
`EP_HEX`	Ouput numbers in hexadecimal when using MPS format

`filename` Name of the output file; if empty, output printed to standard output (screen)

`obj` Objective function (quadratic expression)

Example

The following example prints the problem to screen using the default format, and then exports the problem in LP-format to the file `prob1.lp` maximizing constraint `Profit`:

```
uses "mmquad"
declarations
 Profit:qexp
end-declarations
 ...
exportprob(0, "", Profit)
exportprob(EP_MAX, "prob1", Profit)
```

Further information

This procedure overloads the `exportprob` subroutine of Mosel to handle quadratic objective functions. It exports the current problem to a file, or if no file name is given (empty string `""`), prints it on screen. If the given filename has no extension, Mosel appends `.lp` to it for LP format files and `.mat` for MPS format.

Module

mmquad

getsol

Purpose

Get the solution value of a quadratic expression.

Synopsis

```
function getsol(q:qexp):real
```

Argument

`q` A quadratic expression

Return value

Solution value or 0.

Example

```
uses "mmquad"
declarations
 x,y,z: mpvar
 Profit:qexp
end-declarations
  ...                          ! (Define and solve the problem)
writeln("Profit value: ", getsol(Profit))
writeln("Evaluation of an expression: ", getsol(x*y+5*z^2))
```

Further information

This function returns the evaluation of a given quadratic expression using the current (primal) solution values of its variables. Note that the solution value of a variable is 0 if the problem has not been solved or the variable is not contained in the problem that has been solved.

Module

mmquad

12.2 Published library functions

The module *mmquad* publishes some of its library functions via the service IMCI for use by other modules (see the Mosel Native Interface Reference Manual for more detail about services). The list of published functions is contained in the interface structure `mmquad_imci` that is defined in the module header file `mmquad.h`.

From another module, the context of *mmquad* and its communication interface can be obtained using functions of the Mosel Native Interface as shown in the following example.

```
static XPRMnifct mm;
XPRMcontext mmctx;
XPRMdsolib dso;
mmquad_imci mq;
void **quadctx;

dso=mm->finddso("mmquad");            /* Retrieve the mmquad module*/
quadctx=*(mm->getdsoctx(mmctx, dso, (void **)(&mq)));
                                      /* Get the module context and the
                                         communication interface of mmquad */
```

Typically, a module calling functions that are provided by *mmquad* will include this module into its list of dependencies in order to make sure that *mmquad* will be loaded by Mosel at the same time as the calling module. The “dependency” service of the Mosel Native Interface has to be used to set the list of module dependencies:

```
static const char *deplist[]={"mmquad",NULL};   /* Module dependency list */

static XPRMdsoserv tabserv[]=                   /* Table of services */
    {
     {XPRM_SRV_DEPLST, (void *)deplist}
    };
```

12.2.1 Complete module example

If the Mosel procedures `write` / `writeln` are applied to a quadratic expression, they print the address of the expression and not its contents (just the same would happen for types `mpvar` or `linctr`). Especially for debugging purposes, it may be useful to be able to display some more detailed information. The module example printed below defines the procedure `printqexp` that displays all the terms of a quadratic expression (for simplicity’s sake, we do not retrieve the model names for the variables but simply print their addresses).

```
model "Test printqexp module"
 uses "printqexp"

 declarations
  x: array(1..5) of mpvar
  q: qexp
 end-declarations

 printqexp(10+x(1)*x(2)-3*x(3)^2)

 q:= x(1)*(sum(i in 1..5) i*x(i))
 printqexp(q)
end-model
```

Note that in this model it is not necessary to load explicitly the *mmquad* module. This will be done by the *printqexp* module because *mmquad* appears in its dependency list.

```
#include <stdlib.h>
```

```
#include "xprm_ni.h"
#include "mmquad.h"

/**** Function prototypes ****/
static int printqexp(XPRMcontext ctx,void *libctx);

/**** Structures for passing info to Mosel ****/
/* Subroutines */
static XPRMdsofct tabfct[]=
    {
     {"printqexp", 1000, XPRM_TYP_NOT, 1, "|qexp|", printqexp}
    };

static const char *deplist[]={"mmquad",NULL};   /* Module dependency list */

/* Services */
static XPRMdsoserv tabserv[]=
    {
     {XPRM_SRV_DEPLST, (void *)deplist}
    };

/* Interface structure */
static XPRMdsointer dsointer=
    {
     0,NULL, sizeof(tabfct)/sizeof(XPRMdsofct),tabfct,
     0,NULL, sizeof(tabserv)/sizeof(XPRMdsoserv),tabserv
    };

/**** Structures used by this module ****/
static XPRMnifct mm;         /* For storing Mosel NI function table */


/**** Initialize the module library just after loading it ****/
DSO_INIT printqexp_init(XPRMnifct nifct, int *interver,int *libver, XPRMdsointer **interf)
{
 mm=nifct;                  /* Save the table of Mosel NI functions */
 *interver=MM_NIVERS;       /* Mosel NI version */
 *libver=MM_MKVER(0,0,1);   /* Module version */
 *interf=&dsointer;         /* Pass info about module contents to Mosel */

 return 0;
}

/**** Implementation of "printqexp" ****/
static int printqexp(XPRMcontext ctx, void *libctx)
{
 XPRMdsolib dso;
 mmquad_imci mq;
 mmquad_qexp q;
 void **quadctx;
 void *prev;
 XPRMmpvar v1,v2;
 double coeff;
 int nlin,i;

 dso=mm->finddso("mmquad");    /* Retrieve reference to the mmquad module*/
 quadctx=*(mm->getdsoctx(ctx, dso, (void **)(&mq)));
                               /* Get the module context and the
                                  communication interface of mmquad */

 q = XPRM_POP_REF(ctx);        /* Get the quadratic expression from the stack */

                               /* Get the number of linear terms */
 mq->getqexpstat(ctx, quadctx, q, &nlin, NULL, NULL, NULL);
                               /* Get the first term (constant) */
 prev=mq->getqexpnextterm(ctx, quadctx, q, NULL, &v1, &v2, &coeff);
 if(coeff!=0) mm->printf(ctx, "%g ", coeff);
 for(i=0;i<nlin;i++)           /* Print all linear terms */
 {
```

```
 prev=mq->getqexpnextterm(ctx, quadctx, q, prev, &v1, &v2, &coeff);
 mm->printf(ctx,"%+g %p ", coeff, v2);
}
while(prev!=NULL)             /* Print all quadratic terms */
{
 prev=mq->getqexpnextterm(ctx, quadctx, q, prev, &v1, &v2, &coeff);
 mm->printf(ctx,"%+g %p * %p ", coeff, v1, v2);
}
mm->printf(ctx,"\n");

 return XPRM_RT_OK;
}
```

12.2.2 Description of the library functions

clearqexpstat	Free the memory allocated by getqexpstat.	p. 392
getqexpnextterm	Enumerate the terms of a quadratic expression.	p. 393
getqexpsol	Evaluate a quadratic expression.	p. 390
getqexpstat	Get information about a quadratic expression.	p. 391

getqexpsol

Purpose

Return an evaluation of a quadratic expression based on the current solution.

Synopsis

```
double getqexpsol(XPRMctx ctx, void *quadctx, mmquad_qexp q);
```

Arguments

`ctx`	Mosel's execution context
`quadctx`	Context of *mmquad*
`q`	Reference to a quadratic expression

Return value

An evaluation of the expression on the current solution.

Further information

This function returns an evaluation of a quadratic expression based on last solution obtained from the optimizer. This is the function called when using `getsol` on a quadratic expression from a Mosel program.

Module

mmquad

getqexpstat

Purpose

Get information about a quadratic expression.

Synopsis

```
int getqexpstat(XPRMctx ctx, void *quadctx, mmquad_qexp q, int *nblin, int
      *nbqd, int *changed, XPRMmpvar **lsvar);
```

Arguments

`ctx` Mosel's execution context

`quadctx` Context of *mmquad*

`q` Reference to a quadratic expression

`nblin` Pointer to which the number of linear terms is returned (may be `NULL`)

`nbqd` Pointer to which the number of quadratic terms is returned (may be `NULL`)

`changed` Pointer to which the change flag is returned (may be `NULL`). Possible values of this flag:

- `1` The expression `q` has been modified since the last call to this function
- `0` Otherwise

`lsvar` Pointer to which is returned the table of variables that appear in the quadratic expression `q` (may be `NULL`)

Return value

Total number of terms in the expression.

Further information

This function returns in its arguments information about a given quadratic expression. Any of these arguments may be `NULL` to indicate that the corresponding information is not required. The last entry of the table `lsvar` is `NULL` to indicate its end. This table is allocated by the module *mmquad*, it must be freed by the next call to this function or with function `clearqexpstat`.

Module

mmquad

clearqexpstat

Purpose

Free the memory allocated by `getqexpstat`.

Synopsis

```
void clearqexpstat(XPRMctx ctx, void *quadctx);
```

Arguments

`ctx`	Mosel's execution context
`quadctx`	Context of *mmquad*

Further information

A call to this function frees the table of variables that has previously been allocated by a call to function `getqexpstat`.

Related topics

`getqexpstat`.

Module

mmquad

getqexpnextterm

Purpose

Enumerate the list of terms contained in a quadratic expression.

Synopsis

```
void *getqexpnextterm(XPRMctx ctx, void *quadctx, mmquad_qexp q, void *prev,
      XPRMmpvar *v1, XPRMmpvar *v2, double *coeff);
```

Arguments

`ctx`	Mosel's execution context
`quadctx`	Context of *mmquad*
`q`	Reference to a quadratic expression
`prev`	Last value returned by this function. Should be `NULL` for the first call
`v1,v2`	Pointers to return the decision variable references for the current term
`coeff`	Pointer to return the coefficient of the current term

Return value

The value to be used as `prev` for the next call o `NULL` when all terms have been returned.

Example

The following displays the terms of a quadratic expression:

```
void dispqexp(XPRMcontext ctx, mmquad_qexp q)
{
 void *prev;
 XPRMmpvar v1,v2;
 double coeff;
 int nlin,ct;

 mq->getqexpstat(ctx, quadctx, q, &nlin, NULL, NULL, NULL);
 ct=0;
 prev=mq->getqexpnextterm(ctx, quadctx, q, NULL, &v1, &v2, &coeff);
 mm->printf(ctx, "%g ", coeff);
 while(prev!=NULL) {
  prev=mq->getqexpnextterm(ctx, quadctx, q, prev, &v1, &v2, &coeff);
  if(ct<nlin) { mm->printf(ctx,"%+g %p", coeff, v2); ct++; }
  else mm->printf(ctx,"%+g %p * %p", coeff, v1, v2);
 }
 mm->printf(ctx,"\n");
}
```

Further information

This function can be called repeatedly to enumerate all terms of a quadratic expression. For the first call, the parameter `prev` must be `NULL` and the function returns the constant term of the quadratic expression (for `v1` and `v2` the value `NULL` is returned and `coeff` contains the constant term). For the following calls, the value of `prev` must be the last value returned by the function. The enumeration is completed when the function returns `NULL`.
If this function is called repeatedly, after the constant term it returns next all linear terms and then the quadratic terms.

Module

mmquad

CHAPTER 13

mmreflect

This module allows a model or package to programatically access Mosel entities whose names and types were not known at compile-time. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmreflect'
```

13.1 New functionality for the Mosel language

13.1.1 The type `iterator`

This module provides the type `iterator` for enumerating the cells of an array without referring to its individual indices. This type acts as an *indexer* such that an entity of this type can be used as the only index of a compatible array for its dereferencing. Internally it maintains a reference to an array and a position in this array in the form of an index tuple.

Before an iterator is used it must be initialised and bound to an array with a call to `inititer` (this association may be cancelled by resetting the entity with `reset`). The status of an iterator (*e.g.* whether it has been initialised, whether the enumeration has been completed) is returned by `getstatus` and positioning it to the next available cell of the array is achieved by calling `nextcell`. The index tuple held in an iterator can be accessed with `getindices` and `setindices`. The following example shows how to copy the content of array `ar1` to array `ar2` using an iterator:

```
declarations
  ar1:dynamic array(S1:set of string,R1:range) of integer
  ar2:dynamic array(set of string,set of integer) of real
  itr:iterator
end-declarations
ar1('a',1):=10
ar1('b',1):=20

inititer(itr,ar1)           ! 'itr' is associated to 'ar1'
while(nextcell(itr)) do     ! iterate over the existing cells of 'ar1'
  ar2(itr):=ar1(itr)        ! 'itr' can be used with both 'ar1' and 'ar2'
  writeln("indices:", itr.indices)
end-do
```

Note that although the iterator `itr` is bound to array `ar1`, it can also be used to dereference `ar2` since this array is compatible with `ar1` in terms of number and type of its indexing sets.

13.1.2 The type `reflecterror`

An entity of type `reflecterror` is returned by certain functions of this module: it characterises the execution status of the function. The code and message associated to this status can be retrieved with

getcode and getmsg, no error occurred if the code is 0.

This type is defined such that an expression of type reflecterror used as a statement will cause a runtime error if the status is not null and it will be ignored otherwise. Thanks to this property a function returning an entity of this type can be used either as a function or as a procedure: in the first case error management will be handled by the model and in the second case any error will cause a program termination.

```
err:=callproc("myproc")
if err.code<>0 then
  writeln("Failed to call 'myproc' (",err.msg,")")
  exit(1)
end-if
```

13.2 Procedures and functions

callfunc, callfunclsa

Purpose

Call a public function with the given name.

Synopsis

```
function callfunc(func:string|any, retval:any):reflecterror
function callfunc(func:string|any, retval:any, p1, p2...):reflecterror
function callfunclsa(func:string|any, retval:any, lsa:list):reflecterror
```

Arguments

`func`	The name or a reference to the function to call
`retval`	Union where the result of the function call is returned
`pi`	Parameters of the function
`lsa`	List of parameters of the function

Return value

The error status as a `reflecterror`

Example

The following Mosel code:

```
public function product(i:integer,j:integer):integer
 returned:=i*j
end-function
declarations
 u:any
end-declarations

callfunc('product',u,4,4)
writeln("4*4=",u.integer)
```

produces this output:

```
4*4=16
```

Further information

1. When used with a name, this routine selects the function to call based on the provided arguments without performing any conversion (for instance, using an integer where a real is expected will not work). The execution will terminate on a runtime error if no compatible function can be found.
2. The result of the function call is returned via the parameter `retval` that must be a union compatible with the type of the function. The execution will terminate on a runtime error if the result of the call cannot be saved in the provided entity.
3. The last version of the subroutine makes it possible to pass all the subroutine parameters via a single list.
4. The execution status of the function is notified via its return value. If this value is ignored (*i.e.* the function is used as a procedure) the execution of the model will be interrupted in case of error (*e.g.* routine not found or invalid number or type of parameters).

Related topics

`callproc`

Module

mmreflect

callproc, callproclsa

Purpose

Call a public procedure with the given name.

Synopsis

```
function callproc(proc:string|any):reflecterror
function callproc(proc:string|any, p1, p2...):reflecterror
function callproclsa(proc:string|any, lsa:list):reflecterror
```

Arguments

`proc`	The name or a reference to the procedure to call
`pi`	Parameters of the procedure
`lsa`	List of parameters of the procedure

Return value

The error status as a `reflecterror`

Example

The following Mosel code:

```
public procedure myproc(i:integer)
 writeln('hello world ',i);
end-procedure

callproc('myproc',333)
```

produces this output:

```
hello world 333
```

Further information

1. When used with a name this routine selects the procedure to call based on the provided arguments without performing any conversion (for instance, using an integer where a real is expected will not work). The execution will terminate on a runtime error if no compatible procedure can be found.
2. The last version of the subroutine makes it possible to pass all the subroutine parameters via a single list.
3. The execution status of the function is notified via its return value. If this value is ignored (*i.e.* the function is used as a procedure) the execution of the model will be interrupted in case of error (*e.g.* routine not found or invalid number or type of parameters).

Related topics

`callfunc`

Module

mmreflect

findident

Purpose

Find an identifier in the dictionary.

Synopsis

```
function findident(name:string, value:any):integer
function findident(name:string, value:any, exptype:integer):integer
function findident(name:string, values:list of any):integer
```

Arguments

`name`	Identifier
`value`	Union where the value of the dictionary entry is returned
`values`	List of all entities having this name as a list of unions
`exptype`	Expected type

Return value

Aggregated type information of the returned dictionary entry, 0 if the identifier cannot be found or -1 if the value cannot be saved in the `value` variable.

Example

The following:

```
public declarations
 glbint:integer
 val:any
 procintarg=procedure(integer)
end-declarations

public procedure doit(i:integer)
 writeln("Got ",i)
end-procedure

writeln("glbint=",glbint)
if testtype(findident("glbint",val),STRUCT_REF+integer.id) then
 val.integer:=123
end-if
writeln("glbint=",glbint)

if findident("doit",val,procintarg.id)<>0 then
 val.procintarg(33)     ! Call the procedure
end-if
```

produces this output:

```
glbint=0
glbint=123
Got 33
```

Further information

1. This function returns the dictionary entry of a given identifier along with its type. The returned type information is bit encoded and includes a *type code* and a *structure* that can be decoded using `getstruct`, `geteltype` and `gettypeid`. Alternatively, `testtype` might be used to filter this value.
2. When using the second form, the function succeeds only if it can find an entity of the provided type *exptype*. Note that the value returned in this case is not necessarily *exptype* (*i.e.* the function has succeeded when its return value is positive).
3. The last form of the function makes it possible to retrieve all overloaded versions of a subroutine. As for the previous case, the function has succeeded if its return value is positive.
4. If the identifier corresponds to a global entity of a basic type (*i.e.* integer, real, boolean or string) the resulting union value will contain a reference to the actual variable and any change to its value will be applied to the global entity.

Related topics

`testtype`, `getstruct`, `geteltype`

Module

mmreflect

getallidents

Purpose

Get all identitifiers of a model.

Synopsis

```
procedure getallidents(li:list of string)
```

Argument

`li` List receiving the identifiers

Further information

When the model is compiled with debugging information both private and public identifiers are returned (otherwise only the public symbols are reported).

Related topics

`getallparams`, `getannidents`.

Module

mmreflect

getallparams

Purpose

Get all runtime parameters.

Synopsis

```
procedure getallparams(li:list of string)
```

Argument

`li` List receiving the identifiers

Related topics

`getallidents`, `getannidents`.

Module

mmreflect

getannidents

Purpose

Get all identitifiers of a model for which annotations are available.

Synopsis

```
procedure getannidents(si:set of string)
procedure getannidents(li:list of string)
```

Arguments

`si`	Set receiving the identifiers
`li`	List receiving the identifiers

Related topics

`getannotations`, applied to submodels: `getannidents`.

Module

mmreflect

getannotations

Purpose

Get model annotations associated to a given symbol.

Synopsis

```
procedure getannotations(id:string, prefix:string, si:set of string,
       ann:array(string) of string)
procedure getannotations(id:string, prefix:string, lsa:list of string)
```

Arguments

`id`	Symbol for which annotations are requested (an empty string will report global annotations)
`prefix`	Prefix filter: only annotations with a name starting with the specified prefix will be returned
`si`	Set receiving the annotation names
`ann`	Array receiving the annotation values (indexed by anootation names)
`lsa`	List receiving the annotation names and values

Example

The following code snippet implements a function to retrieve a specific annotation for the specified model entity (if several matching annotations are found the value of the first is returned):

```
public function getannot(symb:string, aname:string):string
  declarations
    l:list of string
  end-declarations
  getannotations(symb,aname,l)
  if l.size>=2 and l(1)=aname then
    returned:=l(2)
  end-if
end-function

writeln("Value of first annotation 'my.annot' for entity 'x': ",
        getannot("x","my.annot"))
writeln("Value of first global annotation 'my.annot': ",
        getannot("","my.annot"))
```

Further information

With the version taking a list, each annotation is represented by 2 entries: the first one is the annotation name and the second one its value. Note that the version returning information via an array will only report partial information in the case of annotations defined several times.

Related topics

`getannidents`, applied to submodels: `getannotations`.

Module

mmreflect

getarrval

Purpose

Get the value of a cell of an array.

Synopsis

```
function getarrval(arr:array, val:any, ...):reflecterror
function getarrval(arr:array, val:any, lsndx:list):reflecterror
```

Arguments

`arr`	An array or a union containg an array
`val`	A union reference where the value will be returned
`lsndx`	List of indices to use

Return value

The error status as a `reflecterror`

Further information

1. The procedure will use the arguments after `val` as the list of indices to use (that can be an iterator) or take the provided list `lsndx` if it is the only argument.
2. Thanks to this procedure it is possible to retrieve the value of an array cell without knowing its type. However, it is more efficient to dereference the array directly when the type is known (*e.g.* `un.array(1).integer`).
3. The execution status of the function is notified via its return value. If this value is ignored (*i.e.* the function is used as a procedure) the execution of the model will be interrupted in case of error (*e.g.* invalid number or type of indices).

Related topics

`setarrval`.

Module

mmreflect

getcode

Purpose

Get the code associated to a reflect error.

Synopsis

```
function getcode(rst:reflecterror):integer
```

Argument

`rst` A reflect error

Return value

The code associated to the error entity or `0` if no error was recorded

Related topics

`getmsg`.

Module

mmreflect

geteltype

Purpose

Get the type ID of an element of a collection.

Synopsis

```
function geteltype(a: array): integer
function geteltype(s: set): integer
function geteltype(l: list): integer
```

Arguments

`a`	An array
`s`	A set
`l`	A list

Return value

A type ID.

Example

```
public declarations
  myar: dynamic array(range,set of integer) of real
end-declarations

writeln(myar.eltype=real.id)        ! = true
```

Related topics

`geteltype`.

Module

mmreflect

getindices

Purpose

Retrieve the index tuple held in an iterator.

Synopsis

```
function getindices(it:iterator):list of any
```

Argument

`it` An iterator

Return value

The list of indices stored in the iterator or an empty list if the iterator is not in the state `ITER_READY`

Example

See example in section 13.1.1.

Further information

Trying to use this function on an unbound iterator will cause a runtime error.

Related topics

`setindices`.

Module

mmreflect

getmsg

Purpose

Get the message associated to a reflect error.

Synopsis

```
function getmsg(rst:reflecterror):string
```

Argument

`rst` A reflect error

Return value

The message associated to the error entity

Related topics

`getcode`.

Module

mmreflect

getnbargs

Purpose

Retrieve the number of arguments required by a subroutine.

Synopsis

```
function getnbargs(sbr:procedure|function):integer
```

Argument

`sbr` A reference to a subroutine or a union containing a subroutine

Return value

The number of arguments required by the subroutine

Example

See example for `getsignature`.

Related topics

`getsignature`, `getrettype`.

Module

mmreflect

getrettype

Purpose

Retrieve the return type of a subroutine.

Synopsis

```
function getrettype(sbr:procedure|function):integer
```

Argument

`sbr` A reference to a subroutine or a union containing a subroutine

Return value

The return type of the subroutine (this is 0 for a procedure)

Example

See example for `getsignature`.

Related topics

`getsignature`, `getnbargs`.

Module

mmreflect

getsignature

Purpose

Retrieve the signature of a subroutine.

Synopsis

```
function getsignature(sbr:procedure|function):string
```

Argument

`sbr` A reference to a subroutine or a union containing a subroutine

Return value

The signature of the subroutine

Example

```
public declarations
  f2: function(real, set of string):boolean
end-declarations

writeln("f takes ", getnbargs(->f2)," arguments, ",       ! = 2
  "f returns a boolean: ", getrettype(->f2)=boolean.id,   ! = true
  ", signature of f: ", getsignature(->f2))               ! = rEs
```

Further information

The signature of a subroutine is a text string characterising the types of the parameters it requires (but it does not provide information on the return type of a function). This string is empty for a subroutine not requiring any argument.

Related topics

`getnbargs`, `getrettype`.

Module

mmreflect

getstatus

Purpose

Get the status of an iterator.

Synopsis

```
function getstatus(it:iterator):integer
```

Argument

`it` An iterator

Return value

Status of the iterator:

`ITER_FREE`	Not bound to any array (initial state)
`ITER_BOUND`	Bound to an array but enumeration has not yet started
`ITER_READY`	The iterator contains a valid reference
`ITER_DONE`	Enumeration has finished

Example

```
declarations
  it: iterator
  A: hashmap array(range,string) of real
end-declarations
A(2,'a'):= 0.5; A(3,'b'):= 1.25
writeln(it.status=ITER_FREE)              ! true
inititer(it,A)
writeln(it.status=ITER_BOUND)             ! true
while (nextcell(it)) do
  writeln(it.status=ITER_READY)           ! true
  writeln('A(', it.indices, ')=', A(it))  ! A([2,'a'])=0.5  A([3,'b'])=1.25
end-do
writeln(it.status=ITER_DONE)              ! true
reset(it)
writeln(it.status=ITER_FREE)              ! true
```

Further information

An iterator can be used to dereference an array only when it is in the `ITER_READY` state.

Related topics

`inititer`, `nextcell`.

Module

mmreflect

inititer

Purpose

Initialise an iterator.

Synopsis

```
procedure inititer(it:iterator, a:array)
procedure inititer(it:iterator, a:array, sparsenum:boolean)
```

Arguments

`it`	An iterator
`a`	An array reference
`sparsenum`	Sparse enumeration (default: `true`)

Example

See example for `getstatus` and section 13.1.1.

Further information

1. This function (re)initialises an iterator by binding it to the specified array and setting its state to `ITER_BOUND`. The iterator is first reset if it was already in use.
2. The `sparsenum` argument decides whether the enumeration should select only the existing entries of the array if it is of a sparse format (this option has no effect on a dense array).

Related topics

`getstatus`, `nextcell`.

Module

mmreflect

nextcell

Purpose

Advance an iterator to the next cell of its array.

Synopsis

```
function nextcell(it:iterator):boolean
```

Argument

`it` An iterator

Return value

`true` if the iterator is positioned on a cell, `false` if the enumeration has finished

Example

See example for `getstatus` and section 13.1.1.

Further information

1. Once an iterator has been bound to an array with `inititer` this function can be called iteratively until it returns `false` in order to enumerate all cells of the associated array. The state of the iterator is set to `ITER_READY` whenever `true` is returned (*i.e.* the iterator can be used to dereference an array).
2. After this function has returned `false` the iterator is in the state `ITER_DONE`. Calling it again will have no effect and the return value will remain `false`.
3. Trying to use this function on an unbound iterator will cause a runtime error.

Related topics

`getstatus`, `inititer`.

Module

mmreflect

setarrval

Purpose

Set the value of a cell of an array.

Synopsis

```
function setarrval(arr:array, val:any, ...):reflecterror
function setarrval(arr:array, val:any, lsndx:list):reflecterror
```

Arguments

`arr`	An array or a union containing an array
`val`	Value to be assigned
`lsndx`	List of indices to use

Return value

The error status as a `reflecterror`

Further information

1. The procedure will use the arguments after `val` as the list of indices for accessing a cell of the array (this can also be an iterator) or it takes the provided list `lsndx` if this is the only argument.
2. If the provided value `val` is a string and the array is of a native type, this procedure will try to initialise the array cell from this textual representation. Otherwise the specified value must be of the same type as the array.
3. The execution status of the function is notified via its return value. If this value is ignored (*i.e.* the function is used as a procedure) the execution of the model will be interrupted in case of error (*e.g.* invalid number or type of indices).

Related topics

`getarrval`.

Module

mmreflect

setindices

Purpose

Set the index tuple of an iterator.

Synopsis

```
procedure setindices(it:iterator, lsndx:list)
procedure setindices(it:iterator, ...)
```

Arguments

`it` An iterator

`lsndx` List of indices to use

Further information

1. The procedure will use the arguments after `it` as the list of indices forming the index tuple or it takes the provided list `lsndx` if this is the only argument. After this call the iterator is in state `ITER_READY` even if the designated cell does not exist in the array.
2. This procedure will cause a runtime error if the program is trying to set indices that are not compatible with the corresponding indexing sets of the reference array (*e.g.* incompatible type or non-existent element of a finalised set).
3. Trying to use this procedure on an unbound iterator will cause a runtime error.

Related topics

`getindices`.

Module

mmreflect

testtype

Purpose

Test the return value of `findident`.

Synopsis

```
function testtype(rts:integer, props:integer):boolean
```

Arguments

`rts` Return value of `findident`

`props` Properties to test (can be combined by addition):

`STRUCT_*`	A structure (*e.g.* `STRUCT_ARRAY`)
`*.id`	A type ID (*e.g.* `integer.id`)
`EPROP_PRIV`	Entity is private
`EPROP_PUBLIC`	Entity is public
`EPROP_CONST`	Entity is constant
`EPROP_VAR`	Entity is not constant
`EPROP_RANGE`	Entity is a range set
`EPROP_GENSET`	Entity is a general set (*i.e.* not a range)
`EPROP_DENSE`	Entity is a dense array
`EPROP_SPARSE`	Entity is a sparse array
`EPROP_DYNAMIC`	Entity is a sparse dynamic array
`EPROP_HASHMAP`	Entity is a sparse hashmap array

Return value

`true` if the provided encoded type has all the requested properties

Example

```
public declarations
  Ar: dynamic array(1..10) of real
  S=1..5
  u1,u2:any
end-declarations
r1:=findident("Ar",u1)
r2:=findident("S",u2)
writeln(testtype(r1,STRUCT_ARRAY+EPROP_SPARSE))    ! true
writeln(testtype(r1,EPROP_DENSE))                  ! false
writeln(testtype(r2,EPROP_RANGE+EPROP_CONST))      ! true
writeln(testtype(r2,STRUCT_SET+integer.id))        ! true
```

Further information

1. This function checks whether an encoded type returned by `findident` corresponds to a set of properties.
2. The `props` argument cannot include more than one structure and one type ID each (all conditions must be satisfied at the same time). The function will always return `false` if it is given an invalid combination (for instance `EPROP_CONST+EPROP_VAR` or `STRUCT_SET+EPROP_DENSE` cannot succeed).

Module

mmreflect

CHAPTER 14

mmrobust

The *mmrobust* module extends the Mosel language with new types for representing robust constraints and describe the associated uncertainty sets. To use this module the following line must be included in the header of the Mosel model file:

```
uses 'mmrobust'
```

This is the reference manual of mmrobust. It is highly recommended to study the Xpress white paper on robust optimization found under docs/robust in the Xpress installation.

The first section presents the new functionality for the Mosel language provided by *mmrobust*, namely the new types `uncertain`, `robustctr` and `uncertainctr` and a set of subroutines that may be applied to objects of these types.

The following sections give detailed documentation of the subroutines (other than mathematical operators) defined by this module.

14.1 New functionality for the Mosel language

14.1.1 The problem type `mpproblem.xprs.robust`

This module exposes its functionality through an extension to the `mpproblem.xprs` problem type. As a consequence, all routines presented here are executed in the context of the current problem.

14.1.2 The type `uncertain`

An `uncertain` is a quantity whose value is not known, but carries a level of uncertainty. The type `uncertain` is used in the robust constraints of type `robctr` to express constraints that are subject to uncertainty, and in `uncertainctr` constraints that describe the set of values that the `uncertain` can take. The values of the `uncertain` quantity will take the possible worst case against the optimality and feasibility of the problem. An `uncertain` can be intuitively thought of as a variable that is not under our control, but which has a value defined by an opponent to be the worst with respect to the model.

It is important to note that an `uncertain` does not have a default lower bound of zero imposed by Mosel, in contrast to mpvars. This difference in default behavior is to reflect the most typical use cases.

An uncertain can be assigned a nominal value using the assignement operator `:=`. The working of the nominal value is discussed in the Xpress robust optimization white paper found under docs/robust in the Xpress installation.

The actual value of uncertains and robust constraints can be obtained after the solution of the robust problem through `getsol` and `getact`. The usage of `getsol` is extended as explained below.

If an uncertain `u` is used in a single robust constraint or only in the objective function, then `getsol(u)` returns one of the possible realizations of the uncertainty set that induced the optimal solution found by Mosel.

If the same uncertain is used in two robust constraints named `RCon1` and `RCon2` respectively, the optimal solution of the problem may imply that the uncertain has different values for `RCon1` and `RCon2`. Then its value can be obtained for the two constraints via the command `getsol(u,RCon1)` and `getsol(u,RCon2)`.

Finally, the left-hand side of a robust constraint (*e.g.* `RCon1`) can simply be obtained via the command `getact(RCon1)`, whereas `getsol(RCon1)` returns the evaluation of left-hand side - right-hand side.

14.1.3 The type `robustctr` and its operators

The module *mmrobust* defines the type `robustctr` to represent robust constraints in the Mosel Language. It also defines the standard arithmetic operations that are required for working with objects of this type. By and large, these are the same operations as for linear expressions (type `linctr` of the Mosel language) with additionally the possibility to include uncertain terms (*i.e.* of type `uncertain`).

14.1.4 The type `uncertainctr` and its operators

An uncertainty constraint `uncertainctr` describes the possible values of the `uncertain` data, or in other words defines the feasible set of the `uncertain`s. Intuitively, if we visualize the role of an `uncertain` as a value under the control of an opponent, then the set of `uncertainctr`s defines the limitations under which the opponent is operating when choosing the worst possible values in respect of the optimality and feasibility of the model.

14.1.5 Example: using mmrobust for solving a robust problem

Consider the following example

```
model BaseModel
uses "mmrobust";

declarations
 x, y, z : mpvar
end-declarations

 x + 2*y + 3*z <= 10

 maximize(x+y+z)

 writeln("x = ", getsol(x), "  y = ", getsol(y), "  z = ", getsol(z))

end-model
```

This problem will solve to "x = 10 y = 0 z = 0".

Let us now assume that we only know that the sum of the first two coefficients is 3, and we need a solution that is valid for all realizations within this assumption.

```
model RobustModel
uses "mmrobust";

declarations
 x, y, z : mpvar
 u, v : uncertain
end-declarations
```

```
  u*x + v*y + 3*z <= 10

  u+v <= 4

  setparam("xprs_verbose", true)
  maximize(x+y+z)

  writeln("x = ", getsol(x), "  y = ", getsol(y), "  z = ", getsol(z), "; u = ", getsol(u), "  v = ",

end-model
```

This problem will solve to "x = 2.5 y = 2.5 z = 0; u = 2 v = 2".

It is easy to check that any realization of the uncertains u and v will keep the solution vector feasible, and that it is optimal within this assumption.

14.2 Control parameters

The following parameters are defined by *mmrobust*:

robust_uncertain_overlap

Description This parameter allows for models where more than one robust constraint can use an `uncertain`. Because each robust constraint is dealt with independently in the robust problem, the optimal solution implicitly may associate different values of the uncertain quantities with each robust constraint.

Type Boolean, read/write

Default value false

Module mmrobust

robust_check_feas_uncertainty_set

Description This parameter allows for checking whether the uncertainty sets contain at least one feasible vector of uncertains. In other words, with this parameter set to true Mosel will check if the opponent actually has a choice of uncertains. If at least one uncertainty set is empty, a warning will be issued. Uncertainty sets should *not* be empty as otherwise a robust problem cannot be created.

Type Boolean, read/write

Default value false

Module mmrobust

robust_check_feas_original_problem

Description This parameter allows for checking whether the problem where all uncertains are set to their default value is feasible or not. This is off by default but can be useful to check correctness of one's model without uncertainty before solving the robust problem.

Type Boolean, read/write

Default value false

Module mmrobust

14.3 Procedures and functions

The module *mmrobust* overloads certain mathematical operators making possible the expression of linear and quadratic expressions involving the type `uncertain` in order to create both `robustctr` and `uncertainctr` objects. Since these mathematical operators are fairly self-explanatory, we shall forego any more detailed documentation of these functions.

The following list gives an overview of all other functions and procedures defined by *mmrobust* for which we give detailed descriptions later.

cardinality

Purpose

Create a cardinality uncertain constraint.

Synopsis

```
function cardinality(su:set of uncertain,m:integer):uncertainctr
```

Arguments

`su`	Uncertains to be added to the constraint
`m`	Maximum number of uncertains that can be different from their nominal value

Return value

The new cardinality uncertain constraint.

Further information

A cardinality unertain constraint limits the number of unceratins that can take a non-zero value, or be different from their nominal value.

Module

mmrobust

getsol

Purpose

Get the realisation of an uncertain or robust constraint.

Synopsis

```
function getsol(u:uncertain, rc:robustctr):real
function getsol(u:uncertain):real
function getsol(rc:robustctr):real
```

Arguments

`rc`	A robust constraint
`u`	An uncertain

Return value

Solution value or 0.

Further information

This function returns the realization of uncertain `u` for the robust optimization problem solved. The value of `u` is only available after solving the robust optimization problem. The value of `u` is 0 if the problem has not been solved or the uncertain or constraint is not contained in the problem that has been solved.

If the uncertain `u` appears in more than one constraint, it is necessary to specify the constraint with function call `getsol(u,rc)`: this is a consequence of robust optimization, for which the same uncertain can assume different values in different constraints. If the uncertain `u` only appears in one constraint, then it suffices to call `getsol(u)`.

The function `getsol(rc)` returns the evaluation of a constraint with the current realization of the solution and the uncertains. Therefore, if a constraint is of the form `u*x + v*y + z` $\leq$ `3` and `x,y,z`are variables while `u,v` are uncertains, the current realization of `x,y,z,u,v` will be used to return `u*x + v*y + z - 3`.

Note that robust equality constraints (for instance, `u*x + v*y + z = 3`) have a special status in Mosel. The value of uncertains `u` and `v` is, in general, related to an inequality constraint and can be safely obtained in this case only. In order to use `getsol` for equality robust constraints as well, it would be best to decompose these constraints into two inequality constraints (*i.e.* `u*x + v*y + z` $\leq$ `3` and `u*x + v*y + z` $\geq$ `3`) and then request `u` and `v` from each of the two constraints. Note that both uncertains might differ in value when requested from either inequality constraint.

Related topics

`getact`.

Module

mmrobust

getact

Purpose

Get the activity value of a robust constraint.

Synopsis

```
function getact(rc:robustctr):real
```

Argument

`rc` A robust constraint

Return value

Solution value or 0.

Further information

This function returns returns the value of the left-hand side of a constraint with the current realization of the solution and the uncertains. Therefore, if a constraint is of the form `u*x + v*y + z` $\leq$ `3` and `x,y,z`are variables while `u,v` are uncertains, the current realization of `x,y,z,u,v` will be used to return `u*x + v*y + z`.

Note that robust equality constraints (for instance, `u*x + v*y + z = 3`) have a special status in Mosel. The value of uncertains `u` and `v` is, in general, related to an inequality constraint and can be safely obtained in this case only. In order to use `getact` for equality robust constraints as well, it would be best to decompose these constraints into two inequality constraints (*i.e.* `u*x + v*y + z` $\leq$ `3` and `u*x + v*y + z` $\geq$ `3`) and then request `u` and `v` from each of the two constraints. Note that both uncertains might differ in value when requested from either inequality constraint.

Related topics

`getsol`.

Module

mmrobust

ishidden

Purpose

Test whether a constraint is hidden.

Synopsis

```
function ishidden(rc:robustctr):boolean
function ishidden(uc:uncertainctr):boolean
```

Arguments

`rc` A robust constraint

`uc` An uncertain constraint

Return value

`true` if the constraint is hidden, `false` otherwise.

Further information

This function tests the current status of a constraint. At its creation a constraint is added to the current problem, but using the function `sethidden` it may be hidden. This means, the constraint will not be contained in the problem that is solved by the solver but it is not deleted from the definition of the problem in Mosel.

Related topics

`sethidden`.

Module

mmrobust

scenario

Purpose

Create a scenario uncertain constraint.

Synopsis

```
function scenario(data:array (range,set of uncertain) of real):uncertainctr
```

Argument

`data` Scenario data

Return value

The new scenario uncertain constraint.

Further information

A scenario uncertain constraint takes historical data of the possible realizations of the `uncertain` data. In effect, the introduced uncertain constraint enforced that for any solution to the robust optimization problem, any robust constraint `robustctr` is satisfied for all realizations of the `uncertain`s as defined by the data array.

This function stores a reference to the provided array (*i.e.* it does not make a copy of it). As a consequence any modification to the array will imply modifications to the constraint even after the constraint has been built. Invalid data is only reported at the time of loading the problem into the optimiser.

Module

mmrobust

sethidden

Purpose

Hide or unhide a constraint.

Synopsis

```
procedure sethidden(rc:robustctr, b:boolean)
procedure sethidden(uc:uncertainctr, b:boolean)
```

Arguments

`rc` A robust constraint

`uc` An uncertain constraint

`b` Constraint status:

- `true` Hide the constraint
- `false` Unhide the constraint

Further information

At its creation a constraint is added to the current problem, but using this procedure it may be hidden. This means that the constraint will not be contained in the problem that is solved by the solver but it is not deleted from the definition of the problem in Mosel. Function `ishidden` can be used to test the current status of a constraint.

Related topics

`ishidden`.

Module

mmrobust

getnominal

Purpose

Get the nominal value of an uncertain.

Synopsis

```
function getnominal(u:uncertain):real
```

Argument

`u` An uncertain

Return value

The nominal value of the uncertain

Related topics

`setnominal`.

Module

mmrobust

gettype

Purpose

Get the type of a constraint.

Synopsis

```
function gettype(rc:robustctr):integer
function gettype(uc:uncertainctr):integer
```

Arguments

`rc` A robust constraint

`uc` An uncertain constraint

Return value

Constraint type. Applicable values for nonlinear constraints are:

`CT_EQ` Equality, '='

`CT_GEQ` Greater than or equal to, ' $\geq$ '

`CT_LEQ` Less than or equal to, ' $\leq$ '

`CT_CARD` Cardinality

`CT_SCEN` Scenario

`CT_UNB` Non-binding constraint, *i.e.* free

Related topics

`settype`.

Module

mmrobust

setnominal

Purpose

Set the nominal value of an uncertain.

Synopsis

```
procedure setnominal(u:uncertain,n:real)
```

Arguments

`u`	An uncertain
`n`	A real constant

Further information

Calling this procedure has the same effect as assigning a value to the uncertain using the operator `:=`.

Related topics

`getnominal`.

Module

mmrobust

settype

Purpose

Set the type of a constraint.

Synopsis

```
procedure settype(rc:robustctr, type:integer)
procedure settype(uc:uncertainctr, type:integer)
```

Arguments

`rc` A robust constraint

`uc` An uncertain constraint

`type` Constraint type. Applicable values are:

`CT_EQ`	Equality, '='
`CT_GEQ`	Greater than or equal to, '$\geq$'
`CT_LEQ`	Less than or equal to, '$\leq$'
`CT_UNB`	Non-binding constraint

Further information

This procedure can be used to change the type of a constraint, turning it into an equality or inequality or making it unbounded, *i.e.* free.

Related topics

`gettype`.

Module

mmrobust

CHAPTER 15

mmsheet

The Mosel module *mmsheet* implements several I/O drivers for accessing and modifying spreadsheet files in different formats from 'initializations' blocks. The I/O drivers rely on different technologies for accessing spreadsheets.

15.1 I/O drivers

The I/O drivers provided by *mmsheet* are all designed to be used in 'initializations' blocks and expect the same type of information regarding file names and record references. The common form of a file specification for all the *mmsheet* drivers is:

```
mmsheet.*:[noindex|partndx|autondx[=#];][grow;][skiph;][emptyndx;][bufsize=#;]filename
```

The spreadsheet file name must be a physical file (with its extension), except for the `"csv:"` driver that accepts extended file names. The driver options (stated before the file name) shared by all *mmsheet* drivers are:

`noindex` Indicates that only data (no indices) are transferred between the spreadsheet and Mosel. By default, the first columns of each table are interpreted as index values for the array to be transferred. This behaviour is changed by this option.

`partndx` Indicates that the first *nbdim-1* columns are interpreted as indices (*nbdim* being the number of dimensions of the array to process) and remaining ones are used as data for the last dimension.

`autondx[=st]` Indices are not read or written but automatically generated from the line number (this option only applies to 1-dimension arrays indiced by ranges). By default the first index has value 1 but a different value `st` may be stated.

`grow` When writing data, the driver uses the provided range ignoring the end of the data if there is not enough space. When this option is specified, the driver extends the range by adding lines if necessary.

`skiph` With this option, the driver skips the first line (or header) of the provided range. If the range contains only one line, the following line is selected.

`emptyndx` When reading array indices an empty cell causes a failure. With this option empty cells are replaced by the default value of the corresponding type (*e.g.* 0 for a numerical value)

`bufsize=c` To set the size of the data buffer in kilobytes (default c=2).

The driver-specific options are documented separately for each driver in the following sections.

In the initializations block, each label entry is understood as a range in the workbook: named ranges are represented by their name (*e.g.* `"MyRange"`) and explicit ranges are noted using square brackets (*e.g.* `"[sheet1$a1:c2]"`). For explicit ranges, the sheet is identified by its name or number and separated from the cell selection with the `$` sign. The first sheet of the workbook is selected if no indication is given. Similarly, the used cells of the selected sheet are assumed if no selection is provided. The cell selection can be stated either using the usual format with a letter to select the column followed by a line number (*e.g.* `"a1:c1"`) or by specifying row and column numbers by prefixing the row number by the letter `"R"` and the column number by the letter `"C"` (*e.g.* `"R1C1:R1C3"`). It is also possible to select some of the columns from the specified range: this can be done either with a list of names or a list of column numbers (relative to the beginning of the range) noted in parentheses after the range description. To use names, the option `skiph` must be used and the column names are taken from the *header row* that is skipped through this option. When using `skiph`, column numbers need to be stated by prefixing the column number by #. Note that, before the range selection, one can add options as for the file opening. For instance, `"skiph;grow;"` can be used for writing data to a named range formatted for an ODBC connection.

In addition to the above options a label may consist in the string `"rangesize;"` followed by a range specification (*e.g.* `"rangesize;[]"`), this special label can only be used to populate a list of integers that receives the size of the range in the form of 2 integers (number of lines and number of columns).

Example:

```
initializations from "mmsheet.excel:skiph;auction.xls"
 NWeeks as "[b1:d12]"           ! Initialize `NWeeks' with data in b2:d12
 BPROF as "noindex;BPROFILE"    ! Initialize `BPROF' with named range `BPROFILE'
                                ! all columns being data (no indices)
 mycols as "[b1:h12](#3,#5,#7)" ! Initialize `mycols' with columns d2:d12,
                                ! f2:f12 and h2:h12
 mycol2 as "[b1:h12](nam1,#5,nam3)"
                                ! Initialize `mycol2' with the column named
                                ! 'nam1', the column f2:f12 and the column
                                ! named 'nam3'
end-initializations
```

The mapping between the selected cells of the workbook and the Mosel data structures is similar to the one used for databases (options `noindex` and `partndx` correspond to setting parameter `mmodbc.SQLndxcol` to `false`): refer to the section *Data transfer between Mosel and the database* of the *mmodbc* chapter for further explanation.

Although direct read and write operations are not supported by these drivers, a spreadsheet may be open using `fopen`: this allows to keep the document open across several 'initializations' blocks and avoid the cost of loading and unloading the file (that may be expensive particularly with the `"excel:"` driver).

Cells of a spreadsheet are implicitly typed as either numbers, booleans or text strings. When getting the value of a cell the driver may have to perform a type conversion: the conversion from a number to its textual representation relies on the real format `"realfmt"` (see `setparam`) that may have to be changed when using a driver of this module. For instance the number `1234567` will be converted to the text string `1.23457e+06` with the default real format (`"%g"`). To preserve the integer representation of such a cell it is required to use `"%.10g"` as the real format.

For further examples of working with databases and spreadsheets, the reader is referred to the Xpress whitepaper *Using ODBC and other database interfaces with Mosel*.

15.1.1 Driver `excel`

```
mmsheet.excel:[noindex|partndx;][grow;][skiph;][emptyndx;][newxl;][bufsize=#;]filename
```

This driver uses directly the application Excel for accessing the file (relying on COM/OLE as the communication channel): as a consequence it is available only under the Windows platform and requires

Excel to be installed on the host executing the Mosel model. All file formats handled by the version of Excel can be used but this driver does not support creation of new files (*i.e.* it can only modify existing files). In addition to the options described in the introductory section, the option `newxl` may be used: by default the driver does not open the file if it can find a running instance of Excel having the required file open: it works directly with the application and modifications made to the workbook are not saved when the file is closed in Mosel. If this option is specified a new instance of Excel is started in all cases and the workbook is saved before quitting the application when the file is closed in Mosel.

15.1.2 Driver `xls/xlsx`

```
mmsheet.xls:[noindex|partndx|autondx[=#];][grow;][skiph[+];][emptyndx;]
            [bufsize=#;]filename

mmsheet.xlsx:[noindex|partndx|autondx[=#];][grow;][skiph[+];]
             [emptyndx;][bufsize=#;]filename
```

These two drivers rely on the `libxl` library to access the spreadsheet file: they are available on the Windows, Linux and MacOS platforms and do not require any additional software. The first driver handles xls files while the second deals with xlsx and xlsm format Excel files. These drivers can be used to create new files: when used for writing (through an 'initializations to' block) non-existing sheets are automatically added to the workbook and the file is created if necessary. When the option `skiph+` is used instead of `skiph` when writing to a file, the necessary header row is created if this row is empty (this option behaves like `skiph` when reading a file and when no column name is provided).

15.1.3 Driver `csv`

```
mmsheet.csv:[noindex|partndx|autondx[=#];][alltxt;][grow;][skiph[+];][emptyndx;]
            [bufsize=#;][fsep=c;][dsep=c;][true=s;][false=s;]filename
```

This driver works on spreadsheets saved in ascii CSV format (Comma Separated Values). It is available on all platforms that are supported by Mosel and can open or create files using extended format file names (*i.e.* combining several I/O drivers). A CSV file contains a single sheet (number 1 identified as `"Sheet1"`) and does not support named ranges, that is, cell references must use the explicit notation. When the option `skiph+` is used instead of `skiph` when writing to a file, the necessary header row is created if this row is empty (this option behaves like `skiph` when reading a file and when no column name is provided). The following driver-specific options may be used to specify the properties of the format to handle:

`alltxt`	by default the driver tries to guess the type of the cells while reading the document (cells can be either numbers, booleans or text strings). When this option is used all cells are recorded as text strings
`dsep=c`	character used as decimal separator (default: `"."`)
`fsep=c`	character used to separate fields. The default value is `","`; tabulation or `";"` are also often employed
`true=s`	text representing the *true* value of a Boolean (default: `"TRUE"`)
`false=s`	text representing the *false* value of a Boolean (default: `"FALSE"`)

For example, the following statements will read data from a file formatted for the French language and that has been compressed with `gzip`:

```
initializations from "mmsheet.csv:fsep=;;dsep=,;true=vrai;false=faux;zlib.gzip:mydata.csv.gz"
 A as "[a1:c12]"
end-initializations
```

The csv driver supports the `getfsize` function applied to a file already loaded into memory: it reports the amount of memory currently allocated for the corresponding document. For instance the following displays the memory used by `"mydata.csv"`:

```
fopen("mmsheet.csv:mydata.csv",F_INPUT)
writeln(getfsize("mmsheet.csv:mydata.csv"))
fclose(F_INPUT)
```

CHAPTER 16

mmssl

The Mosel module *mmssl* is an interface to the OpenSSL cryptographic library (http://www.openssl.org). It brings most of the functionality of this library to the Mosel language and serves as the cryptographic component in other parts of Mosel. In particular, it provides support for the *HTTPS* protocol in *mmhttp* and implements the encryption and signing mechanisms used by the Mosel core libraries when secure BIM files are used.

16.1 Overview

16.1.1 Document encryption in Mosel

Encryption and decryption of documents are achieved by *cipher* algorithms. Ciphers can be of two kinds: *symmetric* ciphers use the same *encryption key* to perform the encryption and decryption tasks while *asymmetric* ciphers require one key to execute the encryption and another one for the decryption. In *mmssl*, symmetric ciphers are made available through the *crypt* I/O driver (Section 16.4.3): the encryption key (the size of which depends on the cipher) is automatically generated based on some given *passphrase* (either input from an external file or directly in the file name specification). The implementation of the *crypt* driver allows the user to select which specific cipher algorithm it should use (for instance AES, DES or IDEA).

For asymmetric encryption, *mmssl* relies on the *RSA cryptographic system*. For the RSA algorithm, a *key* (`RSAgenkey`) consists of two components: a *public* part that is usually distributed to the individuals with whom documents are to be exchanged and a *private* part that must be kept secret by the owner of the key (this private key also includes the public key). In this framework, a document encrypted using a public key (`RSApubencrypt`) can only be decrypted with the corresponding private key (`RSAprivdecrypt`). Moreover, the key pair can also be used for *signing* documents: the *electronic signature* of a document is created with a private key (`msgsign`) and the corresponding public key is used to verify this signature (`msgverify`). Since only the owner of the private key can create the signature, the recipient has a guarantee on the origin of the document.

RSA keys are commonly stored as text files in the OpenSSL PEM standard format, this is also the most convenient representation for exchanging key information (`RSAsavekey`). In addition to this file format, *mmssl* can store a key in the form of a Mosel array of integers (`RSAloadkey`). By using this encoding a model may embbed keys or retrieve them from any of the usual model data sources.

16.1.2 The `mmssl` command

The module *mmssl* is distributed together with a command line tool of the same name as the module: `mmssl`. This program helps setting up an initial working environment and performs basic key and certificate operations directly from a shell (Unix) or command window (Windows). Running the `mmssl` program without any arguments will display a short help message, otherwise the following commands can be used:

setup
Check the configuration directory of *mmssl* and create it if necessary (see parameter `ssl_dir`)

genkey `keyfile [size]`
Generate a new RSA key pair of the specified size (default: 1024) and save it into `keyfile`.

getpub `keyfile keyfilepub`
Extract the public key of the private RSA key file `keyfile` and save it into `keyfilepub`

chkkey `keyfile [keyfile...]`
Check the validity of the provided key file(s)

gencert `certfile [prod=value...]`
Generate an X509 certificate using the provided properties (see `x509newcrt` for further detail)

chkcert `certfile [keyfile]`
Check the validity of the provided X509 certificate. If an additional private key file is provided, its compatibility with the certificate is also checked.

list [**digest**|**cipher**]
Display the list of supported message digests (`digest`) or cipher algorithms (`cipher`). Both lists are reported with the short form of the command.

Many procedures of the *mmssl* module require the availability of a *configuration directory*. To create and populate an initial setup it is recommended to run the following command before starting to use the module:

```
> mmssl setup
```

Note that the setup procedure is not destructive: if the configuration directory has already been created the command will only check its validity, add any missing components and suggest how to proceed in case of incorrect settings.

16.2 Control parameters

Via the `getparam` function and the `setparam` procedure it is possible to access the following control parameters of module *mmssl* (the reader is reminded that parameters may be spelled with lower or upper case letters or a mix of both):

`https_cacerts`	List of trusted certification authorities.	p. 438
`https_ciphers`	Ciphers accepted for SSL communication.	p. 438
`https_cltcrt`	HTTPS client certificate.	p. 438
`https_cltkey`	HTTPS client private key.	p. 439
`https_srvcrt`	HTTPS server certificate.	p. 439
`https_srvkey`	HTTPS server private key.	p. 439
`https_trustsrv`	Whether to trust server certificates.	p. 440
`ssl_cipher`	Default symmetric cipher.	p. 440
`ssl_digest`	Default message digest algorithm.	p. 440
`ssl_dir`	mmssl configuration directory.	p. 441
`ssl_privkey`	Default user private key.	p. 441

https_cacerts

Description Location of the file containing the certificates of the trusted certification authorities.

Type String, read/write

Note The file identified by this parameter consists of a list of certificates (in PEM format) of trusted certification authorities (in order to be able to check the validity of servers they have certified) and certificates of servers trusted by the application (typically using self-signed certificates that could not be certified by an external authority, see `x509newcrt`). This file is used when HTTPS client connections are established to check the identity of the server unless the control parameter `https_trustsrv` is set to `true`. It is also required by servers that perform client authentication (see option `HTTP_CLTAUTH` of server configuration `http_srvconfig`): in this case the certificates are used to identify the clients.
When this parameter has not been initialised, the default location `getparam("ssl_dir")+"/ca-bundle.crt"` is used. This default file collecting the certificates of the major certification authorities is installed by the `mmssl setup` command (Section 16.1.2).

Affects routines `httpget`, `httppost`, `httpdel`, `httpput`, `httpstartsrv`

See also `https_trustsrv`

Module mmssl

https_ciphers

Description This parameter is used during the algorithm negociation of an HTTPS session initialisation to select which cryptographic algorithm to use.

Type String, read/write

Default value `"TLSv1.2+HIGH:TLSv1+HIGH:@STRENGTH"`

Note This parameter is employed by both the server and the client in an HTTPS session. Please refer to the OpenSSL documentation for a detailed explanation on how to build this selection string.

Affects routines `httpstartsrv`, `httpget`, `httppost`, `httpdel`, `httpput`

Module mmssl

https_cltcrt

Description Location of the client certificate (for HTTPS queries).

Type String, read/write

Note This parameter specifies the location of the client certificate (that must be in PEM format). Such a certificate (and its associated private key `https_cltkey`) is required when sending HTTPS requests to a server that requires client authentication (see option `HTTP_CLTAUTH` of server configuration `http_srvconfig`).

Affects routines `httpget`, `httppost`, `httpdel`, `httpput`

See also `https_cltkey`

Module mmssl

https_cltkey

Description Location of the client private key (for HTTPS queries).

Type String, read/write

Note This parameter specifies the location of the client private key. Such a key (and its associated certificate `https_cltcrt`) is required when sending HTTPS requests to a server that requires client authentication (see option `HTTP_CLTAUTH` of server configuration `http_srvconfig`).

Affects routines `httpget`, `httppost`, `httpdel`, `httpput`

See also `https_cltcrt`

Module mmssl

https_srvcrt

Description Location of the server certificate (required by an HTTPS server).

Type String, read/write

Note Running an HTTPS server requires a server certificate and its associated private key. This parameter defines the location of the certificate file (in PEM format); to create a certificate you can either use the `mmssl` command (Section 16.1.2) or the Mosel function `x509newcrt`. If no value has been assigned to this parameter the default certificate file `getparam("ssl_dir")+"/server.crt"` will be used by the server.

Affects routines `httpstartsrv`

See also `https_srvkey`

Module mmssl

https_srvkey

Description Location of the server private key (required by an HTTPS server).

Type String, read/write

Note Running an HTTPS server requires a server certificate and its associated private key. This parameter defines the location of the private key file; to create a certificate use either the `mmssl` command (Section 16.1.2) or the function `x509newcrt`). If no value has been assigned to this parameter the default key file `getparam("ssl_dir")+"/server.key"` will be used by the server.

Affects routines `httpstartsrv`

See also `https_srvcrt`

Module mmssl

https_trustsrv

Description This parameter decides whether the HTTPS client should trust servers without checking their certificates.

Type Boolean, read/write

Default value `false`

Note When this parameter is `false` (the default) whenever an HTTPS connection is opened (via `httpget` for instance) the authenticity of the remote server is checked using the list of trusted certification authorities (as defined by the control parameter `https_cacerts`) and the operation is aborted if the verification fails. Changing the value of this parameter disables this test.

Affects routines `httpget`, `httppost`, `httpdel`, `httpput`

See also `https_cacerts`

Module mmssl

ssl_cipher

Description Name of symmetric cipher to use when no algorithm is specified.

Type String, read/write

Default value `"AES-128-CBC"`

Note This parameter defines the default symmetric cipher used by the *crypt* I/O driver. The name of a cipher consists in up to 3 components separated by the `"-"` symbol: the algorithm name (*e.g.* aes, bf, des), the key size (when the algorithm may be used with different sizes of keys) and the block chaining mode (*e.g.* cbc, cfb1, cfb8, ecb, ofb). For instance, `"des-ofb"` designates DES with *Output Feedback* chaining.
Use the command `mmssl list cipher` to get a full list of the supported cipher names.

Affects routines I/O driver `"crypt:"` (Section 16.4.3)

Module mmssl

ssl_digest

Description Name of message digest to use when no algorithm is specified.

Type String, read/write

Default value `"SHA256"`

Note This parameter defines the default message digest algorithm used by the *crypt* I/O driver, `msgdigest`, `msgsign` and `msgverify`.
Use the command `mmssl list digest` to get a full list of the supported names.

Affects routines `msgdigest`, `msgsign`, `msgverify`, I/O driver `"crypt:"` (Section 16.4.3)

Module mmssl

ssl_dir

Description This parameter is the path to the *configuration directory* of *mmssl*. Its content is used by both the *mmssl* routines and the Mosel core libraries for handling signed and encrypted bim files.

Type String, read only

Note By default this location is the path `"$HOME/.mmssl"` (on Unix systems) or `"%USERPROFILE%\.mmssl"` (on Windows). Assuming the active restrictions do not prevent the operation, this directory will be created if it does not exist at the time of loading the module. It is also possible to select a different location by defining the environment variable `MOSEL_SSL` (in this case, the directory is not automatically created and must be available at loading time).

The configuration directory should contain the following entries:

`personal.key`	RSA private key of the user: it is used for signing documents to be published and for decrypting documents that have been encrypted with the corresponding public key.
`personal`	RSA public key of the user: to be provided with documents signed with `personal.key` such that recipients can check the signature. The public key is also used to encrypt documents to be decrypted with `personal.key`.
`pubkeys`	public keys repository: this directory is the default location where public keys are searched for checking the signature of a document.
`ca-bundle.crt`	trusted certificates file: *mmhttp* uses this file when checking authenticity of servers (HTTPS client) or clients (HTTPS server).
`server.crt`	HTTPS server certificate: this file is required by the HTTPS server of *mmhttp* together with the corresponding private key.
`server.key`	HTTPS server private key: this file is required by the HTTPS server of *mmhttp* together with the corresponding certificate.

The program `mmssl` can be used to create and populate this directory (Section 16.1.2).

Even if Mosel is run under restrictions, `mmssl` can still access its configuration directory for getting public keys stored under the `pubkeys` directory, read the file of trusted certificates `ca-bundle.crt` and load the private key `personal.key` to decrypt a document. However, the module requires explicit read access to use the private key `personal.key` for signing tasks and load the HTTPS server configuration (files `server.key` and `server.crt`).

Module mmssl

ssl_privkey

Description Name of the file holding the user's private key.

Type String, read/write

Note The key identified by this parameter is used when a required private key is not provided. If no value has been assigned to this parameter the default key file `getparam("ssl_dir")+"/personal.key"` will be used.

Affects routines `msgsign`, `x509newcrt`, `RSAprivdecrypt`, BIM file signing and encryption

Module mmssl

16.3 Procedures and functions

RSAfingerprint

Purpose

Generate the fingerprint of an RSA key.

Synopsis

```
function RSAfingerprint(key:array(range) of integer):text
function RSAfingerprint(key:array(range) of integer, mdalg:string):text
function RSAfingerprint(kfile:string):text
```

Arguments

`key`	RSA key in the form of an array of integer
`kfile`	File containing the key
`mdalg`	Name of the digest algorithm to use (default: MD5)

Return value

Fingerprint as a text string of hexadecimal digits.

Further information

1. By default *mmssl* uses an MD5 hash of the public part of the RSA key as its fingerprint. Unless another digest algorithm is selected, the return value of this function is therefore a text string of 32 hexadecimal digits that characterises a given key.
2. The function can process both public and private keys either directly from a key file or from an array of integers (as produced by `RSAloadkey` or `RSAgenkey`).

Related topics

`RSAloadkey`

Module

mmssl

RSAgenkey

Purpose

Create a new RSA key pair.

Synopsis

```
function RSAgenkey(size:integer, key:array(range) of integer):integer
function RSAgenkey(size:integer, kfile:string):integer
```

Arguments

`size`	Size of the key to generate (in bits, must be at least `1024`)
`key`	Array to store the new key
`kfile`	File where to save the key

Return value

Number of integers (first syntax) or size of the file (second syntax) or `-1` in case of I/O error and `-2` if the provided array is not suitable to store the key.

Further information

1. The generated key can be retrieved either as an array of integers or directly saved into a file. In both cases, the *public* key may be extracted using `RSAsavekey`.
2. The function creates keys of at least 1024 bits: a request for a key of a smaller size will result in a 1024 bits key.

Related topics

`RSAloadkey`, `RSAsavekey`

Module

mmssl

RSAgetkeysize

Purpose

Get the size of an RSA key.

Synopsis

```
function RSAgetkeysize(key:array(range) of integer):integer
function RSAgetkeysize(kfile:string, ispriv:boolean):integer
```

Arguments

`key`	RSA key in the form of an array of integer
`kfile`	File containing the key
`ispriv`	Must be `true` if the key file contains a private key

Return value

Size of the key (number of bits) or `-1` in case of an error.

Further information

A return value of -1 indicates an error condition. Typically this will occur if the file cannot be accessed or the `ispriv` parameter is not correct (*e.g.* `ispriv` is `true` and the file is a public key).

Related topics

`RSAisprivate`, `RSAloadkey`

Module

mmssl

RSAisprivate

Purpose

Check whether an RSA key is private.

Synopsis

```
function RSAisprivate(key:array(range) of integer):boolean
function RSAisprivate(kfile:string):boolean
```

Arguments

`key` RSA key in the form of an array of integer

`kfile` File containing the key

Return value

`true` if the key is an RSA private key, `false` otherwise.

Further information

A return value of `false` does not necessarily indicate that the provided data corresponds to a valid public key: this value is also returned in the case of an I/O error (*e.g.* the file does not exist).

Related topics

`RSAloadkey`

Module

mmssl

RSAloadkey

Purpose

Load an RSA key file into memory.

Synopsis

```
function RSAloadkey(key:array(range) of integer, kfile:string,
      ispriv:boolean):integer
function RSAloadkey(key:array(range) of integer, kfile:string):integer
```

Arguments

`key`	RSA key in the form of an array of integer
`kfile`	File containing the key
`ispriv`	Must be `true` if the key file contains a private key

Return value

The number of integers saved into the array, or `-1` in the case of an I/O error, or `-2` if the provided array is not suitable to store the key.

Further information

If the `ispriv` parameter is not provided, the function calls first `RSAisprivate` to determine its value.

Related topics

`RSAsavekey`

Module

mmssl

RSApubdecrypt

Purpose

Decrypt a document using an RSA public key.

Synopsis

```
function RSApubdecrypt(kfile:string, src:string, dest:string):integer
```

Arguments

`kfile`	File containing the public key
`src`	Name of the file to decrypt
`dst`	Name of the file to store the decrypted document

Return value

Length of the resulting document or `-1` in the case of an error.

Further information

1. This function is used to decrypt a document that has been encrypted using `RSAprivencrypt`. It requires the public part of the key used for encryption.
2. If the key file name does not include an explicit path (*e.g.* `"somekey"`), it is searched for in the default public keys directory located at `getparam("ssl_dir")+"/pubkeys"` instead of the current working directory. It is required to prefix the key file name with `"./"` in order to access a key file from the current directory (*e.g.* `"./somekey"`).

Related topics

`RSAprivencrypt`, `msgverify`

Module

mmssl

RSAprivdecrypt

Purpose

Decrypt a document using an RSA private key.

Synopsis

```
function RSAprivdecrypt(kfile:string, src:string, dest:string):integer
```

Arguments

`kfile`	File containing the private key
`src`	Name of the file to decrypt
`dst`	Name of the file to store the decrypted document

Return value

Length of the resulting document or `-1` in the case of an error.

Further information

This function is used to decrypt a document that has been encrypted using `RSApubencrypt`. It requires the private part of the key used for encryption.

Related topics

`RSApubencrypt`

Module

mmssl

RSAprivencrypt

Purpose

Encrypt a document using an RSA private key.

Synopsis

```
function RSAprivencrypt(kfile:string, src:string, dest:string):integer
```

Arguments

`kfile`	File containing the private key
`src`	Name of the file to encrypt
`dst`	Name of the file to store the encrypted document

Return value

Length of the resulting document or `-1` in the case of an error.

Further information

1. This function can be used to encrypt a document using an RSA private key (with PKCS1 as the padding algorithm). Decryption will be done using function `RSApubdecrypt` with the help of the corresponding RSA public key.
2. The algorithm used here cannot handle documents larger than `(RSAgetkeysize(kfile)/8-11)` bytes. It is usually used to generate a digital signature from a message digest.

Related topics

`RSApubdecrypt`, `msgsign`

Module

mmssl

RSApubencrypt

Purpose

Encrypt a document using an RSA public key.

Synopsis

```
function RSApubencrypt(kfile:string, src:string, dest:string):integer
```

Arguments

`kfile`	File containing the public key
`src`	Name of the file to encrypt
`dst`	Name of the file to store the encrypted document

Return value

Length of the resulting document or `-1` in the case of an error.

Further information

1. This function can be used to encrypt a document using an RSA public key (with PKCS1 OAEP as the padding algorithm). Decryption will be done using function `RSAprivdecrypt` with the help of the corresponding RSA private key.

2. The algorithm used here cannot handle documents larger than `(RSAgetkeysize(kfile)/8-41)` bytes. Typically, encryption of larger documents will be performed with a *symmetric cipher* (see `crypt` I/O driver, Section 16.4.3) using a randomly generated key (that can be produced with `sslrandomdata`), in which case the asymmetric cipher is used to encrypt only this random key. The decryption then also operates in two steps: the key is first decrypted using `RSAprivdecrypt` (with a private key) and after this the document can be restored from the decrypted symmetric key.

3. If the key file name does not include an explicit path (*e.g.* `"somekey"`), it is searched for in the default public keys directory located at `getparam("ssl_dir")+"/pubkeys"` instead of the current working directory. It is required to prefix the key file name with `"./"` in order to access a key file from the current directory (*e.g.* `"./somekey"`).

Related topics

`RSAprivdecrypt`

Module

mmssl

RSAsavekey

Purpose

Save an RSA key to a file.

Synopsis

```
function RSAsavekey(key:array(range) of integer, kfile:string,
      ispriv:boolean):integer
function RSAsavekey(key:array(range) of integer, kfile:string):integer
```

Arguments

`key`	RSA key in the form of an array of integer
`kfile`	Destination file
`ispriv`	Save the private key if `true`, only the public key otherwise

Return value

A positive value on success or `-1` in case of error.

Example

In the code below a new 2048 bits key is generated and both, private and public parts are saved into different files:

```
if RSAgenkey(2048,k)<=0 then
 writeln("Failed to create RSA key")
elif RSAsavekey(k,"perso.key",true)<1 or
     RSAsavekey(k,"perso",false)<1 then
 writeln("Failed to save key file")
end-if
```

Further information

1. This function saves the RSA key that is provided as an array of string into a file in a textual representation. The `ispriv` parameter can be used to select which part of the key to export.
2. If the `ispriv` parameter is not provided, the function will produce a private key file if the key is private and a public key file otherwise.

Related topics

`RSAloadkey`, `RSAgenkey`

Module

mmssl

msgdigest

Purpose

Compute the message digest of a document.

Synopsis

```
function msgdigest(mdalg:string, fname:string, mdf:string):integer
function msgdigest(fname:string, mdf:string):integer
```

Arguments

`mdalg`	Name of the algorithm to use
`fname`	Name of the file to be processed
`mdf`	File where to store the digest

Return value

Size of the message digest in bytes or `-1` if case of error.

Example

The following procedure implements the command 'md5sum':

```
procedure md5sum(f:string)
 if msgdigest("md5",f,"mem:dgst")<>16 then
  writeln("Failed to compute digest")
 else
  fcopy("mem:dgst",F_BINARY,"hex:",F_TEXT)
  writeln("  ",f)
 end-if
end-procedure
```

Further information

1. This function computes a message digest (MD) using either the algorithm specified by the `mdalg` argument or the default algorithm as defined by the control parameter `ssl_digest`. The produced output takes the form of a binary file the size of which is returned by the function.
2. The set of supported algorithms includes `"md5"`, `"sha"`, and `"sha256"`. For a full list use the command `mmssl list digest`.

Related topics

`sslmdsize`

Module

mmssl

msgsign

Purpose

Compute the digital signature of a document.

Synopsis

```
function msgsign(mdalg:string, pkey:string, fname:string,
       sgf:string):integer
function msgsign(fname:string, sgf:string):integer
```

Arguments

`mdalg`	Name of the message digest algorithm to use
`pkey`	Name of the private key file to use for signing
`fname`	File to sign
`sgf`	File where the signature is to be saved

Return value

Length of the signature or `-1` in the case of an error.

Further information

1. This function computes the digital signature of a document by encrypting the message digest of its input file using an RSA private key. The resulting signature can be verified with the function `msgverify` used with the appropriate public key.
2. If no message digest algorithm is specified, the default algorithm defined by the control parameter `ssl_digest` is used. Unless a specific key file is selected, the default private key defined by the control parameter `ssl_privkey` or, (if this parameter is not defined) the key under `getparam("ssl_dir")+"/personal.key"` is used.

Related topics

`msgverify`

Module

mmssl

msgverify

Purpose

Verify the digital signature of a document.

Synopsis

```
function msgverify(mdalg:string, key:string, fname:string,
       sgf:string):integer
function msgverify(key:string, fname:string, sgf:string):integer
```

Arguments

`mdalg`	Name of the message digest algorithm to use
`key`	Name of the public key file to use
`fname`	File to verify
`sgf`	Signature used for the verification

Return value

`1` if the signature is valid, `0` if the verification failed and `-1` in the case of an error.

Further information

1. This function verifies the digital signature of a document by comparing the message digest of the document with the information obtained by decrypting the provided signature with a given RSA public key. Typically this signature has been obtained with the function `msgsign` and the appropriate private key.
2. If no message digest algorithm is specified, the default algorithm defined by the control parameter `ssl_digest` is used. Note that the same algorithm has to be used for both signing and verifying.
3. If the key file name does not include an explicit path (*e.g.* `"somekey"`), it is searched for in the default public keys directory located at `getparam("ssl_dir")+"/pubkeys"` instead of the current working directory. It is required to prefix the key file name with `"./"` in order to access a key file from the current directory (*e.g.* `"./somekey"`).

Related topics

`msgsign`

Module

mmssl

sslivsize

Purpose

Get the size of the initialisation vector (IV) required by a symmetric cipher.

Synopsis

```
function sslivsize(cipalg:string):integer
```

Argument

`cipalg` Name of the cipher to consider

Return value

Size of a IV in bytes or `-1` if the cipher is not supported.

Example

The following statement generates a random IV for the default cipher algorithm:

```
sslrandomdata("myiv",sslivsize(""))
```

Further information

Some encryption algorithms require an initialisation vector (IV) in addition to the encryption key. Like the key, the IV is an array of bytes of a fixed size. This function returns the length (in bytes) of the IV required by a given symmetric cipher algorithm. A return value of `-1` indicates an unrecognised algorithm name: this property can be used to check whether a given algorithm is available.

Related topics

`sslkeysize`

Module

mmssl

sslkeysize

Purpose

Get the size of the key required by a symmetric cipher.

Synopsis

```
function sslkeysize(cipalg:string):integer
```

Argument

`cipalg` Name of the cipher to consider

Return value

Size of a key in bytes or `-1` if the cipher is not supported.

Further information

This function returns the length (in bytes) of an encryption key required by a given symmetric cipher algorithm. A return value of `-1` indicates that the algorithm name has not been recognised: this property can be used to check whether a given algorithm is available.

Related topics

`sslivsize`

Module

mmssl

sslmdsize

Purpose

Get the size of a message digest.

Synopsis

```
function sslmdsize(mdalg:string):integer
```

Argument

`mdalg` Algorithm to consider

Return value

Size of the message digest in bytes or `-1` if the algorithm is not supported.

Further information

This function returns the length (in bytes) of a digest produced by the requested message digest algorithm. A return value of `-1` indicates that the algorithm name has not been recognised: this property can be used to check whether a given algorithm is available.

Related topics

`msgdigest`

Module

mmssl

sslrandom

Purpose

Generate a random number.

Synopsis

```
function sslrandom:integer
```

Return value

A randomly generated integer.

Further information

This function returns an integer by combining 4 bytes obtained from a cryptographically strong pseudo-random generator.

Related topics

sslrandomdata

Module

mmssl

sslrandomdata

Purpose

Generate a random data file.

Synopsis

```
procedure sslrandomdata(fname:string, size:integer)
```

Arguments

`fname` Name of the file where to save the generated data

`size` Number of bytes to generate

Example

The following statement generates a random key for the default cipher algorithm:

```
sslrandomdata("mykey",sslkeysize(""))
```

Further information

1. This function generates `size` bytes from a cryptographically strong pseudo-random generator that it saves in the specified file `fname`.
2. An IO error will be raised if the destination file cannot be accessed.

Related topics

`sslrandom`

Module

mmssl

x509check

Purpose

Check the compatibility of a private key with an X509 certificate.

Synopsis

```
function x509check(x509:string, kfile:string):integer
```

Arguments

`x509` File containing the certificate in PEM format

`kfile` File containing the private key

Return value

`0` if the key is compatible with the certificate, `1` if the key is not compatibe and `-1` in the case of an error.

Further information

This function checks whether the public key recorded in the specified certificate corresponds to the provided private key (the certificate can only be used by the owner of the public key).

Related topics

`x509getinfo`

Module

mmssl

x509getinfo

Purpose

Retrieve information stored in an X509 certificate.

Synopsis

```
function x509getinfo(x509:string, info:array(string) of text):integer
```

Arguments

`x509` Certificate file in PEM format

`info` Array where to store certificate information

Return value

Number of items stored in the array or `-1` in case of error.

Example

The example below shows how to display the properties of a certificate:

```
declarations
 info:array(S:set of string) of text
end-declarations

if x509getinfo("srv.crt",info)<1 then
 writeln("Failed to load certificate")
else
 forall(s in S | exists(info(s)))
  writeln("   ", s, ":", info(s))
end-if
```

Further information

This function retrieves some of the information recorded in an X509 certificate. The data is recorded in the provided array indexed by the labels of the records in the certificate. The possible labels are:

`Version` Format version of the certificate

`Serial` Serial number

`Issuer` Issuer of the certificate

`Subject` Entity associated to the public key stored in the certificate

`NotBefore` Valid after this date

`NotAfter` Valid until this date

`SgnAlg` Algorithm used to sign the certificate

A self-signed certificate (such as those created with `x509newcrt`) will have identical values for `Issuer` and `Subject`.

Related topics

`x509check`

Module

mmssl

x509newcrt

Purpose

Create a new self-signed X509 certificate.

Synopsis

```
function x509newcrt(x509:string, kfile:string, info:array(string) of
       text):integer
```

Arguments

`x509` Certificate file to create (PEM format)

`kfile` File containing the private key

`info` Array describing the certificate properties

Return value

`0` if success or `-1` in the case of an error.

Example

The following example creates a certificate that is valid for 3 years, using a new RSA key:

```
info("Version"):="1"
info("Serial"):="123456789"
info("Duration"):=text(365*3)
info("C"):="FR"
info("O"):="My Company"
info("CN"):="www.mycomp.com"
if RSAgenkey(1024,"srv.key")<=0 then
 writeln("Failed to create RSA key")
elif x509newcrt("srv.crt","srv.key",info)<>0 then
 writeln("Failed to create certificate")
end-if
```

Further information

1. This function creates a self-signed X509 certificate. Such a certificate can be used to run an HTTPS server but clients of such a server have to disable server certificate verification (see `https_trustsrv`) or include this certificate in their trusted certificate file (see `https_cacerts`).

2. The routine expects an array with indices defining the following entries (a default value applies if the entry is missing):

   `Version` Format version of the certificate (default: 1)

   `Serial` Serial number (default: 1)

   `Duration` Validity (in days) from the current date (default: 365)

   `C` Country code (default: system country or 'EU')

   `O` Organisation name (default: anonymous)

   `CN` Common Name (typically the host name to authenticate, default: localhost)

   The entries `C`, `O` and `CN` are used to generate the *Issuer* and *Subject* records of the certificate. The provided key is used both as the certificate key (using the public part of the key) and as the signing key.

Related topics

`x509check`, `x509getinfo`

Module

mmssl

16.4 I/O drivers

The *mmssl* module publishes two drivers for converting binary documents to textual representation and a driver dedicated to symmetric encryption. These drivers have the same behaviour: encryption or encoding is performed when the driver is used for writing while decryption/decoding is done on a stream that is open for reading.

16.4.1 Driver `base64`

```
base64:[nonl,]filename
```

This driver can be used to handle documents encoded using the *base64* standard. When used in an output stream, it generates the base64 encoded version of its binary input and in an input stream it expects a base64 encoded document that it decodes.

For instance the following statement encodes `"mydata.bin"`:

```
fcopy("mydata.bin",F_BINARY,"mmssl.base64:mydata.b64",F_TEXT)
```

By default a base64 document is split into lines of 76 characters but with the option `nonl` the entire document is output as (or read from) a single line.

16.4.2 Driver `hex`

```
hex:filename
```

This driver produces a textual representation of a binary document by replacing each byte by its hexadecimal representation (*e.g.* the value 13 is converted to the string `"0d"`).

The following code extract displays the hexadecimal representation of the binary input file `"mem:md5"`:

```
fcopy("mem:md5",F_BINARY,"mmssl.hex:",F_TEXT)
writeln
```

16.4.3 Driver `crypt`

```
crypt:[[nosalt,][md=a,][cipher=c,][key=kf,][iv=if,]pwd=p|pf]filename
```

The *crypt* driver performs encryption (when writing) or decryption (when reading) of its stream using a symmetric cipher (that is, the same key is used for encryption and decryption). Options are provided enclosed in square brackets, at the least a password has to be provided. For instance, the following statement encrypts the file `"mydata"` using the password stored in the file `"passfile"`:

```
fcopy("mydata","mmssl.crypt:[passfile]mydata.enc")
```

The password is read from the first line of the password file (that is opened as a text document). Alternatively, the password may be directly passed through the file name using the `pwd=` option:

```
fcopy("mydata","mmssl.crypt:[pwd=mysecret]mydata.enc")
```

Encryption (or decryption) is performed using the default cipher as defined by the control parameter `ssl_cipher`. Another cipher can be selected using the `cipher` option.

The encryption (or decryption) process requires a *key* as well as an *initialisation vector*. The size of these components depends of the selected cipher and the appropriate data is generated by a *key derivation*

routine using the provided password as input. This procedure employs a message digest algorithm and may use some initial value (or *salt*). Without any specific option the driver relies on the default message digest algorithm defined by the control parameter `ssl_digest` and generates a random salt of 8 bytes. These bytes are then saved at the beginning of the encrypted document such that the decryption process can retrieve them and regenerate the encryption key and initialisation vector from the provided password. This default behaviour can be changed using the `nosalt` option to avoid using a salt and the option `md` to select some other message digest algorithm. It is also possible to provide the encryption key and the initialisation vector via dedicated files using options `key` and `iv`. In this case no password has to be provided.

16.4.4 Driver `hmac`

```
hmac:[[md=a,]key=kf|key]filename
```

The *hmac* driver computes a HMAC (*keyed-hash message authentication code*) of its input stream using the provided key and hash function (the driver does not support reading). Options are provided enclosed in square brackets, at the least a key has to be provided. For instance, the following statement generates the HMAC of the file `"mydata"` using the key stored in the file `"keyfile"`:

```
fcopy("mydata","mmssl.hmac:[keyfile]mydata.hmac")
```

The key is read from the key file that is opened as a binary document. Alternatively, the key may be directly passed through the file name using the `key=` option:

```
fcopy("mydata","mmssl.hmac:[key=mykey]mydata.hmac")
```

Computation of a HMAC is based on a message digest algorithm, without any specific option the driver relies on the default message digest algorithm defined by the control parameter `ssl_digest` otherwise, the option `md` can be used to select some other algorithm.

CHAPTER 17

mmsvg

The *mmsvg* package provides a set procedures which allow users to display graphs of functions, diagrams, networks, various shapes *etc.* in SVG format. To use this module the following line must be included in the header of the Mosel model file:

```
uses "mmsvg"
```

mmsvg requires a webbrowser in order to be able to display graphics. Running a Mosel model that uses the `svgrefresh` routine provided by this module opens a window in the default browser that is configured on the system. In the absence of a webbrowser, it is still possible to generate graphics and save them to file via `svgsave`.

17.1 SVG graph structure

The SVG graph format is an XML format, that is, the elements of a graph are organized in a hierarchical tree structure. *mmsvg* structures graphical objects in three levels:

1. SVG graph
2. object group
3. graphical object

Each individual graphical object (line, polygon, text *etc.*) must be created within an *object group*. By default this is the last group that has been added to the graph, but some other object reference can be stated. A default graph object is always present and object groups are created within this default graph.

17.1.1 Object groups

Object groups are identified via a string ID that is specified by the user at their creation, this ID must be unique. Each object group receives an entry in the *legend* of the graph. Typically a group serves to represent a collection of graphical objects that are logically related. The style defined for a group is applied to all its objects unless it is overwritten by individual settings, meaning that it is usually more efficient to state generally valid style settings for an entire group instead of repeating them for each individual object.

At the creation of a group, optionally a *group color* can be specified. If no color is given, then a default color will be selected from a built-in list of color values.

Graphical objects are displayed in the order of definition of object groups, and within each group in the order of their definition.

17.1.2 SVG styling

Style definitions can be applied to all levels of SVG elements, to the graph, object groups, or for individual objects. *mmsvg* defines a set of property constants but other SVG styling options can equally be used by directly stating their name in the `svgset[graph]style` routines. For a complete list of SVG style properties and their permissible values the reader is refered to the SVG property specifications at https://www.w3.org/TR/SVG/propidx.html.

`SVG_COLOR`	Default color name (for object groups)
`SVG_DECORATION`	Text decoration; possible values include 'none', 'underline', 'overline', 'line-through', 'blink'
`SVG_FILL`	Fill color name
`SVG_FILLOPACITY`	Fill opacity; values between 0.0 and 1.0
`SVG_FONT`	Whitespace separated list of font settings
`SVG_FONTFAMILY`	Font family definition; this can be generic families ('serif', 'sans-serif', 'cursive', 'fantasy', 'monospace') or specific font names
`SVG_FONTSIZE`	Font size; constants ('xx-small', 'x-small', 'small', 'medium', 'large', 'x-large', 'xx-large) or percentage value or length (*e.g.* in 'em', 'pt', 'px', 'cm')
`SVG_FONTSTYLE`	Font style; values 'normal', 'italic', 'oblique'
`SVG_FONTWEIGHT`	Font weight; numbers 100,...900 or constants ('bold', 'bolder', 'lighter', 'normal')
`SVG_OPACITY`	Generic opacity setting; values between 0.0 and 1.0
`SVG_STROKE`	Color for lines and borders
`SVG_STROKEDASH`	Line style; comma-separated list of lengths or percentages specifying lengths of alternating dashes and gaps
`SVG_STROKEOPACITY`	Stroke opacity, values between 0.0 and 1.0
`SVG_STROKEWIDTH`	Stroke width; percentage or length
`SVG_TEXTANCHOR`	Vertical alignment of text; possible values include 'start', 'middle', 'end'

Other predefined constants are `SVG_CURRENT` for the current color and `SVG_NONE`.

mmsvg defines the following color constants (applicable to the properties `SVG_COLOR`, `SVG_FILL`, `SVG_STROKE`) that can be used in place of SVG color keywords or color definitions generated via the `svgcolor` routine:

- `SVG_BLACK`, `SVG_BLUE`, `SVG_BROWN`, `SVG_CYAN`, `SVG_GOLD`, `SVG_GRAY`, `SVG_GREEN`, `SVG_LIME`, `SVG_MAGENTA`, `SVG_ORANGE`, `SVG_PINK`, `SVG_PURPLE`, `SVG_RED`, `SVG_SILVER`, `SVG_WHITE`, `SVG_YELLOW`

For a full list of SVG color keywords and their definitions please see https://www.w3.org/TR/SVG/types.html.

The complete set of style properties specified for a graph, object group or individual objects can be retrieved via the routines `svggetstylesheet` and `svggetgraphstylesheet`, for example in order to copy them to some other object via `svgsetstylesheet` or `svgsetgraphstylesheet` respectively.

17.1.3 Interaction with the graphical display

The command `svgrefresh` sends the current graph and any additional files that might have been added to it (see `svgaddfile`) to the built-in server that handles the coordination with the display and triggers an update of the graphical display. The end of the model execution will also terminate the display, unless a call to the routine `svgwaitclose` is added at the end of the model, in which case the model waits for the closing of the display window.

Inserting a call to the routine `svgpause` into a model will pause its execution at this point until the user hits the 'Continue' button in the graphical display. Typically, this feature will be used to allow the user time for visual inspection of the output if a model iteratively generates graphics or updates to a graphic.

17.1.4 Example

The following example shows how to define a few simple graphical objects, saves the resulting graphic to a file and also displays it in a webbrowser. The model waits until the browser is closed.

```
model "svg example"
 uses "mmsvg"

! **** Line objects ****
 svgaddgroup("gl", "Lines")              ! Group with automatic color
 svgaddline(10,10,250,10)                ! Simple line with default style
 PointList:=sum(i in 1..20)[i*10,40+round(20*random)]
 svgaddline(PointList)                   ! Polyline
 l:=svggetlastobj                        ! Retrieve object reference
 svgsetstyle(l, SVG_STROKE, SVG_MAGENTA) ! Change line color
 svgsetstyle(l, SVG_STROKEDASH, "1,1")   ! Dotted line

! **** Various shapes ****
 svgaddgroup("gs", "Shapes", SVG_GREY)   ! Group with user-defined color
 svgaddrectangle(275,25,250,250)         ! Draw a square
 svgsetstyle(svggetlastobj, SVG_STROKEWIDTH, 3)    ! Wider border
 svgaddcircle(400,150,75)                ! Draw a circle
 svgsetstyle(svggetlastobj, SVG_FILL, SVG_CURRENT) ! Fill with group color
 svgaddpolygon([200,400,200,350,300,300,500,350,600,350,600,400])
 svgsetstyle(svggetlastobj, SVG_FILL, SVG_GREEN)   ! Fill with user color

! **** Pie chart ****
 forall(i in 1..6) svgaddgroup("gp"+i,"Pie"+i)     ! Pie slices with auto-colors
 setrandseed(3); ttl:=0.0
 forall(i in 1..5) do
   rd:=random/6
   svgaddpie("gp"+i, 150, 525, 100, ttl, ttl+rd)
   ttl+=rd
 end-do
 svgaddpie("gp6", 150, 525, 100, ttl, 1)

! **** Text objects ****
 svgaddgroup("gt", "Text", SVG_BLACK)    ! Group with user-defined color
 svgaddtext(20, 100, "Text with default formatting")
 svgaddtext(20, 120, "Formatted text")
 t:=svggetlastobj
 svgsetstyle(t, SVG_FONTSIZE, "20pt")
 svgsetstyle(t, SVG_FONTSTYLE, "italic")
 svgsetstyle(t, SVG_FONTWEIGHT, "bold")
 svgsetstyle(t, SVG_COLOR, SVG_BLUE)
 svgaddxmltext(20, 150, 'XML formatted text:
   <tspan font-size="large"> large</tspan>
   <tspan text-decoration="underline">underlined</tspan>
   <tspan stroke="red"> red</tspan>')

 svgsetgraphviewbox(0,0,610,635)        ! Optional: specify graph size

 svgsave("svgexpl.svg")                 ! Save graphic to file
```

```
svgrefresh                          ! Display graphic
svgwaitclose                        ! Wait until window is closed
end-model
```

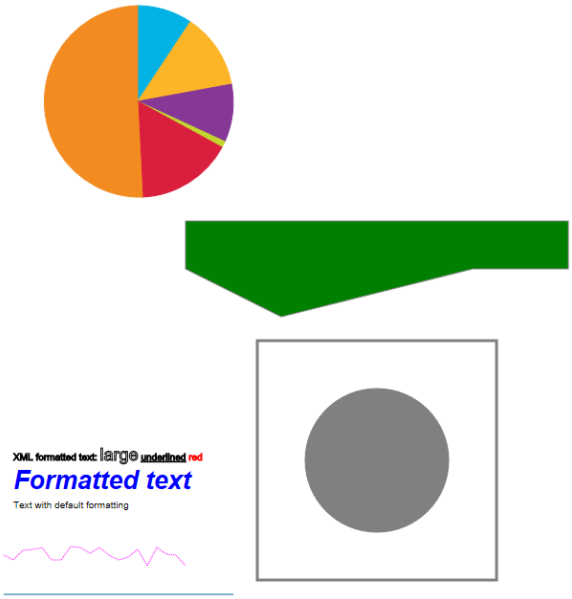


Figure 17.1: Graphical output produced by the example

17.2 Control parameters

The following parameters are defined by *mmsvg*:

MMSVGDISPLAY

Description When this parameter is set to `true` (the default) the first call to `svgrefresh` starts a web browser for displaying the current graph. Changing the value of this parameter disables rendering: after a warning message is reported calls to `svgrefresh` have no effect and the function `svgclosing` always returns `true`. Note that setting the environment variable `MMSVGDISPLAY` to a non empty string has the same effect as changing this control parameter.

Type Boolean, read/write

Values
- `true` Enable rendering.
- `false` Disable rendering.

Default value `true`

Affects routines `svgrefresh`, `svgclosing`.

Module mmsvg

MMSVGTGZ

Description The function `svgrefresh` requires the archive `mmsvg.tgz` for its processing. By default this file is expected to be located in the same directory as the module *mmsystem*. This parameter makes it possible to specify an alternate location.

Type String, read/write

Default value `""`

Affects routines `svgrefresh`.

Module mmsvg

17.3 Procedures and Functions

svgaddgroup

Purpose

Add a new object group to the user graph.

Synopsis

```
procedure svgaddgroup(gid: string, desc: text, color: text)
procedure svgaddgroup(gid: string, desc: text)
```

Arguments

`gid` Object group ID (must be unique within a graph).

`desc` A text that will appear in the legend.

`color` A color specification obtained using `svgcolor` or one of the predefined constants (see list in section 17.1.2).

Example

The following adds two groups 'g1' and 'g2' to the user graph:

```
svgaddgroup("g1", "sine", SVG_RED)    ! User-specified group color
svgaddgroup("g2", "random numbers")   ! Automatically selected color
```

Further information

1. A group is identified by its ID whereas the 'desc' serves as text for the legend of the graphic. A group contains any number of individual objects (points, lines, arrows, texts *etc.*) which were added to it.
2. An empty string for the 'desc' attribute indicates that the group is not to be included in the legend.
3. If no color is specified at the creation of a group it will be assigned a default color from a built-in list. This setting can be overwritten for individual objects within the group. Note that any style settings that are common to a large number of objects within a group should preferrably be specified for the group rather than for the individual objects.

Related topics

`svgsetstyle`.

svgaddarrow

Purpose

Add an arrow to an object group.

Synopsis

```
procedure svgaddarrow(gid: string, x1: real, y1: real, x2: real, y2: real)
procedure svgaddarrow(x1: real, y1: real, x2: real, y2: real)
```

Arguments

`gid`	Object group ID.
`x1`	The x coordinate of the first point.
`y1`	The y coordinate of the first point.
`x2`	The x coordinate of the second point.
`y2`	The y coordinate of the second point.

Example

The following adds two arrows to a group named ‘thetime’. The arrows suggest three o’clock:

```
svgaddgroup("arrows", "thetime", SVG_BLACK)
svgaddarrow("arrows", 0, 0, 0, 5)
svgaddarrow(0, 0, 4.5, 0)
svgsetgraphviewbox(-5, -6, 10, 12)
```

Further information

1. The arrow connects the two points whose coordinates are given as parameters, pointing to the second one.
2. If no group ID is specified, the arrow is added to the last group that has been created.

svgaddcircle

Purpose

Add a circle to an object group.

Synopsis

```
procedure svgaddcircle(gid: string, x: real, y: real, r: real)
procedure svgaddcircle(x: real, y: real, r: real)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the center point.
`y`	The y coordinate of the center point.
`r`	The length of the radius of the circle.

Example

The following code draws a filled, semi-transparent circle centered at the origin with a radius of 10.

```
declarations
  circ: integer
end-declarations

svgaddcircle(0, 0, 10)
circ:=svggetlastobj
svgsetstyle(circ, SVG_FILL, SVG_CYAN)
svgsetstyle(circ, SVG_OPACITY, 0.5)
```

Further information

If no group ID is specified, the circle is added to the last group that has been created.

svgaddellipse

Purpose

Add an ellipse to an object group.

Synopsis

```
procedure svgaddellipse(gid: string, x: real, y: real, rx: real, ry: real)
procedure svgaddellipse(x: real, y: real, rx: real, ry: real)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the center point of the ellipse.
`y`	The y coordinate of the center point of the ellipse.
`rx`	The horizontal radius.
`ry`	The vertical radius.

Example

The following code draws a very "flat" ellipse centered at the origin filled with the group color.

```
svgaddellipse(0,0,5,0.5)
svgsetstyle(svggetlastobj, SVG_FILL, SVG_CURRENT)
```

Further information

If no group ID is specified, the ellipse is added to the last group that has been created.

svgaddfile

Purpose

Add a file to a graph.

Synopsis

```
procedure svgaddfile(fname: string, fid: string)
```

Arguments

`fname` Filename (including path) of the file to be included.

`fid` Name for the file used within the SVG graph.

Example

The following code adds an image file to the current graph and displays it in an area with corner points at the coordinates (100,100) and (250,250).

```
svgaddfile("./someimage.png", "myimg.png")
svgaddimage("myimg.png", 100, 100, 150, 150)
```

Further information

1. This routine is typically used in combination with `svgaddimage` to associate some external file with the graph.
2. Using an empty file name `fname` will remove the corresponding `fid` from the file database.

Related topics

`svgaddimage`.

svgaddimage

Purpose

Add an image to an object group.

Synopsis

```
procedure svgaddimage(gid: string, fid: text, x: real, y: real, w: real, h:
      real)
procedure svgaddimage(fid: text, x: real, y: real, w: real, h: real)
```

Arguments

`gid`	Object group ID.
`fid`	Name for the file used within the SVG graph.
`x`	The x coordinate of the lower left corner.
`y`	The y coordinate of the lower left corner.
`w`	The width of the image.
`h`	The height of the image.

Example

The following code adds an image file to the current graph and displays it 3 times at different positions (3 squares forming a row).

```
svgaddfile("./someimage.png", "myimg.png")
forall(i in 1..3)
  svgaddimage("myimg.png", 100*i, 100, 100, 100)
```

Further information

1. Any external file to be displayed within a graph needs to be associated with the graph via a call to `svgaddfile`.
2. If no group ID is specified, the image is added to the last group that has been created.

Related topics

`svgaddfile`.

svgaddline

Purpose

Add a line or polyline to an object group.

Synopsis

```
procedure svgaddline(gid: string, x1: real, y1: real, x2: real, y2: real)
procedure svgaddline(x1: real, y1: real, x2: real, y2: real)
procedure svgaddline(gid: string, points: list of integer|real)
procedure svgaddline(points: list of integer|real)
```

Arguments

`gid`	Object group ID.
`x1`	The x coordinate of the first point.
`y1`	The y coordinate of the first point.
`x2`	The x coordinate of the second point.
`y2`	The y coordinate of the second point.
`points`	A list of points.

Example

The following code draws the outline of a triangle, given the correct aspect ratio of the user graph.

```
svgaddgroup("t", "triangle", SVG_ORANGE)
svgaddline([-2, -2, 0, 2, 2, -2, -2, -2)])
svgsetgraphviewbox(-5, -5, 10, 10)
```

If the shape is to be filled (here: using the group color), you need to use polygon drawing instead of a polyline:

```
svgaddpolygon([-2, -2, 0, 2, 2, -2)])
svgsetstyel(svggetlastobj, SVG_FILL, SVG_CURRENT)
```

Further information

1. The line connects the two points whose coordinates are given as parameters or the points contained in the specified list in their order of appearance in the list.
2. If no group ID is specified, the line is added to the last group that has been created.

Related topics

`svgaddpolygon`.

svgaddpie

Purpose

Add a filled pie slice at the given coordinates.

Synopsis

```
procedure svgaddpie(gid: string, x: real, y: real, r: real, p1: real, p2:
      real)
procedure svgaddpie(x: real, y: real, r: real, p1: real, p2: real)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the center point.
`y`	The y coordinate of the center point.
`r`	Radius (side length of the pie slice).
`p1`	Start position on the circle (percentage).
`p2`	End position on the circle (percentage).

Example

This code draws a pie chart with 5 slices of 20% width each around the center point (150,150) with a radius of 100.

```
forall(i in 1..5) do
  svgaddgroup("gp"+i, "Pie"+i)
  svgaddpie(150, 150, 100, (i-1)*0.2, i*0.2)
end-do
```

Further information

1. Pie slices are by default filled with the group color. If they are not to be filled with any color specify value `SVG_NONE` for the style property `SVG_FILL`.
2. If no group ID is specified, the pie slice is added to the last group that has been created.

svgaddpoint

Purpose

Add a small square to mark a point at the given coordinates.

Synopsis

```
procedure svgaddpoint(gid: string, x: real, y: real)
procedure svgaddpoint(x: real, y: real)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the point.
`y`	The y coordinate of the point.

Example

This code plots 100 random points:

```
svgaddgroup("cloud", "Random points", SVG_YELLOW)
svgsetgraphviewbox(-5, -5, 10, 10)
forall(i in 1..100)
  svgaddpoint("cloud", -2+4*random, -2+4*random)
```

Further information

If no group ID is specified, the point is added to the last group that has been created.

Related topics

`svgsetgraphpointsize`.

svgaddpolygon

Purpose

Add a polygon to an object group.

Synopsis

```
procedure svgaddpolygon(gid: string, points: list of integer|real)
procedure svgaddpolygon(points: list of integer|real)
```

Arguments

`gid`	Object group ID.
`points`	A list of points.

Example

The following code draws two semi-transparent, partially overlapping polygons, the first is filled with the group color, the second with a different color:

```
svgaddgroup("p", "Polygons")
svgsetstyle(SVG_OPACITY, 0.5)
svgsetstyle(SVG_FILL, SVG_CURRENT)
svgaddpolygon([-2, -2, 0, 2, 2, -2)])
svgaddpolygon([-1, -2, 1, 2, 3, -2)])
svgsetstyle(svggetlastobj, SVG_FILL, SVG_GREY)
```

Further information

1. The last point in the list of points is automatically connected to the first point in the list to form a closed shape.
2. If no group ID is specified, the polygon is added to the last group that has been created.

Related topics

`svgaddline`.

svgaddrectangle

Purpose

Add a rectangle to an object group.

Synopsis

```
procedure svgaddrectangle(gid: string, x: real, y: real, w: real, h: real)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the lower left corner.
`y`	The y coordinate of the lower left corner.
`w`	The width of the rectangle.
`h`	The height of the rectangle.

Example

The following code draws a rectangle filled with the group color covering an area 10 units long and 1 unit high starting at the origin.

```
svgaddrectangle(0,0,10,1)
svgsetstyle(svggetlastobj, SVG_FILL, SVG_CURRENT
```

Further information

If no group ID is specified, the rectangle is added to the last group that has been created.

svgaddtext

Purpose

Add a text to an object group.

Synopsis

```
procedure svgaddtext(gid: string, x: real, y: real, msg: text)
procedure svgaddtext(x: real, y: real, msg: text)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the point.
`y`	The y coordinate of the point.
`text`	The text that will be displayed at the given point.

Example

This code complements the time graph with a dial:

```
! This should complement the example for svgaddarrow
forall(i in 1..12)
  svgaddtext(4.8*cos(1.57-6.28*i/12), 5*sin(1.57-6.28*i/12), text(i))
```

Further information

1. By default the specified point denotes the lower left corner of the text display area; the vertical alignment can be changed via the style option `SVG_ANCHOR` (values 'start', 'middle', or 'end').
2. If no group ID is specified, the text is added to the last group that has been created.

Related topics

`svgaddxmltext`.

svgaddxmltext

Purpose

Add an XML formatted text to an object group.

Synopsis

```
procedure svgaddxmltext(gid: string, x: real, y: real, msg: text)
procedure svgaddxmltext(x: real, y: real, msg: text)
```

Arguments

`gid`	Object group ID.
`x`	The x coordinate of the point.
`y`	The y coordinate of the point.
`text`	The text that will be displayed at the given point.

Example

This code displays some text with individual formatting on different words:

```
svgaddxmltext(20, 150, 'XML formatted text:
  <tspan font-size="20px">large</tspan>,
  <tspan font-style="oblique">oblique</tspan>,
  <tspan font-weight="bold">bold</tspan>,
  <tspan text-decoration="underline">underlined</tspan>,
  <tspan stroke="red">red</tspan>')
```

Further information

1. By default the specified point denotes the lower left corner of the text display area; the vertical alignment can be changed via the style option `SVG_ANCHOR` (values 'start', 'middle', or 'end').
2. If no group ID is specified, the text is added to the last group that has been created.

Related topics

`svgaddtext`.

svgclosing

Purpose

Test whether the display window is being closed.

Synopsis

```
function svgclosing:boolean
```

Return value

'false' until the display window is about to be closed, 'true' afterwards.

Example

The following loop uses the browser window opening status as stopping criterion.

```
solct:= 0
svgrefresh              ! Start graph display before svgclosing test
while (solct<NBSOL and not svgclosing) do
  solct+=1
  draw_solution(solct)  ! Draws a graph calling svgrefresh and svgpause
end-do
svgwaitclose
```

Further information

This function can be used to intercept the event of the display window being closed in order to adapt the behaviour of the model execution (*e.g.* to interrupt a loop with repeated graphical displays or an optimization solver run).

Related topics

svgwaitclose.

svgcolor

Purpose

Compute a composite color by combining amounts of red, green and blue.

Synopsis

```
function svgcolor(red, green, blue: integer): text
function svgcolor(red, green, blue: real): text
function svgcolor(red, green, blue: text): text
```

Arguments

`red` Amount of red (integer between 0 and 255, real between 0 and 1, or hexadecimal value between 0 and FF).

`green` Amount of green (integer between 0 and 255, real between 0 and 1, or hexadecimal value between 0 and FF).

`blue` Amount of blue (integer between 0 and 255, real between 0 and 1, or hexadecimal value between 0 and FF).

Return value

Hexadecimal representation of the composite color.

Example

The following definitions mix red with green and store the result in a variable. All three forms result in the same color.

```
declarations
  a_color: text
end-declarations

a_color:=svgcolor(255,255,0)
a_color:=svgcolor(1.0,1.0,0.0)
a_color:=svgcolor("FF","FF","0")
```

Further information

If the color component values are out of range, *mmsvg* will raise an I/O error.

svgdelobj

Purpose

Delete the specified graphical object.

Synopsis

```
procedure svgdelobj(obj: integer)
```

Argument

`obj` Object ID as returned by `svggetlastobj`.

Further information

This procedure serves for deleting a specific graphical object. Use `svgerase` to delete the whole contents of an object group or all groups.

Related topics

`svgerase`, `svggetlastobj`.

svgerase

Purpose

Erase all object groups or the contents of a specific group.

Synopsis

```
procedure svgerase
procedure svgerase(gid: string)
```

Argument

`gid` Object group ID.

Further information

1. This procedure can be used together with `svgpause` to explore a number of different user graph versions during the execution of a Mosel model.
2. If a group ID is specified only the objects within this group are removed without deleting the group definition itself.
3. Use `svgdelobj` to delete individual graphical objects.

Related topics

`svgdelobj`, `svgpause`.

svggetgraphstyle

Purpose

Retrieve a style property of a graph.

Synopsis

```
function svggetgraphstyle(prop: string):text
```

Argument

`prop` The desired property (*mmsvg* constant or SVG property name).

Return value

Value of the property or empty string.

Example

This code retrieves the font family defined for a graph and applies it to an object group.

```
svgaddgroup("g", "A group")
svgsetstyle("g", SVG_FONTFAMILY, svggetgraphstyle("b", SVG_FONTFAMILY))
```

Further information

This function can be used to retrieve a style property of a graph in order to apply it to some object or group of objects. Use `svggetgraphstylesheet` to retrieve the whole set of style properties of a graph.

Related topics

`svggetstyle`, `svgsetstyle`, `svgsetgraphstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svggetgraphstylesheet

Purpose

Retrieve the style definitions of a graph.

Synopsis

```
function svggetgraphstylesheet:array of text
```

Return value

An array of style properties ('stylesheet') with their respective values.

Example

This code retrieves the style properties of a graph and applies them to an object group.

```
svgaddgroup("a", "A group")
svgsetstylesheet("a", svggetgraphstylesheet)
```

Further information

This function can be used to retrieve the set of style properties ('stylesheet') of a graph in order to apply it to some object or group of objects. Use `svggetgraphstyle` to retrieve individual style properties of a graph.

Related topics

`svggetstyle`, `svgsetstyle`, `svggetgraphstyle`, `svgsetgraphstyle`, `svgsetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svggetgraphviewbox

Purpose

Retrieve the viewbox definition of a graph.

Synopsis

```
function svggetgraphviewbox:svgbox
```

Return value

An object of type 'svgbox' that holds the view box defined for the graph.

Example

This code displays the viewbox defined for a graph.

```
writeln(svggetgraphviewbox)
```

Further information

This function can be used to retrieve the viewbox (=visible area) defined for a graph.

Related topics

svgsetgraphviewbox.

svggetlastobj

Purpose

Retrieve the identifier of a graphical object.

Synopsis

```
function svggetlastobj:integer
```

Return value

Integer identifier of the last graphical object that has been added.

Example

This code retrieves an object identifier to apply several style settings.

```
declarations
  t: integer
end-declarations

svgaddgroup("gt", "Text")
svgaddtext(20, 120, "Formatted text")
t:=svggetlastobj
svgsetstyle(t, SVG_COLOR, SVG_GREEN)
svgsetstyle(t, SVG_FONTSTYLE, "italic")
```

Further information

This function serves for retrieving the identifier of a graphical object, in particular in order to apply style settings to this object.

Related topics

svgsetstyle.

svggetstyle

Purpose

Retrieve a style property of a graphical object or object group.

Synopsis

```
function svggetstyle(gid: string, prop: string):text
function svggetstyle(prop: string):text
function svggetstyle(obj: integer, prop: string):text
```

Arguments

`gid`	Object group ID.
`obj`	Object ID.
`prop`	The desired property (*mmsvg* constant or SVG property name).

Return value

Value of the property or empty string.

Example

This code retrieves the color of a group and applies it to an object belonging to another group.

```
svgaddgroup("a", "Group A")
svgaddgroup("b", "Group B")
svgaddtext("a", 20, 120, "Formatted text")
svgsetstyle(svggetlastobj, SVG_COLOR, svggetstyle("b", SVG_COLOR))
```

Further information

This function can be used to retrieve a style property of some object in order to apply it to some other object or group of objects. Use `svggetstylesheet` to retrieve the whole set of style properties of an object or group of objects.

Related topics

`svgsetstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svggetstylesheet

Purpose

Retrieve style definitions of a graphical object or object group.

Synopsis

```
function svggetstylesheet(gid: string):array of text
function svggetstylesheet:array of text
function svggetstylesheet(obj: integer):array of text
```

Arguments

`gid` Object group ID.

`obj` Object ID.

Return value

An array of style properties ('stylesheet') with their respective values.

Example

This code retrieves the style properties of a group and applies them to an object belonging to another group.

```
svgaddgroup("a", "Group A")
svgaddgroup("b", "Group B")
svgaddtext("a", 20, 120, "Formatted text")
svgsetstylesheet(svggetlastobj, svggetstylesheet("b"))
```

Further information

This function can be used to retrieve the set of style properties ('stylesheet') of some object in order to apply it to some other object or group of objects. Use `svggetstyle` to retrieve individual style properties of an object or group of objects.

Related topics

`svggetstyle`, `svgsetstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svgsetstylesheet`.

svgpause

Purpose

Suspend the execution of a Mosel model at the line where the call occurs.

Synopsis

```
procedure svgpause
```

Further information

While the model run is suspended, the displayed graph or other model output can be inspected. This allows for visualization of intermediate states or solutions. To continue, click on the 'Continue' button in the display window.

svgrefresh

Purpose

Refresh the graph display.

Synopsis

```
procedure svgrefresh
```

Example

This code defines some objects and draws the graph, it then adds further objects and updates te display..

```
svgaddgroup("a", "Group A")
svgaddtext(0, 0, "Some text")
svgrefresh                              ! Display the graph
svgaddgroup("b", "Group B")
svgaddtext("a", 0, 20, "Some more text")
svgaddcircle(10,10, 45)
svgrefresh                              ! Update the display
```

Further information

`svgrefresh` needs to be called in order to trigger the display of a graph. The subroutine can be called repeatedly in order to update the display—each time it will be completely redrawn. The refresh frequency can be controlled via `svgsetreffreq`.

Related topics

`svgsetreffreq`.

svgsave

Purpose

Save a graph to a file.

Synopsis

```
procedure svgsave(fname: string)
```

Argument

`fname` The (extended) filename to be used as output destination.

Example

This code saves a graph to the file 'mygraph.svg' in the model working directory.

```
svgaddgroup("a", "Group A")
svgaddrectangle(20, 120, 200, 250)
svgsave("mygraph.svg")
```

Further information

This procedure can be used independently of the graphical display in order to produce output in SVG format of the current graph definition.

svgsetgraphlabels

Purpose

Set x- and y-axis labels for a graph.

Synopsis

```
procedure svgsetgraphlabels(xlabel: text, ylabel: text)
```

Arguments

`xlabel` Label text for the x-axis.

`ylabel` Label text for the y-axis.

Example

The following line sets the x-axis label text to 'Time in sec' and the y-axis label to 'Solution value'.

```
svgsetgraphlabels("Time in sec", "Solution value")
```

Further information

1. By default (no labels specified or empty strings) no label text is displayed.
2. The axes are displayed only if a label is defined (for x or y axis) unless `svgshowgraphaxes` has been used.

Related topics

`svgsetgraphscale`, `svgsetgraphpointsize`, `svgsetgraphviewbox`, `svgshowgraphaxes`.

svgsetgraphpointsize

Purpose

Set point size property for a graph.

Synopsis

```
procedure svgsetgraphpointsize(val: real)
```

Argument

`val` The new value for the point size.

Example

This code shows how to modify graph scaling properties.

```
svgsetgraphpointsize(0.5)
svgsetgraphscale(10)
```

Further information

This routine is likely to be used in combination with `svgsetgraphscale` in order to resize a graph.

Related topics

`svgsetgraphscale`, `svggetgraphstyle`, `svgsetgraphstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`.

svgsetgraphscale

Purpose

Set scaling value for a graph.

Synopsis

```
procedure svgsetgraphscale(val: real)
```

Argument

`val` The new scaling value.

Example

This code shows how to modify graph scaling properties.

```
svgsetgraphpointsize(0.5)
svgsetgraphscale(10)
```

Further information

This routine is likely to be used in combination with `svgsetgraphpointsize` in order to resize a graph for display.

Related topics

`svgsetgraphpointsize`, `svggetgraphstyle`, `svgsetgraphstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`.

svgsetgraphstyle

Purpose

Set a style property of a graph.

Synopsis

```
procedure svgsetgraphstyle(prop: string, val: text|real)
```

Arguments

`prop` The desired property (*mmsvg* constant or SVG property name).

`val` The new value for the property (usually a text, but properties like `SVG_OPACITY` or `SVG_STROKEWIDTH` also accept numerical values).

Return value

Value of the property or empty string.

Example

This code retrieves the font family defined for a group and applies it to the entire graph.

```
svgaddgroup("g", "A group")
svgsetgraphstyle(SVG_FONTFAMILY, svggetstyle("g", SVG_FONTFAMILY))
```

Further information

This procedure can be used to define a style property of a graph. Use `svgsetgraphstylesheet` to define the whole set of style properties of a graph.

Related topics

`svggetstyle`, `svgsetstyle`, `svggetgraphstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svgsetgraphstylesheet

Purpose

Set the style definitions for a graph.

Synopsis

```
procedure svgsetgraphstylesheet(stsh: array (svgstyleattrs) of text)
```

Argument

`stsh` Style definition.

Example

This code retrieves the style properties of a group and applies them to the entire graph.

```
svgaddgroup("a", "A group")
svgsetgraphstylesheet(svggetstylesheet("a"))
```

Further information

This procedure can be used to define the set of style properties ('stylesheet') of a graph. Use `svgsetgraphstyle` to define individual style properties of a graph.

Related topics

`svggetstyle`, `svgsetstyle`, `svggetgraphstyle`, `svgsetgraphstyle`, `svggetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svgsetgraphviewbox

Purpose

Set the visible area for a user graph.

Synopsis

```
procedure svgsetgraphviewbox(x: real, y: real, w: real, h: real)
procedure svgsetgraphviewbox(box: svgbox)
```

Arguments

`x`	The x coordinate of the lower left corner.
`y`	The y coordinate of the lower left corner.
`w`	The width of the viewbox.
`h`	The height of the viewbox.
`box`	Viewbox specification as returned by `svggetgraphviewbox`.

Further information

1. The viewable area is determined by its lower left corner, its width and height.
2. *mmsvg* automatically determines a viewbox (enclosing all specified coordinates) that can be retrieved with `svggetgraphviewbox`.

Related topics

`svggetgraphviewbox`, `svgsetgraphlabels`, `svgsetgraphscale`.

svgsetreffreq

Purpose

Set the refresh frequency for a graph.

Synopsis

```
procedure svgsetreffreq(val: real)
```

Argument

`val` The new refresh frequency (maximum number of refreshs per second).

Further information

The refresh frequency indicates how often individual calls to `svgrefresh` are posted to the display. If several refresh occur during the specified time span, only the last one is executed.

Related topics

`svgrefresh`.

svgsetstyle

Purpose

Set a style property for a graphical object or object group.

Synopsis

```
procedure svgsetstyle(gid: string, prop: string, val: text|real)
procedure svgsetstyle(prop: string, val: text|real)
procedure svgsetstyle(obj: integer, prop: string, val: text|real)
```

Arguments

`gid` Object group ID.

`obj` Object ID.

`prop` The desired property (*mmsvg* constant or SVG property name).

`val` The new value for the property (usually a text, but properties like `SVG_OPACITY` or `SVG_STROKEWIDTH` also accept numerical values).

Example

This code retrieves the color of a group and applies it to an object belonging to another group.

```
svgaddgroup("a", "Group A")
svgaddgroup("b", "Group B")
svgaddtext("a", 20, 120, "Formatted text")
svgsetstyle(svggetlastobj, SVG_COLOR, svggetstyle("b", SVG_COLOR))
```

Further information

This procedure can be used to define a style property of some object or group of objects. Use `svgsetstylesheet` to redefine the whole set of style properties of an object or group of objects.

Related topics

`svggetstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svggetstylesheet`, `svgsetstylesheet`.

svgsetstylesheet

Purpose

Set the style for a graphical object or object group.

Synopsis

```
procedure svgsetstylesheet(gid: string, stsh: array (svgstyleattrs) of
      text)
procedure svgsetstylesheet(stsh: array(svgstyleattrs) of text)
procedure svgsetstylesheet(obj: integer, stsh: array(svgstyleattrs) of
      text)
```

Arguments

`gid` Object group ID.

`obj` Object ID.

`stsh` Style definition.

Example

This code retrieves the style properties of a group and applies them to an object belonging to another group.

```
svgaddgroup("a", "Group A")
svgaddgroup("b", "Group B")
svgaddtext("a", 20, 120, "Formatted text")
svgsetstylesheet(svggetlastobj, svggetstylesheet("b"))
```

Further information

This procedure can be used to define a set of style properties ('stylesheet') of some object or group of objects. Use `svgsetstyle` to modify individual style properties of an object or group of objects.

Related topics

`svggetstyle`, `svgsetstyle`, `svggetgraphstylesheet`, `svgsetgraphstylesheet`, `svgsetstylesheet`.

svgshowgraphaxes

Purpose

Force displaying of graph axes.

Synopsis

```
procedure svgshowgraphaxes(force:boolean)
```

Argument

`force` Decide whether graph axes must be shown when no label is defined.

Further information

By default the axes are only shown if a label text is defined (for x or y axis). This procedure makes it possible to display the axes even if no label is used.

Related topics

`svgsetgraphlabels`.

svgwaitclose

Purpose

Delay model termination.

Synopsis

```
procedure svgwaitclose(msg:text,mode:integer)
procedure svgwaitclose(msg:text)
procedure svgwaitclose
```

Arguments

`msg` Some message to display.

`mode` Mode of operation:

- `0` Wait until the browser window is closed
- `1` Same as above except if running from Workbench: termination occurs after the graph is loaded

Example

This code shows a typical call sequence for graphical display.

```
svgaddgroup("a", "Group A")
svgaddrectangle(20, 120, 200, 250)
svgrefresh        ! Display the graphic
svgwaitclose      ! Model waits here until display window is closed
```

Further information

1. A call to this routine is typically added to the end of any model that includes graphical display (that is, calls to `svgrefresh`) via *mmsvg* to allow the user time for inspecting the graphical output. If this subroutine call is not present, then model termination may close the display window or prevent the browser to load the graph.
2. The last form of the routine is equivalent to `svgwaitclose("",0)`.

Related topics

`svgrefresh`, `svgclosing`.

CHAPTER 18

mmsystem

The *mmsystem* module provides a set of procedures and functions related to the operating system. Note that the behavior of these operators may vary between systems. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmsystem'
```

18.1 New functionality for the Mosel language

18.1.1 The type `text`

This module provides the type `text` for text manipulation. Like the Mosel basic type `string`, this new type may be generated from all objects that can be converted to a text representation and supports the usual string operations (like concatenation or formatting). In addition, text objects can be generated from structured entities (like arrays or lists); altered (one can get and change a single as well as a sequence of characters in a text); offer a wider set of operations (like insertion/deletion/search of substrings) and, as all module types, are passed by reference to subroutines. Note that this type supports creation of constants (*i.e.* it can be used in sets of constants) and implicit conversion from `string`: a routine expecting a `text` as parameter may be used with a `string` instead (in this case the compiler creates a temporary text from the provided string). When creating a text object from a structured type it is possible to specify a limit on the size of the generated string. For instance if `S` is a set, `text(S,128)` will produce a textual representation of S of at most 128 characters.

18.1.2 The type `date`

As the name suggests, the type `date` is used to represent a calendar date. Internally, a date is stored as three independent integers for representing the year (-32768 to 32767), the month (-128 to 127) and the day in the month (-128 to 127). The validity of a date can be checked using the function `isvalid`. A date object can be initialized by a text string, a single or three numerical values. In the first case, the conversion is processed using a predefined date format (see `datefmt`); in the second case, the integer is interpreted as the number of days elapsed since 1/1/1970 (this value can be negative); finally, if three integers are used, they are respectively interpreted as the year, month and day for the date. The constant `SYS_NOW` may also be used to initialize a date: `date(SYS_NOW)` is the current date (local time). This type also supports creation of constants (*i.e.* it can be used in sets of constants), assignment, comparison as well as difference (returned in number of days) and addition/subtraction of an integer (number of days).

18.1.3 The type `time`

The type `time` is used to represent a time during the day. Internally, a time object is stored as an integer representing a number of milliseconds. A time object can be initialized by a text string or one to four numerical values. In the first case, the conversion is processed using a predefined time format (see

timefmt); in the second case, the integer is interpreted as a number of milliseconds. When two to four integers are used, they are understood as the hours, minutes, seconds and milliseconds. The constant SYS_NOW may also be used to initialize a time: time(SYS_NOW) is the current time (local time). This type also supports creation of constants (*i.e.* it can be used in sets of constants), assignment, comparison as well as difference (returned in number of milliseconds) and addition/subtraction of an integer (number of milliseconds).

18.1.4 The type datetime

The type datetime is used to represent a timestamp by combining a date and a time. A datetime object can be initialized by a text string, a pair date and time or a numerical value. In the first case, the conversion is processed using a predefined time format (see datetimefmt); in the third case, the number is interpreted as the number of seconds elapsed since 1/1/1970 at midnight (this value can be negative). If the provided number is a real value, the fractional part is stored as a number of milliseconds. The constant SYS_NOW may also be used to initialize a datetime: datetime(SYS_NOW) is the current date and time (local time). This type also supports creation of constants (*i.e.* it cand be used in sets of constants), assignment, comparison as well as difference (returned in number of seconds) and addition/subtraction of a numerical value (number of seconds).

18.1.5 The type parsectx

This module publishes a set of routines for parsing input text strings (for instance parseint or nextfield). These routines use several module parameters for both their configuration and as a way to record their internal state: a variable of type parsectx may be used as a replacement for these module parameters in order to implement parsing procedures independent of the rest of the program. A single parsectx object integrates endparse (see sys_endparse), sepchar (see sys_sepchar), trim (see sys_trim) and qtype (see sys_qtype). The current value of each of these components can be accessed using the corresponding *set* and *get* routine (for instance getendparse).

18.1.6 The type textarea

The textarea type is used by the regular expression matching function regmatch to return locations in the input string. Each text area is defined by a *starting position* (that is an offset in the original string) and an *ending position* characterised by the offset of the character following the region to be considered. Functions getstart and getsucc can be used to retrieve these properties.

For instance, the following statement displays the region ta of the text txt:

```
writeln(copytext(txt,ta.start,ta.succ-1))
```

This can also be written as follows:

```
writeln(copytext(txt,ta))
```

18.2 Control parameters

Via the getparam function and the setparam procedure it is possible to access the following control parameters of module *mmsystem* (the reader is reminded that parameters may be spelled with lower or upper case letters or a mix of both):

datefmt	Date text format.	p. 511
datetimefmt	Date and time text format.	p. 512

datefmt

Description Define the text format for both reading and writing a date.

Type String, read/write

Default value `"%.y-%0m-%0d"`

Note The date format consists in a text string in which the date information (like day number) is specified using tags. A tag begins by the character `"%"` optionally followed by `"."` or `"0"` and a character indicating which specific information must be provided. The possible values are:

- `C` Century
- `Y` Year number in the century
- `y` Year
- `m` Month (1-12)
- `N` Name of month according to parameter `monthnames`
- `d` Day (1-31)
- `%` The symbol `"%"`

If the second character is used, the corresponding information is produced in fixed format with space (`"."`) or zero (`"0"`) as the padding character. For instance, the day 1 will be displayed as `"1"` with the format `"%d"`; as `" 1"` with `"%.d"` and as `"01"` with `"%0d"`.

See also `datetimefmt`,`monthnames`

Module mmsystem

timefmt

Description Define the text format for both reading and writing time.

Type String, read/write

Default value `"%0H:%0M:%0S%f"`

Note The time format consists in a text string in which the time information (like number of seconds) is specified using tags. A tag begins by the character `"%"` optionally followed by `"."` or `"0"` and a character indicating which specific information must be provided. The possible values are:

`H` Hour (0-23)
`h` Hour (1-12)
`M` Minute (0-59)
`S` Seconds (0-59)
`s` Milliseconds (0-999)
`f` Milliseconds as a fractonal value with a comma as the decimal separator (,001-,999)
`F` Milliseconds as a fractonal value with a dot as the decimal separator (.001-.999)
`p` text `"pm"` or `"am"`
`P` text `"PM"` or `"AM"`
`%` The symbol `"%"`

If the second character is used, the corresponding information is produced in fixed format with space (`" ."`) or zero (`"0"`) as the padding character. For instance, the hour 1 will be displayed as `"1"` with the format `"%H"`; as `" 1"` with `"% .H"` and as `"01"` with `"%0H"`. When the formats `f` or `F` are used for parsing they both accept dot and comma as the decimal separator. The formats `f` and `F` without second character (`" ."` or `"0"`) display nothing if the number of milliseconds is 0.

See also datetimefmt

Module mmsystem

datetimefmt

Description Define the text format for both reading and writing a datetime object.

Type String, read/write

Default value `"%.y-%0m-%0dT%0H:%0M:%0S%f"`

Note The datetime format accepts the syntaxes of the date format and the time format in the same string.

See also datefmt,timefmt

Module mmsystem

monthnames

Description Define month names to be used with the %N format.

Type String, read/write

Default value `"jan feb mar apr may jun jul aug sep oct nov dec"`

Note This parameter is used when converting dates from/to strings with the `%N` format. The string must contain 12 words separated by spaces. For conversions from strings, the comparison is not case sensitive.

See also datefmt,datetimefmt

Module mmsystem

sys_endparse

Description Index in the text string where the parsing stopped. This parameter is updated and may be used (as a starting position) by the `parse*` routines.

Type Integer, read/write

Set by routines `parseint`, `parsereal`, `parseextn`, `parsetext`, `nextfield`

Module mmsystem

sys_fillchar

Description Character code used to fill empty regions generated in text strings when using the function `setchar`.

Type Integer, read/write

Values Between 1 and 127

Default value 32 (space character)

Affects routines `setchar`

Module mmsystem

sys_pid

Description System identification (Process ID) of the process running Mosel.

Type Integer, read only

Default value assigned by the operating system

Module mmsystem

sys_qtype

Description Convention to use when quoting/parsing a text string.

Type Integer, read/write

Default value 0

Note Supported quoting conventions are:

- `0` Mosel: strings optionally quoted with either single or double quotes. With double quotes, escape sequences starting with the backslash character (`"\"`) are supported
- `1` C/C++: double quotes with escape sequences starting with the backslash character (`"\"`)
- `2` CSV: strings are optionally quoted with double quotes. The symbol "double quotes" is doubled when it is included in a quoted string
- `3` JSON: double quotes with escape sequences starting with the backslash character (`"\"`)
- `-1` No quoting

Affects routines `parsetext`, `quote`

Module mmsystem

sys_regcache

Description Regular expression searches require a compilation procedure to be performed before the actual search. In order to speedup handling of expressions, a number of compiled expressions are saved in a cache pool: this parameter specifies the size of this pool. Note that setting this parameter has the effect of clearing the cache (even if the pool size if kept unchanged).

Type Integer, read/write

Values Between 1 and 25

Default value 3

Affects routines `regmatch`, `regreplace`

Module mmsystem

sys_sepchar

Description Character code used as a field separator for text parsing routines.

Type Integer, read/write

Values Between 1 and 127

Default value 32 (space character)

Affects routines `parsetext`, `quote`, `nextfield`

Module mmsystem

sys_trim

Description If this parameter is `true`, function `nextfield` skips blank characters around field separators.

Type Boolean, read/write

Default value true

Affects routines `nextfield`

Set by routines `nextfield`

See also `sys_sepchar`

Module mmsystem

sys_txtmem

Description All `text` objects are stored in a single block of memory. This parameter corresponds to the size of this block expressed in kilobytes. Changing this value makes it possible either to pre-allocate memory by increasing the size of the block or release unused memory by reducing its size. If the requested size is not large enough to contain the currently defined text objects, the memory block is reduced to the smallest possible size.

Type Integer, read/write

Default value 0 (at program startup)

Module mmsystem

18.3 Procedures and functions

In general, the procedures and functions of *mmsystem* do not fail but set a status variable that can be read with `getsysstat`. To make sure the operation has been performed correctly, check the value of this variable after each system call.

addmonths

Purpose

Add a number of months to a date or datetime.

Synopsis

```
function addmonths(d:date, nbm:integer):date
function addmonths(dt:datetime, nbm:integer):datetime
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object
`nbm`	The number of months to be added (can be negative)

Return value

The modified date or datetime.

Example

```
writeln(addmonths(date(2000,1,31),1))     ! displays: 2000-02-29
writeln(addmonths(date(2012,12,12),-12)) ! displays: 2011-12-12
```

Further information

The day number is preserved unless it is not compatible with the computed month: in this case the day number is moved to the last day of the month.

Module

mmsystem

compareic

Purpose

Compare 2 text strings ignoring case.

Synopsis

```
function compareic(arg1:string|text, arg2:string|text):integer
```

Arguments

`arg1`	First operand for the comparison
`arg2`	Second operand for the comparison

Return value

`0` if strings are identical, `-1` if the first string is less than the second string and `1` otherwise.

Further information

This function behaves like `compare` but ignoring case.

Module

mmsystem

copytext

Purpose

Copy a part of a text or string.

Synopsis

```
function copytext(t:text|string, i1:integer, i2:integer):text
function copytext(t:text|string, ta:textarea):text
```

Arguments

`t`	A string or text object
`i1`	Starting position of the region to copy
`i2`	End position of the region to copy
`ta`	A text area object

Return value

A copy of the region.

Example

The following:

```
writeln(copytext("abcdefgh",3,7))
writeln(copytext("abcdefgh",7,10))
```

produces this output:

```
cdefg
gh
```

Further information

This function returns an empty text if the bounds are not compatible with the string (*e.g.* starting position larger than the length of the string) or inconsistent (*e.g.* starting position after end position).

Related topics

`deltext`, `inserttext`, `pastetext`, `cuttext`

Module

mmsystem

cuttext

Purpose

Cut a part of a text returning a copy of the deleted string.

Synopsis

```
function cuttext(txt:text, i1:integer, i2:integer):text
function cuttext(txt:text, ta:textarea):text
```

Arguments

`txt`	A text object
`i1`	Starting position of the region to cut
`i2`	End position of the region to cut
`ta`	A text area object

Return value

A copy of the region. The input text is modified accordingly.

Example

The following:

```
t:=text("abcdefgh")
writeln(cuttext(t,3,7))
writeln(t)
```

produces this output:

```
cdefg
abh
```

Further information

This function returns an empty text if the bounds are not compatible with the string (*e.g.* starting position larger than the length of the string) or inconsistent (*e.g.* starting position after end position).

Related topics

`deltext`, `inserttext`, `pastetext`, `copytext`

Module

mmsystem

deltext

Purpose

Delete a part of a text.

Synopsis

```
procedure deltext(txt:text, i1:integer, i2:integer)
procedure deltext(txt:text, ta:textarea)
```

Arguments

`txt`	A text object
`i1`	Starting position of the region to delete
`i2`	End position of the region to delete
`ta`	A text area object

Example

The following:

```
t:=text("abcdefgh")
deltext(t,3,7)
writeln(t)
```

produces this output:

```
abh
```

Related topics

`cuttext`, `inserttext`, `pastetext`, `copytext`

Module

mmsystem

endswith

Purpose

Check whether a text or string ends with a given string.

Synopsis

```
function endswith(txt:text|string, tofs:text|string):boolean
```

Arguments

`txt`	A string or text object
`tofs`	String to find

Return value

`true` if the ending of `txt` corresponds to `tofs`.

Related topics

`startswith`

Module

mmsystem

erase

Purpose

Securely deletes the content of a text entity.

Synopsis

```
procedure erase(txt:text)
```

Argument

`txt` A text object to be erased

Further information

This function resets the text string it receives after having replaced each of its characters by a space.

Module

mmsystem

expandpath

Purpose

Expand a path or file name.

Synopsis

```
function expandpath(fname:string|text):text
```

Argument

`fname` File name to be expanded

Return value

An absolute path to the given file name or an empty string in case of failure.

Further information

1. This function *expands* a path or file name: it replaces all relative references (like `"."` or `".."`) and completes the path such that the returned string is an absolute path to the provided file name.
2. Only the `"tmp:"` IO driver can be expanded: any other driver reference will make the function fail and result in an empty string.

Module

mmsystem

fcopy

Purpose

Copy a file.

Synopsis

```
procedure fcopy(namesrc:string|text, namedest:string|text)
procedure fcopy(namesrc:text, opts:integer, namedest:text, optd:integer)
```

Arguments

`namesrc`	The name of the file to be copied
`opts`	Open options for the input file
`namedest`	The destination name
`optd`	Open options for the output file

Example

The following statement appends file `"src"` to file `"dst"`:

```
fcopy("src",0,"dst",F_APPEND)
```

Further information

1. This procedure copies the file `namesrc` to `namedest` (that is replaced if it already exists). The provided names may use extended notation.
2. With the second form of the procedure it is possible to select options used to open the 2 files (as used with the `fopen` procedure). The first syntax corresponds to:
   `fcopy(src,F_SILENT+F_BINARY,dst,F_SILENT+F_BINARY)`

Related topics

`fopen`, `getsysstat`

Module

mmsystem

fdelete

Purpose

Delete a file.

Synopsis

```
procedure fdelete(filename:string|text)
```

Argument

`filename` The extended name of the file to be deleted

Further information

The provided name may use extended notation.

Related topics

`removedir`, `removefiles`, `getsysstat`

Module

mmsystem

findfiles

Purpose

Search for files according to file name patterns.

Synopsis

```
procedure findfiles(opt:integer,lsf:list of text,
       dir:string|text,filters:string|text)
procedure findfiles(opt:integer,lsf:list of text,filters:string|text)
procedure findfiles(lsf:list of text,filters:string|text)
procedure findfiles(lsf:list of text)
```

Arguments

`opt` Options (several options can be combined):

`SYS_RECURS`	Recursive search in subdirectories
`SYS_NODIR`	Do not report directories (only files)
`SYS_DIRONLY`	Report only directories
`SYS_REVORD`	Reverse sort order
`SYS_NOSORT`	Do not sort resulting list

`lsf` Resulting list of file names

`dir` Base directory for the search (default: current directory)

`filters` File name filters (default: all files reported)

Example

The following prints the list of files with extension `.mos` and `.bim` of the current directory:

```
findfiles(lsf,"*.mos|*.bim")
writeln(lsf)
```

Further information

1. The `filters` argument consists in a list of patterns separated by the symbol `";"`: for each of these patterns the function executes a search from the specified `dir` directory. A pattern is composed of a path (using the usual operating system conventions) which last component may include wildcard characters `"*"` (any text of any length), `"?"` (any single character) and `"|"` (logical "or"). For instance `"bin/*.exe;models/*.mos|*.dat"` will select all files with extension `".exe"` in the `"bin"` directory as well as files with extension `".mos"` and `".dat"` in the `"models"` directory.
2. File name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).
3. Unless option `SYS_NOSORT` is used, the resulting list is sorted and duplicate entries are removed. Note also that the provided list `lsf` is not reset: the result of the search is appended to this list.

Related topics

`removefiles`, `getsysstat`

Module

mmsystem

findtext

Purpose

Search for a string in a text or string.

Synopsis

```
function findtext(txt:text, toft:text, start:integer):integer
function findtext(txt:text, tofs:string, start:integer):integer
function findtext(str:string, tofs:string, start:integer):integer
```

Arguments

`txt`	A text object
`str`	String
`toft`	Text to find
`tofs`	String to find
`start`	Starting position for the search

Return value

Index of the string or 0 if not found.

Example

The following:

```
writeln(findtext("abcdefgh","de",2))
writeln(findtext("abcdefgh","de",5))
```

produces this output:

```
4
0
```

Related topics

`regmatch`

Module

mmsystem

fmove

Purpose

Rename or move a file.

Synopsis

```
procedure fmove(namesrc:string|text,namedest:string|text)
```

Arguments

`namesrc`	The name of the file to be moved or renamed
`namedest`	The destination name and/or path

Further information

This procedure renames the file `namesrc` to `namedest`. If the second name is a directory, the file is moved into that directory; if it is an existing file it is first removed before the renaming. The provided names may use extended notation.

Related topics

`getsysstat`

Module

mmsystem

formattext

Purpose

Create a text from a format string and its parameters.

Synopsis

```
function formattext(fmt:string, a1, a2...):text
function formattext(fmt:string, l: list):text
```

Arguments

`fmt`	Format string
`ai`	Parameters of the format string
`l`	List of parameters of the format string

Return value

Formatted text.

Example

The following:

```
writeln(formattext("text1%8stext3", "text2"))
writeln(formattext("text1%-8stext3", "text2"))
r:=789.123456
writeln(formattext("%1$r %1$4.2f%1$8.0f",r))
```

produces this output:

```
text1     text2text3
text1text2     text3
789.123 789.12        789
```

Further information

1. This procedure behaves in a similar way as the `sprintf` function of the C language: the resulting text is generated by inserting each of the parameters *ai* in the format string at locations identified by a marker. This marker is of the form:

   ```
   %[index$][flags][width][.precision]conv
   ```

   Where *index* (a non negative integer), *flags* (string of `' '`,`'-'`,`'+'`,`'0'` and `'#'`), *width* (positive integer) and *precision* (non negative integer) are optional.
   The *index* indicates which parameter to use for the conversion (first parameter has number 1), when it is not specified the marker position is used instead (*e.g.* the third marker is used for the third parameter).
   The *flags* essentially affect numerical conversions: with the flag `'0'` the value is zero padded; with `'-'` the value is left justified; with a space a blank is put before positive numbers and with `'+'` positive numbers are preceded by the '+' sign.
   The *width* defines a minimum width for the field.
   The *precision* gives the minimum number of digits to appear for an integer conversion. With a floating point value and a conversion `'a'`,`'A'`,`'e'`,`'E'` or `'f'` it states the number of digits to appear after the radix and for a `'g'` conversion it is the maximum number of significant digits. The precision indicates a maximum number of characters to display with textual conversions.
   The conversion specifier *conv* is a letter indicating how to process the corresponding parameter and what to ouput. Possible values for this character are:

   `diouxX` an integer value is output: the parameter must be an integer or a Boolean. The value is displayed as a decimal number (`'d'` or `'i'`), an octal number (`'o'`), an unsigned number (`'u'`) or a hexadecimal number (`'x'` or `'X'`)

   `eEfgraAjy` a real value is output: the parameter must be a real or an integer. If it is a real and parameter `txtztol` is `true` then any value smaller than parameter `zerotol` will be replaced `0`. When using the `'r'` conversion the optional part components of the marker are ignored and the value is converted using the current real printing format (according to the `realfmt` parameter, see setparam). The conversions `'e'` and `'E'` format the number as `[-]d.ddde+/-dd`; conversion `'f'` uses a format of the form `[-]ddd.ddd` and conversion `'g'` selects format `'e'` or `'f'` depending on the value of the number. With `'a'` and `'A'` the value is converted to an hexadecimal representation of the form `[-]0`*`x`*`h.hhh`*`p`*`[+/-]ddd` where `'h'` are hexadecimal digits and `'d'` decimal digits. The conversions `'j'` and `'y'` produce a reversible textual representation of the real number (*i.e.* converting the string back to real restores the exact original value). The format `'j'` generates a decimal notation similar to the specification ECMA-262 (*e.g.* `"123.456"`) while the format `'y'` produces a scientific notation in all cases (*e.g.* `"1.2345e2"`).

   `b` `'true'` or `'false'` is output: the parameter must be a Boolean

   `c` a character is output: the parameter must be an integer that is interpreted as a Unicode code point

   `s` a text string is output: the parameter must be a string or any type supporting conversion to text

   `p` a pointer expressed in hexadecimal is output: the parameter can be any referenced entity

2. To include the symbol `'%'` in the format string use the sequence `'%%'`.

Related topics

textfmt, setparam

Module

mmsystem

getasnumber

Purpose

Convert a date, time or datetime into a number.

Synopsis

```
function getasnumber(d:date):integer
function getasnumber(t:time):integer
function getasnumber(dt:datetime):real
```

Arguments

`d`	A `date` object
`t`	A `time` object
`dt`	A `datetime` object

Return value

The numerical representation of the argument.

Further information

A date is converted to an integer Julian Day Number (number of days since 1/1/1970 at midnight). This function returns an integer number of milliseconds for a time and a real number of seconds for a `datetime`. This number represents the number of seconds and milliseconds (as the fractional part of the number) since 1/1/1970 at midnight.

Module

mmsystem

getchar

Purpose

Get a character in a string or text.

Synopsis

```
function getchar(txt:text, index:integer):integer
function getchar(str:string, index:integer):integer
```

Arguments

`txt`	A text object
`str`	String
`index`	Position of the character

Return value

Character code or -1 if the index is not valid.

Related topics

`setchar`

Module

mmsystem

getcwd

Purpose

Get the current working directory.

Synopsis

```
function getcwd:string
```

Return value

The current working directory.

Further information

1. This function returns the current working directory, that is the directory where the model is being executed and where files are looked for.
2. The returned value corresponds to `getparam("workdir")`. The current working directory can also be changed via this control parameter (for instance `setparam("workdir","../somedir")`.

Module

mmsystem

getdate

Purpose

Get the date part of a datetime.

Synopsis

```
function getdate(dt:datetime):date
```

Argument

`dt` A `datetime` object

Return value

A `date` object.

Related topics

`gettime`, `getasnumber`

Module

mmsystem

getday

Purpose

Get the day number in the month of a date or datetime.

Synopsis

```
function getday(d:date):integer
function getday(dt:datetime):integer
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object

Return value

Day number in the month.

Related topics

`getyear`, `getmonth`, `getdaynum`

Module

mmsystem

getdaynum

Purpose

Get the day number in the year of a date or datetime.

Synopsis

```
function getdaynum(d:date):integer
function getdaynum(dt:datetime):integer
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object

Return value

Day number in the year.

Example

```
writeln(getdaynum(date(2010,2,1)))    ! displays: 32
```

Related topics

`getday`

Module

mmsystem

getdays

Purpose

Get the number of days of a month.

Synopsis

```
function getdays(y:integer, m:integer):integer
function getdays(d:date):integer
function getdays(dt:datetime):integer
```

Arguments

`y`	Year
`m`	Month
`d`	A `date` object
`dt`	A `datetime` object

Return value

Number of days for the given month in the specified year.

Example

```
writeln(getdays(2016,2))    ! displays: 29
```

Module

mmsystem

getdirsep

Purpose

Get the directory separator of the running operating system.

Synopsis

```
function getdirsep:string
```

Return value

`"/"` on Posix systems and `"\"` on Windows.

Related topics

`getpathsep`

Module

mmsystem

getdsoparam

Purpose

Get the value of a control parameter.

Synopsis

```
function getdsoparam(name:string|text):text
```

Argument

`name` Name of a control parameter (including the module name).

Return value

Current setting of the control parameter as a text.

Further information

1. This function is similar to `getparam` except that the control parameter name is searched at runtime. As a consequence this identifier does not need to be a constant string but the execution is significantly slower than `getparam` and it cannot be applied to package parameters.
2. The provided parameter name must include the module name (*e.g.* `"mmsystem.datefmt"`) otherwise the identifier is searched only in the list of Mosel parameters.
3. As opposed to `getparam` this procedure does not raise an error in case of failure (like parameter not found): use `getsysstat` to detect error conditions.

Related topics

`setdsoparam`, `getsysstat`

getendparse, setendparse

Purpose

Get and set `endparse` property of a parser context.

Synopsis

```
function getendparse(pctx:parsectx):integer
procedure setendparse(pctx:parsectx, ep:integer)
```

Arguments

`pctx`	A parser context
`ep`	New `endparse` value

Return value

Current `endparse` value stored in the context.

Related topics

`sys_endparse`, `getsepchar`, `gettrim`, `getqtype`

Module

mmsystem

getenv

Purpose

Get the value of an environment variable of the operating system.

Synopsis

```
function getenv(name:string|text):string
```

Argument

`name` Name of the environment variable

Return value

Value of the environment variable (an empty string if the variable is not defined).

Further information

This procedure is included in the published interface of `mmsystem` (see Section 18.5).

Example

The value of the environment variable PATH is retrieved as follows:

```
str:= getenv("PATH")
```

Related topics

`setenv`

Module

mmsystem

getfsize

Purpose

Get the size of a file.

Synopsis

```
function getfsize(filename:string|text):integer
```

Argument

`filename` Name (and path) of the file

Return value

The size of the file in bytes or -1 in case of error

Further information

The function returns -1 if the file cannot be found or accessed and `MAX_INT` if the size exceeds the integer capacity (~2Gb).

Related topics

`getsysstat`

Module

mmsystem

getfstat, getflstat

Purpose

Get the status (type and access mode) of a file or directory.

Synopsis

```
function getfstat(filename:string|text):integer
function getflstat(filename:string|text):integer
```

Argument

`filename` Name (and path) of the file or directory to check

Return value

Bit encoded type and mode of the given file or 0 if the file cannot be accessed.

Example

The following determines whether `ftest` is a directory and if it is writable:

```
fstat:= getfstat("ftest")
if bittest(fstat, SYS_TYP)=SYS_DIR
then writeln("ftest is a directory")
end-if
if bittest(fstat, SYS_WRITE)=SYS_WRITE
then writeln("ftest is writeable")
end-if
```

Further information

1. The returned status type may be decoded using the constant mask `SYS_TYP` (the types are exclusive). Possible values are:
   `SYS_DIR` Directory
   `SYS_REG` Regular file
   `SYS_LNK` Symbolic link
   `SYS_OTH` Special file (device, pipe...)

   The access mode may be decoded using the constant mask `SYS_MOD` (the access modes are additive). Possible values are:
   `SYS_READ` Can be read
   `SYS_WRITE` Can be modified
   `SYS_EXEC` Is executable
2. The 2 versions of this function behave the same except for symbolic links: the first one (*getfstat*) reports the properties of the linked file while the second (*getflstat*) reports a type `SYS_LNK`.

Related topics

`readlink`, `getsysstat`

Module

mmsystem

getftime

Purpose

Get time information of a file.

Synopsis

```
function getftime(filename:string|text,what:integer):real
```

Arguments

`filename`	Name (and path) of the file
`what`	Information requested. Possible values: `SYS_FTIM_ACC` Last access `SYS_FTIM_MOD` Last modification

Return value

The time requested as the number of seconds elapsed since 1/1/1970 at midnight or 0 in case of error.

Related topics

`getsysstat`

Module

mmsystem

gethour

Purpose

Get the hour part of a time or datetime.

Synopsis

```
function gethour(t:time):integer
function gethour(dt:datetime):integer
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object

Return value

Hour as an integer.

Related topics

`getminute`, `getsecond`, `getmsec`

Module

mmsystem

getminute

Purpose

Get the minute part of a time or datetime.

Synopsis

```
function getminute(t:time):integer
function getminute(dt:datetime):integer
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object

Return value

Minute as an integer.

Related topics

`gethour`, `getsecond`, `getmsec`

Module

mmsystem

getmonth

Purpose

Get the month number of a date or datetime.

Synopsis

```
function getmonth(d:date):integer
function getmonth(dt:datetime):integer
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object

Return value

Month number in the year.

Related topics

`getyear`, `getday`

getmsec

Purpose

Get the millisecond part of a time or datetime.

Synopsis

```
function getmsec(t:time):integer
function getmsec(dt:datetime):integer
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object

Return value

Millisecond as an integer.

Related topics

`gethour`, `getminute`, `getsecond`

Module

mmsystem

getoserror

Purpose

Get the system error code of the last command.

Synopsis

```
function getoserror:integer
```

Return value

A system error code or 0 if the last operation of the module was executed sucessfully.

Further information

This function reports the current system error code (corresponding to the C-variable `errno` on Posix and the C-function `GetLastError()` on Windows): it can be used after `getsysstat` has returned a non-zero status to get the actual system error (if the failure was actually due to a system error). This code is system dependent but the corresponding error message might be retrieved using `getoserrmsg`.

Related topics

`setoserror`

Module

mmsystem

getoserrmsg

Purpose

Get the message associated to a system error code.

Synopsis

```
function getoserrmsg(ec:integer):text
```

Argument

`ec` A system error code

Return value

The message corresponding to the provided code or an empty string if the code is not known.

Further information

This function returns an explanatory message associated to the error code obtained from `getoserror`.

Module

mmsystem

getpathsep

Purpose

Get the path separator of the running operating system.

Synopsis

```
function getpathsep:string
```

Return value

`":"` on Posix systems and `";"` on Windows.

Related topics

getdirsep

Module

mmsystem

getsucc, setsucc

Purpose

Get and set `succ` (position of successor character) property of a text area.

Synopsis

```
function getsucc(ta:textarea):integer
procedure setsucc(ta:textarea, st:integer)
```

Arguments

`ta`	A text area object
`st`	New `succ` value

Return value

Current `succ` value stored in the object.

Related topics

`getstart`

Module

mmsystem

getqtype, setqtype

Purpose

Get and set `qtype` property of a parser context.

Synopsis

```
function getqtype(pctx:parsectx):integer
procedure setqtype(pctx:parsectx, qt:integer)
```

Arguments

`pctx`	A parser context
`qt`	New `qtype` value

Return value

Current `qtype` value stored in the context.

Related topics

`sys_qtype`, `getsepchar`, `gettrim`, `getendparse`

Module

mmsystem

getsecond

Purpose

Get the second part of a time or datetime.

Synopsis

```
function getsecond(t:time):integer
function getsecond(dt:datetime):integer
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object

Return value

Second as an integer.

Related topics

`gethour`, `getminute`, `getmsec`

Module

mmsystem

getsepchar, setsepchar

Purpose

Get and set `sepchar` property of a parser context.

Synopsis

```
function getsepchar(pctx:parsectx):integer
procedure setsepchar(pctx:parsectx, sc:integer)
```

Arguments

`pctx`	A parser context
`sc`	New `sepchar` value

Return value

Current `sepchar` value stored in the context.

Related topics

`sys_sepchar`, `getendparse`, `gettrim`, `getqtype`

Module

mmsystem

getsize

Purpose

Get the size of a text.

Synopsis

```
function getsize(txt:text):integer
function getsize(ta:textarea):integer
```

Arguments

`txt`	A `text` object
`ta`	A text area object

Return value

The number of characters included in the text or text area.

Module

mmsystem

getstart, setstart

Purpose

Get and set `start` property of a text area.

Synopsis

```
function getstart(ta:textarea):integer
procedure setstart(ta:textarea, st:integer)
```

Arguments

`ta`	A text area object
`st`	New `start` value

Return value

Current `start` value stored in the object.

Related topics

`getsucc`

Module

mmsystem

getsysinfo

Purpose

Get information about the running operating system.

Synopsis

```
function getsysinfo:string
function getsysinfo(what:integer):string
function getsysinfo(I:Mosel):string
function getsysinfo(I:Mosel,what:integer):string
```

Arguments

`what` What information to collect:

`SYS_NAME`	Name of the operating system
`SYS_VER`	Version name of the operating system
`SYS_REL`	Release number of the operating system
`SYS_PROC`	Processor type
`SYS_ARCH`	Processor architecture (32 or 64 bit)
`SYS_NODE`	Computer name
`SYS_RAM`	Total amount of system memory (in megabytes)

`I` A Mosel instance

Return value

A text string reporting the requested information.

Example

The following prints the computer name and its operating system version:

```
writeln("Node ",getsysinfo(SYS_NODE),
        " is running ",getsysinfo(SYS_NAME+SYS_REL))
```

Further information

1. Several information items can be obtained in a single call by summing up the option codes. In such a case, the resulting string consists in the different items separated by commas.
2. When the function is used without the `what` parameter, all information items are returned.
3. This function may also be used with a Mosel instance as its first parameter. In this case the returned information relates to the system running this instance instead of the current system.

Related topics

mmjobs

Module

mmsystem

getsysstat

Purpose

Get the system status.

Synopsis

```
function getsysstat:integer
```

Return value

0 if the last operation of the module was executed sucessfully.

Example

In this example we attempt to delete the file `randomfile`. If this is unsuccessful, a warning message is displayed:

```
fdelete("randomfile")
if getsysstat <> 0 then
 writeln("randomfile could not be deleted.")
end-if
```

Further information

This function should be used after every system call in order to check the status of the operation.

Related topics

`getoserror`, `getoserrmsg`

Module

mmsystem

gettime

Purpose

Get a time measure or the time part of a datetime.

Synopsis

```
function gettime:real
function gettime(dt:datetime):time
```

Argument

`dt` A `datetime` object

Return value

Time measure in seconds or a `time` object.

Example

The following prints the program execution time:

```
starttime:= gettime                  ! Get the start time
 ...                                 ! Do something
write("Time: ",gettime-starttime)
```

Further information

1. The measure returned by this function corresponds to the elapsed time since the module has been initialized (just before execution of the model starts).
2. The second form of this function is used to extract the time part of a datetime structure.

Related topics

`getdate`, `getasnumber`

Module

mmsystem

gettmpdir

Purpose

Get the temporary directory as a text object.

Synopsis

```
function gettmpdir:text
```

Return value

Temporary directory as a `text` object.

Further information

This function is equivalent to `text(getparam("tmpdir"))`.

Module

mmsystem

gettrim, settrim

Purpose

Get and set `trim` property of a parser context.

Synopsis

```
function gettrim(pctx:parsectx):boolean
procedure settrim(pctx:parsectx, t:boolean)
```

Arguments

`pctx`	A parser context
`t`	New `trim` value

Return value

Current `trim` value stored in the context.

Related topics

`sys_trim`, `getsepchar`, `getendparse`, `getqtype`

Module

mmsystem

getweekday

Purpose

Compute the day of the week for a date or datetime.

Synopsis

```
function getweekday(d:date):integer
function getweekday(dt:datetime):integer
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object

Return value

The number of the day in the week (1-7).

Further information

The first day of the week (number 1) is Monday.

Module

mmsystem

getyear

Purpose

Get the year part of a date or datetime.

Synopsis

```
function getyear(d:date):integer
function getyear(dt:datetime):integer
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object

Return value

Year as an integer.

Related topics

`getmonth`, `getday`

Module

mmsystem

inserttext

Purpose

Paste a text or string into a text.

Synopsis

```
procedure inserttext(txt:text, str:string, start:integer)
procedure inserttext(txt:text, src:text, start:integer)
```

Arguments

`txt`	A text object
`src`	A text object
`str`	A string
`start`	Insert position

Example

The following:

```
t:=text("abcdefgh")
inserttext(t,"123",2)
writeln(t)
inserttext(t,"456",8)
writeln(t)
```

produces this output:

```
a123bcdefgh
a123bcd456efgh
```

Related topics

`cuttext`, `deltext`, `pastetext`, `copytext`

Module

mmsystem

isvalid

Purpose

Check whether a date, time or datetime is valid.

Synopsis

```
function isvalid(d:date):boolean
function isvalid(t:time):boolean
function isvalid(dt:datetime):boolean
```

Arguments

`d`	A `date` object
`t`	A `time` object
`dt`	A `datetime` object

Return value

True if the argument is valid.

Further information

A `date` is valid if its month number is in the range 1-12 and its day number is in the range 1-31 and is compatible with its month number (for instance 2006-2-29 is not a valid date). A `time` is valid if it is positive and smaller than an entire day. A `datetime` is valid if both its date part and its time part are valid.

Module

mmsystem

jointext

Purpose

Merge elements of a list or set into a text string.

Synopsis

```
function jointext(ls:list|set):text
function jointext(ls:list|set, mxe:integer):text
function jointext(ls:list|set, sep:string):text
function jointext(ls:list|set, sep:string, mxe:integer):text
```

Arguments

`ls`	List or set to use as input
`sep`	Separator string (default: `','`)
`mxe`	Maximum number of elements to merge (default: `0` for no limit)

Return value

A text string consisting of the concatenation of set or list elements.

Further information

1. This function concatenates the elements of an input list or set to produce a text string. Items are separated by the provided separator string that may be an empty string.
2. The argument `mxe` may be used to specify a maximum number of elements to process (the remaining portion of the input data is ignored). If this limit is negative then the elements are taken from the end of the collection (*e.g.* with `-3` the last 3 elements of the collection are used), otherwise elements are taken from the beginning.

Related topics

`splittext`

Module

mmsystem

makedir

Purpose

Create a new directory in the given file system.

Synopsis

```
procedure makedir(dirname:string|text)
```

Argument

`dirname` The name and path of the directory to be created

Related topics

`removedir`, `makepath`, `getsysstat`

Module

mmsystem

makepath

Purpose

Create a new directory including its parents if necessary.

Synopsis

```
procedure makepath(dirname:string|text)
procedure makepath(dirname:string|text,last_is_file:boolean)
```

Arguments

`dirname`	The name and path of the directory to be created
`last_is_file`	If `true`, the last component of the path is ignored

Further information

1. This routine creates the directory `dirname` as well as intermediate directories in the path if necessary. For instance, `makepath("/tmp/dir1/dir2")` will create `"/tmp"` then `"/tmp/dir1"` before `"/tmp/dir1/dir2"` if these directories are missing.
2. As opposed to `makedir`, this routine does not return an error condition if the path already exists.
3. The second form of this procedure can be used when the argument is a path to a file in order to create the directory in which the file can be created. For instance, `makepath("/tmp/dir1/myfile",true)` will create `"/tmp/dir1"` such that file `/tmp/dir1/myfile"` can be created.

Related topics

`removedir`, `makedir`, `getsysstat`

Module

mmsystem

newtar

Purpose

Create a Unix tar archive from a list of files.

Synopsis

```
procedure newtar(opt:integer, tarfile:text, dir:text,
       lsf:list of text|string)
procedure newtar(tarfile:text, lsf:list of text|string)
```

Arguments

`opt`	Options:
	`SYS_NODIR` Do not store directories (only files)
	`SYS_DIRONLY` Store only directories
	`SYS_FLAT` Store all files in the root directory of the archive (*i.e.* do not preserve directory structure)
`tarfile`	File name of the archive
`dir`	Base directory (default: current directory)
`lsf`	List of files and directories to store in the archive (file names are relative to the `dir` directory)

Example

The following creates an archive of the Xpress installation including only binary files:

```
findfiles(SYS_RECURS,lsf,getenv("XPRESSDIR"),"bin/*;lib/*;dso/*")
newtar(0,"xpress.tar",getenv("XPRESSDIR"),lsf)
```

Further information

1. This implementation processes only regular files, symbolic links (on Posix systems) and directories: other file types are silently ignored and not included in the archive.
2. By default file names are represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.tar"`).
3. File names including `".."` are silently ignored unless option `SYS_FLAT` is used.

Related topics

`tarlist`, `untar`, `newzip`, `getsysstat`

Module

mmsystem

newzip

Purpose

Create a Zip archive from a list of files.

Synopsis

```
procedure newzip(opt:integer, zipfile:text, dir:text,
       lsf:list of text|string, password:text)
procedure newzip(opt:integer, zipfile:text, dir:text,
       lsf:list of text|string)
procedure newzip(zipfile:text, lsf:list of text|string)
```

Arguments

`opt`	Options:
	`SYS_NODIR` Do not store directories (only files)
	`SYS_DIRONLY` Store only directories
	`SYS_FLAT` Store all files in the root directory of the archive (*i.e.* do not preserve directory structure)
`zipfile`	File name of the archive (that must be a physical file)
`dir`	Base directory (default: current directory)
`lsf`	List of files and directories to store in the archive (file names are relative to the `dir` directory)
`password`	Password to generate en encrypted zip file

Example

The following creates an archive of the Xpress installation including only binary files:

```
findfiles(SYS_RECURS,lsf,getenv("XPRESSDIR"),"bin/*;lib/*;dso/*")
newzip(0,"xpress.zip",getenv("XPRESSDIR"),lsf)
```

Further information

1. This implementation only supports the standard Zip format (only 32bit and basic encryption algorithm) with symbolic links on Posix systems.
2. By default file names are represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.zip"`).
3. File names including `"..."` are silently ignored unless option `SYS_FLAT` is used.

Related topics

`ziplist`, `unzip`, `newtar`, `getsysstat`

Module

mmsystem

nextfield

Purpose

Advance to next field in a structured text string.

Synopsis

```
function nextfield(txt:text,start:integer,trim:boolean):boolean
function nextfield(txt:text):boolean
function nextfield(txt:text,pctx:parsectx):boolean
```

Arguments

`txt`	A `text` object
`pctx`	A parser context
`start`	Starting position in the text (default value depends on which other arguments are used)
`trim`	Whether to skip blank characters around separators

Return value

`true` if more data can be parsed.

Example

The following function returns the list of records of a text string using comma as the field separator character:

```
function split(t:text):list of text
 declarations
  pctx:parsectx
 end-declarations

 pctx.sepchar:=44  ! ','
 while(nextfield(t,pctx)) do
  returned+=[parsetext(t,pctx)]
 end-do
end-function
```

Further information

1. When `start` is `0`, this routine saves the position of the first character of the text string in the control parameter `sys_endparse` and returns `true`.
2. When `start` is greater than `0` and the character located at position `start` is the separator character `sys_sepchar`, the position `start+1` is saved in control parameter `sys_endparse` and `true` is returned. In all other cases `false` is returned.
3. This function returns `false` if the provided text `txt` is empty or the starting position `start` is not valid.
4. If argument `trim` is `true`, blank characters are skipped before and after the separator character. The provided value is saved in parameter `sys_trim` when `start` is `0`.
5. In the second form of the routine, parameters `sys_endparse` and `sys_trim` are used as default values for arguments `start` and `trim`.
6. The version using a parser context works with the information contained in this context instead of the global parameters (see Section 18.1.5).

Related topics

`parseint`, `parsereal`, `parseextn`, `parsetext`, `getsysstat`

Module

mmsystem

openpipe

Purpose

Start an external process for bidirectional communication.

Synopsis

```
procedure openpipe(cmd:string|text)
```

Argument

`cmd` The command to be executed in the separate process

Example

The following example uses an external program *sort* (we assume it writes a sorted copy of what it reads) to display a sorted list of the content of set *ToSort*:

```
openpipe("sort")
forall(i in ToSort)
 writeln(i)
fclose(F_OUTPUT)

while(not iseof) do
 readln(l)
 writeln(l)
end-do
fclose(F_INPUT)
```

Further information

1. Pipes required by this procedure are created using the *pipe* driver of this module (see Section 18.4.2). As a consequence, the string provided as argument must be suitable for the driver (*i.e.* a program name followed by its options separated by spaces).
2. This procedure opens both an input and output streams that must be closed explicitly using `fclose`. Note that the output stream must be closed first otherwise the program may lock up.
3. When Mosel is running in restricted mode (see Section 1.3.4), this procedure behaves like the `system` procedure.
4. In case of failure the procedure raises an IO error.

Module

mmsystem

parseextn

Purpose

Initialise an object of a module type from a text.

Synopsis

```
procedure parseextn(txt:text,start:integer,e:mtype)
procedure parseextn(txt:text,e:mtype)
procedure parseextn(txt:text,pctx:parsectx,e:mtype)
procedure parseextn(txt:text,ta:textarea,e:mtype)
```

Arguments

`txt`	A `text` object
`pctx`	A parser context
`ta`	A text area object
`start`	Starting position in the text (default value depends on which other arguments are used)
`e`	An object of an external type

Example

The following:

```
d:=date(SYS_NOW)
t:=text("1-Oct-2015")
setparam("datefmt", "%d-%N-%y")
parseextn(t,1,d)
if getsysstat<>0 then
 writeln("Error")
else
 writeln("year:",d.year)
end-if
```

produces this output:

```
year:2015
```

Further information

1. This function can only be used with types supporting initialisation from a string (like date or time for instance). The parsing begins at the specified starting position and stops as soon as an invalid character is found or when the end of the text is reached.
   - *Standard (initial two) versions:* if `start` is not provided then the value of the control parameter `sys_endparse` is used as starting position; the location where parsing stops is stored in the parameter `sys_endparse`.
   - *Version using a parser context:* the information contained in the parser context is used instead of the global parameters (see Section 18.1.5); the context property `endparse` indicates the starting position and is updated with the location where parsing stops.
   - *Version using a `textarea` object:* the routine uses the `start` property of the object (see Section 18.1.6) as the starting position but it does not store the position where parsing stops, in particular it does not modify the parameter `sys_endparse`.
2. In case of error the system status is set with a non-zero value (see `getsysstat`).

Related topics

`parseint`, `parsereal`, `parsetext`, `nextfield`, `sys_endparse`

Module

mmsystem

parseint

Purpose

Convert a text into an integer.

Synopsis

```
function parseint(txt:text,start:integer):integer
function parseint(txt:text,start:integer,base:integer):integer
function parseint(txt:text):integer
function parseint(txt:text,pctx:parsectx):integer
function parseint(txt:text,pctx:parsectx,base:integer):integer
function parseint(txt:text,ta:textarea):integer
function parseint(txt:text,ta:textarea,base:integer):integer
```

Arguments

`txt`	A `text` object
`pctx`	A parser context
`ta`	A text area object
`start`	Starting position in the text (default value depends on which other arguments are used)
`base`	Base to use for the conversion (between 2 and 36)

Return value

The integer represented by the string.

Example

The following:

```
t:=text("a123.4b")
writeln(parseint(t,2))
writeln(getparam("sys_endparse"))
```

produces this output:

```
123
5
```

Further information

1. The parsing begins at the specified starting position and stops as soon as an invalid character is found or when the end of the text is reached.
   - *Standard (initial three) versions:* if `start` is not provided then the value of the control parameter `sys_endparse` is used as starting position; the location where parsing stops is stored in the parameter `sys_endparse`.
   - *Version using a parser context:* the information contained in the parser context is used instead of the global parameters (see Section 18.1.5); the context property `endparse` indicates the starting position and is updated with the location where parsing stops.
   - *Version using a `textarea` object:* the routine uses the `start` property of the object (see Section 18.1.6) as the starting position but it does not store the position where parsing stops, in particular it does not modify the parameter `sys_endparse`.
2. In case of error (no valid character found or overflow) the system status is set with a non-zero value (see `getsysstat`) and, depending on the situation, 0, `MAX_INT` or `-MAX_INT-1` is returned.
3. The optional `base` argument may be used if the text is not expressed in base 10. Valid values for this parameter is 0 and 2 to 36. If base is zero or 16, the string may then include a '0x' prefix, and the number will be read in base 16. Furthermore, if the base is 0, the text will be read in base 8 if the first character is 0 and in base 10 otherwise.
4. The base value may also be negative: in this case the input data is interpreted as an unsigned integer.

Related topics

`parsereal`, `parseextn`, `parsetext`, `nextfield`, `sys_endparse`

Module

mmsystem

parsereal

Purpose

Convert a text into a real.

Synopsis

```
function parsereal(txt:text,start:integer):real
function parsereal(txt:text):real
function parsereal(txt:text,pctx:parsectx):real
function parsereal(txt:text,ta:textarea):real
```

Arguments

`txt`	A `text` object
`pctx`	A parser context
`ta`	A text area object
`start`	Starting position in the text (default value depends on which other arguments are used)

Return value

The real represented by the string.

Example

The following:

```
t:=text("a123.4b")
writeln(parsereal(t,2))
writeln(getparam("sys_endparse"))
```

produces this output:

```
123.4
7
```

Further information

1. The parsing begins at the specified starting position and stops as soon as an invalid character is found or when the end of the text is reached.
   - *Standard (initial two) versions:* if `start` is not provided then the value of the control parameter `sys_endparse` is used as starting position; the location where parsing stops is stored in the parameter `sys_endparse`.
   - *Version using a parser context:* the information contained in the parser context is used instead of the global parameters (see Section 18.1.5); the context property `endparse` indicates the starting position and is updated with the location where parsing stops.
   - *Version using a `textarea` object:* the routine uses the `start` property of the object (see Section 18.1.6) as the starting position but it does not store the position where parsing stops, in particular it does not modify the parameter `sys_endparse`.
2. If the string starts with the sequence `"0x"` or `"OX"` an hexadecimal representation of a floating point value will be expected. This representation is of the form `"[+/-]0xh.hhhp[+/-]ddd"` where `'h'` are hexadecimal digits and `'d'` decimal digits.
3. In case of error (no valid character found or overflow) the system status is set with a non-zero value (see `getsysstat`) and, depending on the situation, 0, `MAX_REAL` or `-MAX_REAL` is returned.

Related topics

`parseint`, `parseextn`, `parsetext`, `nextfield`, `sys_endparse`

Module

mmsystem

parsetext

Purpose

Extract a text from a text.

Synopsis

```
function parsetext(txt:text,start:integer):text
function parsetext(txt:text):text
function parsetext(txt:text,pctx:parsectx):text
function parsetext(txt:text,ta:textarea):text
```

Arguments

`txt`	A `text` object
`pctx`	A parser context
`ta`	A text area object
`start`	Starting position in the text (default value depends on which other arguments are used)

Return value

Decoded text.

Example

The following:

```
t:=text("a123.4b")
setparam("sys_sepchar",46)  ! '.'
writeln(parsetext(t,2))
writeln(getparam("sys_endparse"))
```

produces this output:

```
123
5
```

Further information

1. The behaviour of this routine depends on 2 control parameters: `sys_sepchar` (or context property `sepchar`) defines a field separator that may mark the end of a non-quoted string and the parameter `sys_qtype` (or context property `qtype`) specifies the convention to use for quoted strings: if this parameter has value `0` (the default), Mosel quoting convention is used (both single and double quotes may be employed and with double quotes escape sequences are allowed); with value `-1` no quoting is expected; with value `1`, C/C++ quoting convention applies (only double quotes with escape sequences); with value `3`, JSON quoting convention applies (only double quotes with escape sequences). Finally, with value `2`, CSV convention is expected (double quotes and repetition of double quotes to escape this character). The returned string is decoded: quotes are removed and escape sequences are replaced by their corresponding characters.

2. The parsing begins at the specified starting position and stops as soon as the separator character (`sys_sepchar` or context property `sepchar` respectively) is found or the quoted string is terminated.

   - *Standard (initial two) versions:* if `start` is not provided then the value of the control parameter `sys_endparse` is used as starting position; the location where parsing stops is stored in the parameter `sys_endparse`.
   - *Version using a parser context:* the information contained in the parser context is used instead of the global parameters (see Section 18.1.5); the context property `endparse` indicates the starting position and is updated with the location where parsing stops.
   - *Version using a `textarea` object:* the routine uses the `start` property of the object (see Section 18.1.6) as the starting position but it does not store the position where parsing stops, in particular it does not modify the parameter `sys_endparse`.

3. In case of error, `getsysstat` will return a negative value. A positive value indicates that a quoted string is unfinished (*i.e.* the end of the source text is reached although no matching quote has been found).

Related topics

`parseint`, `parsereal`, `parseextn`, `nextfield`, `sys_sepchar`, `sys_qtype`, `sys_endparse`

Module

mmsystem

pastetext

Purpose

Paste a text or string into a text.

Synopsis

```
procedure pastetext(txt:text, str:string, start:integer)
procedure pastetext(txt:text, src:text, start:integer)
```

Arguments

`txt`	A text object
`src`	A text object
`str`	A string
`start`	Paste position

Example

The following:

```
t:=text("abcdefgh")
pastetext(t,"123",2)
writeln(t)
pastetext(t,"456",8)
writeln(t)
```

produces this output:

```
a123efgh
a123efg456
```

Related topics

`cuttext`, `inserttext`, `deltext`, `copytext`

Module

mmsystem

pathmatch

Purpose

Check whether a file name matches a given pattern.

Synopsis

```
function pathmatch(filename:string|text,pattern:string|text):boolean
```

Arguments

`filename`	The file name to evaluate
`pattern`	Matching pattern that may include `*` (any text of any length) or `?` (any single character)

Return value

`true` if the file name matches the pattern.

Example

The following function identifies Mosel source file names:

```
function is_mosel_file(f:text):boolean
 returned:=pathmatch(f,"*.mos")
end-function
```

Further information

The comparison respects the operating environment conventions and behaviour may differ depending of the operating system. In particular, under Posix systems comparisons are case sensitive; this is not the case on Windows (*i.e.* file names are not case sensitive).

Related topics

`regmatch`

Module

mmsystem

pathsplit

Purpose

Split a path into its components.

Synopsis

```
function pathsplit(how:integer,path:text,rem:text):text
function pathsplit(how:integer,path:text):text
```

Arguments

`how` How to split the path:

`SYS_DIR`	Directory (*i.e.* part preceding the last directory separator)
`SYS_FNAME`	File name (*i.e.* part following the last directory separator)
`SYS_EXTN`	File name extension (*i.e.* part following the last dot)

`path` The path name to split

`rem` Remaining part of the path after the returned value has been removed

Return value

The requested part of the path.

Example

The following function returns the base name of a path (file name without directory and extension):

```
function basename(f:text):text
 returned:=pathsplit(SYS_FNAME,f)
 dummy:=pathsplit(SYS_EXTN,returned,returned)
end-function
```

Further information

Arguments `path` and `rem` can be the same object.

Module

mmsystem

qsort

Purpose

Sort a list or an array or (a subset of) the indices of an array.

Synopsis

```
procedure qsort(sense:boolean, lvals:list)
procedure qsort(sense:boolean, vals:array of integer|real|string)
procedure qsort(sense:boolean, cvals:array|list of array, ndx:array)
procedure qsort(sense:boolean, cvals:array|list of array, ndx:array,
      sel:set)
procedure qsort(sense:boolean, cvals:array|list of array, lndx:list)
procedure qsort(sense:boolean, cvals:array|list of array, lndx:list,
      sel:set)
procedure qsort(sense:boolean, cmpfct:string|function, cmpctx:?, vals:array,
      ndx:array)
procedure qsort(sense:boolean, cmpfct:string|function, cmpctx:?, vals:array,
      ndx:array, sel:set)
procedure qsort(sense:boolean, cmpfct:string|function, cmpctx:?, vals:array,
      lndx:list)
procedure qsort(sense:boolean, cmpfct:string|function, cmpctx:?, vals:array,
      lndx:list, sel:set)
```

Arguments

`sense` Sense of the sorting:

`SYS_UP`	Ascending order
`SYS_DOWN`	Descending order

`lvals` List to be sorted

`vals` One-dimensional array to be sorted

`cvals` One-dimensional array to be sorted or list of one-dimensional arrays

`cmpfct` The name of or a reference to a comparator function of the form `function cmpfct(cmpctx,e1,e2):integer` that behaves as `compare` with `e1` and `e2` of the same type as the array to sort

`cmpctx` The value to be passed as the first argument to `cmpfct` (this parameter is not used by `qsort`)

`ndx` One-dimensional array of the same type and size as the indexing set of `vals`

`lndx` List of the same type as the indexing set of `vals`

`sel` Subset of the indexing set of `vals`

Example

The following example sorts an array of real numbers:

```
declarations
 ar: array(1..10) of real
end-declarations

ar:: [1.2, -3, -8, 10.5, 4, 7, 2.9, -1, 0, 5]
qsort(true, ar)
writeln("Sorted array: ", ar)
```

Further information

1. In the first two versions of the procedure (with two arguments, `sense` and `vals` or `lvals`) the input array (list) `vals` (`lvals`) is overwritten by the resulting sorted array (list).
2. When an array `ndx` is provided, the resulting sorted array is returned in the argument `ndx` in the form of its sorted index set. If a selection set `sel` of indices is provided, only the specified indices are processed.
3. When a list `lndx` is provided, the resulting sorted array is returned in the argument `lndx` in the form of a list of sorted indices. If a selection set `sel` of indices is provided, only the specified indices are processed.
4. When applied to a dynamic array this procedure processes all indices of the index set including those not referring to an existing cell (a subset of the indexing set `sel` can be used to select only the existing entries).
5. The second version of the routine can handle arrays of integers, reals and strings. Other versions also accept module types supporting ordering (like `text` or `date` for instance).
6. When the parameter `cvals` is a list of arrays it is expected that all these arrays have one dimension and are all indiced by the same set. The list can contain up to 10 arrays. When performing the sorting the routine will use the first array values as the primary sorting criteria and then the following array in case of equality.
7. A comparator routine may also be provided in the form of user-defined function which name is `cmpfct` (the function must be declared public). The first parameter of this function is given via `cmpctx` that can be of any scalar type (including a record), it is not used by the `qsort` algorithm but may be employed by the comparator function to store data required for the comparison. The 2 other arguments, that are of the same type as the array to sort, are the elements to compare: the function must return 0 if the 2 elements are identical, -1 if the first element is smaller or 1 otherwise. When using this form there is no restriction on the type of the array to sort.

Module

mmsystem

quote

Purpose

Quote and encode a text string.

Synopsis

```
function quote(txt:text,qtype:integer,sepchar:integer):text
function quote(txt:text):text
```

Arguments

`txt`	A `text` object
`qtype`	Quoting convention
`sepchar`	Code of the separator character or 0

Example

The following statement:

```
writeln(quote('test CSV "quoted" string',2,44))
```

displays: `"test CSV ""quoted"" string"`

Further information

1. This function generates an encoded form of the provided text string according to the given quoting convention `qtype` (see `sys_qtype`) and separator character `sepchar`. The provided text may be returned unchanged if the selected convention does not require quotes and the text does not include any special character or the specified separator character.
2. If argument `sepchar` is `0`, quoting is enforced even if the selected quoting convention would not require quotes.
3. In the second form of the routine, parameters `sys_qtype` and `sys_sepchar` are used as default values for arguments `qtype` and `sepchar`.

Related topics

`parsetext`

Module

mmsystem

readlink

Purpose

Get the value of a symbolic link.

Synopsis

```
function readlink(string|txt:fname):text
```

Argument

`fname` A file name

Return value

Linked file name or an empty string if the file cannot be accessed.

Further information

This function can be applied to a symbolic link to get its value. The file name itself is returned if the provided file is not a symbolic link.

Related topics

`getflstat`, `symlink`, `getsysstat`

readtextline

Purpose

Read a line of text from the current input stream.

Synopsis

```
function readtextline(txt:text):integer
function readtextline(txt:text,msize:integer):integer
```

Arguments

`txt` A text object

`msize` Maximum number of bytes to read

Return value

Number of characters read or -1 if end of file.

Module

mmsystem

regmatch

Purpose

Compare text strings using a regular expression.

Synopsis

```
function regmatch(src:text, regex:string):boolean
function regmatch(src:text, regex:string, start:integer,
       flags:integer):boolean
function regmatch(src:text, regex:string, start:integer, flags:integer,
       mp:array(range) of textarea):boolean
```

Arguments

`src` Text to process

`regex` Regular expression

`start` Position where to start the search

`flags` Search options:

`REG_EXTENDED`	Use Extended Regular Expression syntax (ERE), default is to interpret the expression as a Basic Regular Expression (BRE)
`REG_ICASE`	Comparison is performed case insensitive (by default it is case sensitive)
`REG_NEWLINE`	The character *newline* (`\n`) is treated as the end of line (by default it is handled as an ordinary symbol)
`REG_NOTBOL`	The beginning of the text string is not the beginning of a line
`REG_NOTEOL`	The end of the text string is not the end of a line

`mp` Matching regions as an array of text area objects

Return value

`true` if a match was found.

Example

The following example extracts the value of 'pars2' from an input text consisting of lines of the form *name=value*:

```
declarations
 m:array(range) of textarea
 t:text
end-declarations

t:="p1=10\npars2=234\nparam9=56\n"
if regmatch(t,'pars2=\(.*\)$',1,REG_NEWLINE,m) then
 pars2:=parseint(t,m(1))
 writeln(pars2)
end-if
```

Further information

1. This function relies on the TRE library (see http://laurikari.net/tre). Please refer to the documentation of this library for a detailed description of the supported expression syntax.
2. When the `mp` argument is provided and the search is successful, the result of the processing is returned via this array as `textarea` objects (see Section 18.1.6): the array cell `0` refers to the entire matching region and the following ones to each of the subexpressions.

Related topics

`findtext`, `pathmatch`, `regreplace`, `sys_regcache`

Module

mmsystem

regreplace

Purpose

Replace portions of a text string based on a regular expression.

Synopsis

```
function regreplace(src:text, regex:string, repl:string):integer
function regreplace(src:text, regex:string, repl:string, start:integer,
      flags:integer):integer
```

Arguments

`src` Text to process

`regex` Regular expression

`repl` Replacement string expression

`start` Position where to start the search

`flags` Search options:

`REG_EXTENDED`	Use Extended Regular Expression syntax (ERE), default is to interpret the expression as a Basic Regular Expression (BRE)
`REG_ICASE`	Comparison is performed case insensitive (by default it is case sensitive)
`REG_NEWLINE`	The character *newline* (`\n`) is treated as the end of line (by default it is handled as an ordinary symbol)
`REG_NOTBOL`	The beginning of the text string is not the beginning of a line
`REG_NOTEOL`	The end of the text string is not the end of a line
`REG_ONCE`	Stop after the first replacement (by default the entire input string is processed)

Return value

The number of replacements performed.

Example

The following statement transforms dates expressed as *year-month-day* to dates in the form *day/month/year*

```
nbr:=regreplace(t,
      '([[:digit:]]{4})-([01]?[[:digit:]])-([0-3]?[[:digit:]])',
      '\3/\2/\1',1,REG_EXTENDED)
```

Further information

1. This function relies on the TRE library (see http://laurikari.net/tre). Please refer to the documentation of this library for a detailed description of the supported expression syntax.
2. In the replacement string `repl` the backslash character (`'\'`) has a special meaning: if followed by another baskslash character it is replaced by a single backslash; if followed by a digit it is replaced by the corresponding subexpression defined by the regular expression. The subexpression number 0 corresponds to the entire matching region.

Related topics

`regmatch`, `sys_regcache`

Module

mmsystem

removedir

Purpose

Remove a directory.

Synopsis

```
procedure removedir(dirname:string|text)
```

Argument

`dirname` The name and path of the directory to delete

Further information

For deletion of a directory to succeed, the given directory must be empty.

Related topics

`fdelete`, `makedir`, `removefiles`, `getsysstat`

Module

mmsystem

removefiles

Purpose

Remove files selected using file name patterns.

Synopsis

```
procedure removefiles(opt:integer, dir:text,filters:text)
procedure removefiles(filters:text)
```

Arguments

`opt`	Options (several options can be combined):
	`SYS_RECURS` Recursive search in subdirectories
	`SYS_NODIR` Do not remove directories (only files)
	`SYS_DIRONLY` Remove only directories
`dir`	Base directory for the search (default: current directory)
`filters`	File name filters (default: all files removed)

Example

The following deletes directory `"mydir"` including its content:

```
removefiles(SYS_RECURS,"mydir","*")
removedir("mydir")
```

Further information

1. The `filters` argument consists in a list of patterns separated by the symbol `";"`. A pattern is composed of a path (using the usual operating system conventions) which last component may include wildcard characters `"*"` (any text of any length), `"?"` (any single character) and `"|"` (logical "or"). For instance `"bin/*.exe;models/*.mos|*.dat"` will select all files with extension `".exe"` in the `"bin"` directory as well as files with extension `".mos"` and `".dat"` in the `"models"` directory.

2. File name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).

Related topics

`findfiles`, `fdelete`, `removedir`, `getsysstat`

Module

mmsystem

setchar

Purpose

Set a character in a text.

Synopsis

```
procedure setchar(txt:text, index:integer, c:integer)
```

Arguments

`txt`	A text object
`str`	String
`index`	Position of the character
`c`	Character code

Further information

If the index requested is after the end of the text, the text is expanded as necessary and the newly created space is padded with the character which code is the parameter `sys_fillchar`.

Related topics

`getchar`, `sys_fillchar`, `pastetext`

Module

mmsystem

setdate

Purpose

Set the date part of a datetime.

Synopsis

```
procedure setdate(dt:datetime,d:date)
```

Arguments

`dt`	A `datetime` object
`d`	A `date` object

Related topics

`settime`

Module

mmsystem

setday

Purpose

Set the day number of a date or datetime.

Synopsis

```
procedure setday(d:date,j:integer)
procedure setday(dt:datetime,j:integer)
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object
`j`	Day number

Related topics

`setyear`, `setmonth`

Module

mmsystem

setdsoparam

Purpose

Set the value of a control parameter.

Synopsis

```
procedure
        setdsoparam(name:string|text,val:integer|string|text|real|boolean)
```

Arguments

`name` Name of a control parameter (including the module name).

`val` New value for the control parameter

Further information

1. This procedure is similar to `setparam` except that the control parameter name is searched at runtime. As a consequence this identifier does not need to be a constant string but the execution is significantly slower than `setparam` and it cannot be applied to package parameters.
2. The provided parameter name must include the module name (*e.g.* `"mmsystem.datefmt"`) otherwise the identifier is searched only in the list of Mosel parameters.
3. As opposed to `setparam` this procedure does not raise an error in case of failure (like parameter not found or invalid value): use `getsysstat` to detect error conditions.

Related topics

`getdsoparam`, `getsysstat`

setenv

Purpose

Set the value of an environment variable of the operating system.

Synopsis

```
procedure setenv(name:string|text,value:string|text)
```

Arguments

`name` Name of the environment variable

`value` New value for the environment variable

Further information

1. The environment variable is deleted if it is assigned an empty string.
2. Variables created or modified with this procedure can be retrieved using the `getenv` function and are inherited by processes started by `system` or `openpipe`.
3. The effect of this procedure is local to the running model (*i.e.* system calls like the C function `getenv` will not work for these variables). However, another module may access the environment maintained by `mmsystem` using the IMCI function `getenv` (see Section 18.5).
4. This procedure is included in the published interface of `mmsystem` (see Section 18.5).

Related topics

`getenv`, `system`, `openpipe`, `getsysstat`

Module

mmsystem

setoserror

Purpose

Set the current system error code.

Synopsis

```
procedure setoserror(ec:integer)
```

Argument

`ec` A system error code

Further information

This function sets the current system error code that can be retrieved using `getoserror`. As a side effect of using this routine the status returned by `getsysstat` is 0 if the error code is also 0 and 1 otherwise.

Module

mmsystem

sethour

Purpose

Set the hour part of a time or datetime.

Synopsis

```
procedure sethour(t:time,h:integer)
procedure sethour(dt:datetime,h:integer)
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object
`h`	Hour

Related topics

`setminute`, `setsecond`, `setmsec`

setminute

Purpose

Set the minute part of a time or datetime.

Synopsis

```
procedure setminute(t:time,m:integer)
procedure setminute(dt:datetime,m:integer)
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object
`m`	Minute

Related topics

`sethour`, `setsecond`, `setmsec`

Module

mmsystem

setmonth

Purpose

Set the month number of a date or datetime.

Synopsis

```
procedure setmonth(d:date,m:integer)
procedure setmonth(dt:datetime,m:integer)
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object
`m`	Month number

Related topics

`setyear`, `setday`

setmsec

Purpose

Set the millisecond part of a time or datetime.

Synopsis

```
procedure setmsec(t:time,ms:integer)
procedure setmsec(dt:datetime,ms:integer)
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object
`ms`	Millisecond

Related topics

`sethour`, `setminute`, `setsecond`

Module

mmsystem

setsecond

Purpose

Set the second part of a time or datetime.

Synopsis

```
procedure setsecond(t:time,s:integer)
procedure setsecond(dt:datetime,s:integer)
```

Arguments

`t`	A `time` object
`dt`	A `datetime` object
`s`	Second

Related topics

`sethour`, `setminute`, `setmsec`

Module

mmsystem

settime

Purpose

Set the time part of a datetime.

Synopsis

```
procedure settime(dt:datetime,t:time)
```

Arguments

`dt`	A `datetime` object
`t`	A `time` object

Related topics

`setdate`

Module

mmsystem

setyear

Purpose

Set the year part of a date or datetime.

Synopsis

```
procedure setyear(d:date,y:integer)
procedure setyear(dt:datetime,y:integer)
```

Arguments

`d`	A `date` object
`dt`	A `datetime` object
`y`	Year

Related topics

`setmonth`, `setday`

Module

mmsystem

sleep

Purpose

Suspend execution for a fixed amount of time.

Synopsis

```
procedure sleep(duration:int)
```

Argument

`duration` Sleep time in milliseconds

Further information

The model uses no CPU while it is suspended.

Module

mmsystem

splittext

Purpose

Split a text string.

Synopsis

```
function splittext(ts:text, sep:string):list of text
function splittext(ts:text, sep:string, mxe:integer):list of text
function splittext(qt:integer, ts:text, sep:string):list of text
function splittext(qt:integer, ts:text, sep:string, mxe:integer):list of
      text
```

Arguments

`qt`	Quoting type (see parameter `sys_qtype`, default: -1 for no quoting)
`ts`	Text string to process
`sep`	Separator string
`mxe`	Maximum number of elements to collect (default: `0` for no limit)

Return value

The list of identified items.

Example

The following statements:

```
write(splittext("some/path/to/a.file","/",-2))
writeln(splittext(2,'cv1,"cv""2""",cv3',","))
```

result in this display: `[some/path/to,a.file][cv1,cv"2",cv3]`

Further information

1. This function splits the input text string `ts` using the string `sep` as the field delimiter and returns the identified items as a list of texts. The argument `mxe` defines a maximum number of elements to put into this result list. If this limit is reached while the input string has not been entirely processed the last added item includes the remaining part of the input data as a single record.

2. When the quoting type is not specified or when it is set to `-1` the separator string may be an empty string and the maximum number of elements may take a negative value. With an empty separator the input text is split into individual characters. If the maximum number of elements is negative the decomposition is performed from the end of the string.

3. When quoting is active (*i.e.* `qt` is not `-1`) a parsing error may occur: in this case the system status it set to a non-zero value (see `getsysstat`) and the parsing is interrupted (typically after an error the last item added to the result list is not valid).

Related topics

`jointext`

Module

mmsystem

startswith

Purpose

Check whether a text or string starts with a given string.

Synopsis

```
function startswith(txt:text|string, tofs:text|string):boolean
function startswith(txt:text|string, tofs:text|string,
      start:integer):boolean
```

Arguments

`txt`	A string or text object
`tofs`	String to find
`start`	Starting position for the search

Return value

`true` if the beginning of `txt` corresponds to `tofs`.

Related topics

`endswith`

Module

mmsystem

symlink

Purpose

Create a symbolic link.

Synopsis

```
procedure symlink(string|txt:target, string|txt:linkpath)
```

Arguments

`target`	Value of the link
`linkpath`	File to create

Further information

This procedure works only on systems supporting symbolic links, in particular it cannot be executed on Windows (*i.e.* on this platform `getsysstat` will always report a failure after calling this routine).

Related topics

`readlink`, `getsysstat`

system

Purpose

Execute an external program.

Synopsis

```
procedure system(command:string|text)
procedure system(command:string|text,...)
procedure system(command:string|text,args:list)
```

Arguments

`command`	The command to be executed
`args`	List containing the arguments for the command

Example

The following displays the functionality of the `mmsystem` and `mmjobs` modules using the program `mosel`:

```
system('mosel exam mmsystem"')
system('mosel','exam','mmjobs')
```

Further information

1. The given program is executed directly: if the specified expression is a shell command, it is necessary to call the shell explicitly. For instance to get a directory listing under Windows the command will be `"cmd /C dir"`.
2. Using this procedure should be avoided in applications that are to be run on different systems because such a call is always system dependent and may not be portable.
3. The generated process inherits the current system environment plus the environment variables modified/created using the `setenv` procedure.
4. On Windows the program to execute is located using the current process environment, as a consequence any modification of the `PATH` environment variable or working directory has no effect on finding this executable. The behaviour is different on Posix systems where the search for the program to execute is performed from the subprocess environment.
5. The default output and error streams of the generated process are redirected to the corresponding Mosel streams. The default input stream is closed.
6. This procedure is included in the published interface of `mmsystem` (see Section 18.5).
7. When Mosel is running in restricted mode (see Section 1.3.4), the restriction `NoExec` disables this routine unless the environment variable `MOSEL_EXECPATH` is defined. This variable, used in a similar way as the `PATH` environment variable, gives a list of paths than can still be used under the restriction. In addition to directories, the definition of the variable may include paths to executables such that it may directly specify a list of programs. It is also worth noting that no search is performed (*i.e.* executables must be given with their full path) and that path expansion is performed a the time of loading *mmsystem* relative to the Mosel initial working directory.
8. The command may be preceded by the prefix `"enc:"` to specify the encoding of the output streams (see Section 2.16).
9. When using the second and third forms of the procedure the command and each element of the list of arguments are taken individually. This can be helpful if the command or the arguments contain spaces or special characters (they should be quoted appropriately when using the procedure with a single argument).

Related topics

`getsysstat`

Module

mmsystem

tarlist

Purpose

Get the list of files included in a Unix tar archive.

Synopsis

```
procedure tarlist(opt:integer,tarfile:text,lsf:list of text,
       filters:string)
procedure tarlist(tarfile:text,lsf:list of text)
```

Arguments

`opt`	Options:	
	`SYS_NODIR`	Do not report directories (only files)
	`SYS_DIRONLY`	Report only directories
`tarfile`	File name of the archive	
`lsf`	Resulting list of file names	
`filters`	File name filters (default: all files reported)	

Example

The following prints the list of files included in the archive `myfiles.tar`:

```
tarlist("myfiles.tar",lsf)
writeln(lsf)
```

Further information

1. The `filters` argument has a similar structure as the corresponding argument of procedure `findfiles` except that wildcard characters `"*"` and `"?"` may appear anywhere in a path. A file is reported if it matches any of the patterns of this list.
2. When evaluating the filters, file name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).
3. This implementation processes only regular files and directories: other file types included in the archive (like links) are silently ignored.
4. By default file names are expected to be represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.tar"`).

Related topics

`untar`, `newtar`, `ziplist`, `getsysstat`

Module

mmsystem

textfmt

Purpose

Create a formatted text from a string, a text or a number.

Synopsis

```
function textfmt(str:string, len:integer):text
function textfmt(txt:text, len:integer):text
function textfmt(i:integer, len:integer):text
function textfmt(i:integer, len:integer, flag:integer, base:integer):text
function textfmt(r:real, len:integer):text
function textfmt(r:real, len:integer, dec:integer):text
```

Arguments

`str` String to be formatted

`txt` Text to be formatted

`i` Integer to be formatted

`r` Real to be formatted

`len` Reserved length (may be exceeded if given string is longer, in this case the string is always left justified).

- `<0` Left justified within reserved space
- `>0` Right justified within reserved space
- `0` Use defaults

`flag` Bit encoded options:

- `1` Left padding with `"0"` (instead of space)
- `2` Use capital letters for bases greater than 10

`base` Encoding base (between 2 and 36)

`dec` Number of digits after the decimal point

Return value

Formatted text.

Example

The following:

```
writeln("text1", textfmt("text2",8), "text3")
writeln("text1", textfmt("text2",-8), "text3")
r:=789.123456
writeln(textfmt(r,0)," ", textfmt(r,4,2), textfmt(r,8,0))
```

produces this output:

```
text1     text2text3
text1text2     text3
789.123 789.12        789
```

Further information

1. If the resulting string is longer than the reserved space it is not cut but printed in its entirety, overflowing the reserved space to the right.
2. When processing an integer specifying a base, the provided value is treated as an unsigned integer if the base is negative.

Related topics

`formattext`

Module

mmsystem

tolower

Purpose

Generate the lowercase version of the provided text.

Synopsis

```
function tolower(t:text|string):text
function tolower(c:integer):integer
```

Return value

The lowercase version of the input string or a character code.

Arguments

`t`	Text to convert
`c`	Character code

Further information

When this function is used with a text string, it returns a copy of its argument converted to lowercase. When it is called with an integer, the returned value corresponds to the character code of the lowercase version of the provided code. In both cases, the function will return an unmodified copy of its argument if no conversion can be done.

Related topics

`toupper`

Module

mmsystem

toupper

Purpose

Generate the uppercase version of the provided text.

Synopsis

```
function toupper(t:text|string):text
function toupper(c:integer):integer
```

Return value

The uppercase version of the input string or a character code.

Arguments

`t`	Text to convert
`c`	Character code

Further information

When this function is used with a text string, it returns a copy of its argument converted to uppercase. When it is called with an integer, the returned value corresponds to the character code of the uppercase version of the provided code. In both cases, the function will return an unmodified copy of its argument if no conversion can be done.

Related topics

`tolower`

Module

mmsystem

trim

Purpose

Remove blank characters at the beginning and/or end of a text string.

Synopsis

```
procedure trim(t:text)
procedure trim(t:text,where:boolean)
```

Arguments

`t` Text to trim

`where` Part of the text to trim:

`SYS_LEFT`	Beginning of the string
`SYS_RIGHT`	End of the string

Further information

When the function is used with a single argument, both starting and ending blank characters are deleted.

Module

mmsystem

untar

Purpose

Extract files from a Unix tar archive.

Synopsis

```
procedure untar(opt:integer,tarfile:text,dir:text,
       filters:string)
procedure untar(tarfile:text,dir:text)
procedure untar(tarfile:text)
```

Arguments

`opt`	Options:

`SYS_OVERWRT`	Replace existing files
`SYS_NODIR`	Do not extract directories (only files)
`SYS_DIRONLY`	Extract only directories
`SYS_FLAT`	Extract files without directory structure
`SYS_VERB`	Report activity to the error stream
`SYS_NOFAIL`	Do not abort procedure if a file cannot be written

`tarfile`	File name of the archive
`dir`	Destination path (default: current directory)
`filters`	File name filters (default: all files extracted)

Example

The following extracts all files included in the archive `myfiles.tar` to directory `mydir`:

```
untar("myfiles.tar","mydir")
```

Further information

1. The `filters` argument has a similar structure as the corresponding argument of procedure `findfiles` except that wildcard characters `"*"` and `"?"` may appear anywhere in a path. A file is extracted if it matches any of the patterns of this list.
2. When evaluating the filters, file name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).
3. This implementation processes only regular files, symbolic links (when supported by the system) and directories: other file types included in the archive are silently ignored.
4. By default file names are expected to be represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.tar"`).

Related topics

`tarlist`, `newtar`, `unzip`, `getsysstat`

Module

mmsystem

unzip

Purpose

Extract files from a Zip archive.

Synopsis

```
procedure unzip(opt:integer, zipfile:text, dir:text,
      filters:string, password:text)
procedure unzip(opt:integer, zipfile:text, dir:text,
      filters:string)
procedure unzip(zipfile:text, dir:text)
procedure unzip(zipfile:text)
```

Arguments

`opt` Options:

`SYS_OVERWRT`	Replace existing files
`SYS_NODIR`	Do not extract directories (only files)
`SYS_DIRONLY`	Extract only directories
`SYS_FLAT`	Extract files without directory structure
`SYS_VERB`	Report activity to the error stream
`SYS_NOFAIL`	Do not abort procedure if a file cannot be written

`zipfile` File name of the archive (that must be a physical file)

`dir` Destination path (default: current directory)

`filters` File name filters (default: all files extracted)

`password` Password to access an encrypted archive

Example

The following extracts all files included in the archive `myfiles.zip` to directory `mydir`:

```
unzip("myfiles.zip","mydir")
```

Further information

1. The `filters` argument has a similar structure as the corresponding argument of procedure `findfiles` except that wildcard characters `"*"` and `"?"` may appear anywhere in a path. A file is extracted if it matches any of the patterns of this list.
2. When evaluating the filters, file name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).
3. This implementation only supports the standard Zip format (only 32bit and basic encryption algorithm) and symbolic links are silently ignored if the system does not support them.
4. By default file names are expected to be represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.zip"`).

Related topics

`ziplist`, `newzip`, `untar`, `getsysstat`

Module

mmsystem

ziplist

Purpose

Get the list of files included in a Zip archive.

Synopsis

```
procedure ziplist(opt:integer, zipfile:text, lsf:list of text,
      filters:string)
procedure ziplist(zipfile:text, lsf:list of text)
```

Arguments

`opt`	Options:
	`SYS_NODIR` Do not report directories (only files)
	`SYS_DIRONLY` Report only directories
`zipfile`	File name of the archive
`lsf`	Resulting list of file names
`filters`	File name filters (default: all files reported)

Example

The following prints the list of files included in the archive `myfiles.zip`:

```
ziplist("myfiles.zip",lsf)
writeln(lsf)
```

Further information

1. The `filters` argument has a similar structure as the corresponding argument of procedure `findfiles` except that wildcard characters `"*"` and `"?"` may appear anywhere in a path. A file is reported if it matches any of the patterns of this list.
2. When evaluating the filters, file name matching is achieved using function `pathmatch` and differences may be observed depending on the operating system (*e.g.* file names are case sensitive under Posix systems but not under Windows).
3. By default file names are expected to be represented according the current system encoding in the archive. To select a different encoding use the `enc:` file name prefix (see Section 2.16) on the archive name (*e.g.* `"enc:utf-8,myarc.zip"`).

Related topics

`unzip`, `newzip`, `tarlist`, `getsysstat`

Module

mmsystem

18.4 I/O drivers

The *mmsystem* module provides two IO drivers: the first one allows to use a string or text object as a file and the second connects a Mosel input or output stream to a program started in a different process. Using this driver, it is possible to get the output of an external program (for instance the result of a preprocessor to feed the Mosel compiler) or implement a basic bidirectional inter process communication thanks to the `openpipe` procedure (which relies on this IO driver).

18.4.1 Driver `text`

```
text:ident
```

This driver uses a model variable of type `string` or `text` as its input or output media. The `ident` argument it requires is therefore the name of this variable that must be declared globally public to the model or have been published with `publish` (such that it can always be found independently of the compiler settings).String objects can only be accessed for reading while text entities can be used for both reading and writing.

In the following example the constant string `"T"` is used as the initialization file for variable `"A"`:

```
declarations
 public T="A:123"
 A:integer
end-declarations
initializations from "text:T"
 A
end-initializations
```

18.4.2 Driver `pipe`

```
pipe:program [options...]
```

The file name for this driver is an external *program* with its *options*. Options are separated by spaces or tabulations and may be quoted using either single or double quotes. A quoted option may contain any kind of character except the quote used to delimit the string.

When the system opens a *pipe*, a new process is started for executing the given program and default input and output streams are directed to system pipes. If the file is open for reading (resp. writing), the default ouput stream (resp. input stream) of the new process becomes the current input stream (resp. output stream) of the model. To locate the program to be executed, the system relies on the `PATH` environment variable. Detection of error (typically the program cannot be found or is not executable) differs depending on the operating system: under Windows, the error is reported immediately and the pipe is not open. With Posix systems, no error is reported but following IO operations fail.

When the file is closed, both input and output streams of the external process are closed then the system waits for its termination: in order to avoid a lock up of the Mosel program one must make sure that the external program ends its execution when default input and output streams are closed.

Example: the following command could be used with Mosel Console for compiling the model *mymod.mos* after it has been processed by the C preprocessor. Note that we have to provide an output file name since the compiler cannot deduce it from the source file name.

For a Posix systems:

```
compile 'mmsystem.pipe:cpp mymod.mos' '' mymod.bim
```

For Windows (with MSVC):

```
compile 'mmsystem.pipe:cl /E mymod.mos' '' mymod.bim
```

When Mosel is running in restricted mode (see Section 1.3.4), this driver behaves like the `system` procedure.

18.5 Published library functions

The module *mmsystem* publishes its implementation of `getenv`, `setenv` and `system` as well as the functions `gettxtsize`, `getcsttxtbuf`, `gettxtbuf` and `txtresize` for text access via the service IMCI for use by other modules (see the Mosel Native Interface Reference Manual for more detail about services). The list of published functions is contained in the interface structure `mmsystem_imci` that is defined in the module header file `mmsystem.h`.

From another module, the context of *mmsystem* and its communication interface can be obtained using functions of the Mosel Native Interface as shown in the following example.

```
static XPRMnifct mm;
XPRMcontext mmctx;
XPRMdsolib dso;
mmsystem_imci mmsys;
void **sysctxref;

dso=mm->finddso("mmsystem");          /* Retrieve the mmsystem module*/
sysctxref=mm->getdsoctx(mmctx, dso, (void **)(&mmsys));
                                      /* Get the module context and the
                                         communication interface of mmsystem */
```

Typically, a module calling functions that are provided by *mmsystem* will include this module into its list of dependencies in order to make sure that *mmsystem* will be loaded by Mosel at the same time as the calling module. The “dependency” service of the Mosel Native Interface has to be used to set the list of module dependencies:

```
static const char *deplist[]={"mmsystem",NULL}; /* Module dependency list */

static XPRMdsoserv tabserv[]=                   /* Table of services */
    {
     {XPRM_SRV_DEPLST, (void *)deplist}
    };
```

Using these functions a module may access and modify the environment of the calling model and execute an external program with automatic redirection of default streams:

```
mmsys->setenv(ctx,*sysctxref,"MYVAR","A_VALUE");
rts=mmsys->system(ctx,*sysctxref,"myprogram arg1 arg2");
```

18.5.1 Description of the library functions

`getcsttxtbuf`	Get a reference to the constant character buffer of a text object.	p. 632
`getdate`	Get the date of a `date` object.	p. 628
`getdatetime`	Get the date and time of a `datetime` object.	p. 630
`gettime`	Get the time of a `time` object.	p. 626
`gettxtbuf`	Get a reference to the character buffer of a text object.	p. 634
`gettxtsize`	Get the size of a text object.	p. 633

`setdate`	Set the date of a `date` object.	p. 629
`setdatetime`	Set the date and time of a `datetime` object.	p. 631
`settime`	Set the time of a `time` object.	p. 627
`txtresize`	Resize a text object.	p. 635

gettime

Purpose

Get the time of a `time` object.

Synopsis

```
int gettime(XPRMctx ctx, void *sysctx, void *t, int *h, int *mi, int *s,
      int *ms);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a time object
`h`	Reference to store the hours or `NULL`
`mi`	Reference to store the minutes or `NULL`
`s`	Reference to store the seconds or `NULL`
`ms`	Reference to store the milliseconds or `NULL`

Return value

0 if successful or -1 if `t` is `NULL`.

Further information

Provided references are set even if the function fails.

Related topics

`settime`

Module

mmsystem

settime

Purpose

Set the time of a `time` object.

Synopsis

```
int settime(XPRMctx ctx, void *sysctx, void *t, int h, int mi, int s, int
      ms);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a time object
`h`	hours
`mi`	minutes
`s`	seconds
`ms`	milliseconds

Return value

0 if successful or -1 if `t` is `NULL`.

Related topics

`gettime`

Module

mmsystem

getdate

Purpose

Get the date of a `date` object.

Synopsis

```
int getdate(XPRMctx ctx, void *sysctx, void *t, int *y, int *m, int *d);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a date object
`y`	Reference to store the years or `NULL`
`m`	Reference to store the months or `NULL`
`d`	Reference to store the days or `NULL`

Return value

0 if successful or -1 if `t` is `NULL`.

Further information

Provided references are set even if the function fails.

Related topics

`setdate`

Module

mmsystem

setdate

Purpose

Set the date of a `date` object.

Synopsis

```
int setdate(XPRMctx ctx, void *sysctx, void *t, int y, int m, int d);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a date object
`y`	Years
`m`	Months
`d`	days

Return value

0 if successful or -1 if `t` is `NULL`.

Related topics

`getdate`

Module

mmsystem

getdatetime

Purpose

Get the date and time of a `datetime` object.

Synopsis

```
int getdatetime(XPRMctx ctx, void *sysctx, void *t, int *y, int *m, int *d,
      int *h, int *mi, int *s, int *ms);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a date object
`y`	Reference to store the years or `NULL`
`m`	Reference to store the months or `NULL`
`d`	Reference to store the days or `NULL`
`h`	Reference to store the hours or `NULL`
`mi`	Reference to store the minutes or `NULL`
`s`	Reference to store the seconds or `NULL`
`ms`	Reference to store the milliseconds or `NULL`

Return value

0 if successful or -1 if `t` is `NULL`.

Further information

Provided references are set even if the function fails.

Related topics

`setdatetime`

Module

mmsystem

setdatetime

Purpose

Set the date and time of a `datetime` object.

Synopsis

```
int setdatetime(XPRMctx ctx, void *sysctx, void *t, int y, int m, int d,
      int h, int mi, int s, int ms);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a date object
`y`	Years
`m`	Months
`d`	days
`h`	hours
`mi`	minutes
`s`	seconds
`ms`	milliseconds

Return value

0 if successful or -1 if `t` is `NULL`.

Related topics

`getdatetime`

Module

mmsystem

getcsttxtbuf

Purpose

Get a reference to the constant character buffer of a text object.

Synopsis

```
const char *getcsttxtbuf(XPRMctx ctx, void *sysctx, void *t);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a text object

Return value

A reference to the character buffer.

Further information

1. The buffer returned is terminated by the character 0 (like a C string), and it must not be modified (even if the provided text object is not constant). The function `gettxtbuf` should be used instead when the buffer of a non-constant text has to be altered.
2. Since the memory management of the module may move text buffers when allocating memory, the pointer returned by this function is only valid until the next memory allocation.

Related topics

`gettxtsize`, `gettxtbuf`

Module

mmsystem

gettxtsize

Purpose

Get the size of a text object.

Synopsis

```
int gettxtsize(XPRMctx ctx, void *sysctx, void *t);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a text object

Return value

The size of the character buffer (excluding the terminating 0 character).

Related topics

`txtresize`, `gettxtbuf`

Module

mmsystem

gettxtbuf

Purpose

Get a reference to the character buffer of a text object.

Synopsis

```
char *gettxtbuf(XPRMctx ctx, void *sysctx, void *t);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a text object

Return value

A reference to the character buffer or `NULL` if the provided text object is constant.

Further information

1. The buffer returned is terminated by the character 0 (like a C string) and can be modified as long as the size is not changed. If the length of the buffer has to be altered, use the function `txtresize`.
2. A `NULL` pointer will be returned if the provided text object is constant. Use `getcsttxtbuf` to retrieve the buffer of a constant text.
3. Since the memory management of the module may move text buffers when allocating memory, the pointer returned by this function is only valid until the next memory allocation.

Related topics

`txtresize`, `gettxtsize`, `getcsttxtbuf`

Module

mmsystem

txtresize

Purpose

Resize and get a reference to the character buffer of a text object.

Synopsis

```
char *txtresize(XPRMctx ctx, void *sysctx, void *t, int s);
```

Arguments

`ctx`	Mosel's execution context
`sysctx`	Context of *mmsystem*
`t`	Reference to a text object
`s`	New size of the buffer (terminating 0 is not counted)

Return value

A reference to the new character buffer or `NULL` in case of memory error or if the provided text object is constant.

Further information

1. The buffer returned is terminated by the character 0 (like a C string) and can be modified as long as the size is not changed.
2. Since the memory management of the module may move text buffers when allocating memory, the pointer returned by this function is only valid until the next memory allocation.

Related topics

`gettxtsize`

Module

mmsystem

CHAPTER 19

mmxml

This module provides an XML parser and generator for the manipulation of XML documents from Mosel models. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmxml'
```

`mmxml` relies on the XML parser EXPAT by James Clark (http://www.libexpat.org) for loading documents.

19.1 Document representation in `mmxml`

19.1.1 Data model

The XML document is stored as a list of nodes. Different node types are used to represent the document structure:

- element node
- text section
- comment
- CDATA
- processing instruction

In addition to these usual node types, the type `DATA` is used for XML constructs not supported by `mmxml` (for instance a `DOCTYPE` declaration is recorded as a DATA section). Although they are not directly recorded in the document tree, attributes are also stored as nodes of a dedicated type.

Each node is characterised by a *name* and a *value*. Nodes of type *text*, *comment*, *CDATA* and *DATA* have a constant name. The name of a processing instruction is the processing instruction's target and its value the remaining part of the statement (*e.g.* the name of `<?proc inst>` is `proc` and its value is `inst`). The value of *comment* and *CDATA* sections is the content of the section without its delimiters but the value of a *DATA* block includes the delimiters. Element nodes have also an ordered list of child nodes. The value of an *element* node corresponds to the value of the first child *text* node (if any).

The *root* node is a special element node with no name, no parent and no successor that includes the entire document as its children.

Example of an XML document with node types:

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no" ?>   XML header
<?xml-stylesheet type="text/css" href="examplestyle.css" ?>    Processing instruc.
<!DOCTYPE exampleList SYSTEM "examples.dtd" [                  DATA
   <!ENTITY otherfile SYSTEM "anotherfile.xml">
]>

<!-- List of optimization application examples -->            Comment
<exampleList>                                                  Element node
   <!-- Example B3 -->                                         Comment
   <model id="book_B_3">                                       Element node
     <modFile date="Mar.2002">                                 Element node
       b3jobshop.mos                                           Text node
     </modFile>
     <modData file="b3jobshop.dat" />                          Element node
     <modData file="b3jobshop2.dat" />                         Element node
     <modTitle>                                                Element node
       Job shop scheduling                                     Text node
     </modTitle>
     <modRating>                                               Element node
       3                                                       Text node
     </modRating>
     <modFeatures>                                             Element node
       <![CDATA[dynamic array, range, exists, forall-do]]>     CDATA
    </modFeatures>
   </model>
</exampleList>
```

19.1.2 Paths in a document

Nodes can be retrieved using a *path* similar to a directory path used to locate a file. An XML path consists in a list of *location steps* separated by the slash character (`"/"`): each step selects a set of nodes from the input set resulting from the preceding step (context nodes). The initial set of the path is either the root node (absolute path) or some specified node (relative path).

A step is composed of an optional *axis specifier* followed by a *node test* and possibly completed by a *predicate*. The axis specifies the tree relationship between the nodes selected by the step and the context node. The node test is either an element name (to select elements of the given name) or a node type (to select nodes by their type). The predicate is a Boolean expression the truth value of which decides whether a selected node is kept in the result set of the step.

Examples:

`/examples/chapter` all element nodes 'chapter' under elements 'examples'

`/examples/chapter/model/modRating[number()>=4]/..` all 'model' nodes under 'examples/chapter' for which element 'modRating' has a value greater than or equal to 4

`//*[@attribute1 and @attribute2='value2']` all element nodes of the document having 'attribute1' defined and 'attribute2' with value 'value2'

`/descendant::text()` all text sections of the document

`.//mytag` all element nodes named 'mytag' starting from the current node

19.1.2.1 Axis specifier

An axis specifier consists in an axis name followed the the symbol `::`. The supported axes are:

`child`	children of the context node (this is the default if no axis is given)
`parent`	parent of the context node
`self`	the context node itself
`attribute`	the attributes of the context node
`following`	following node of the context node
`descendant-or-self`	the context node as well as all its descendants
`descendant`	all descendants of the context node

19.1.2.2 Node test

By default only element nodes are considered, the node test is used to select the nodes by their name. The special name `"*"` will keep all element nodes. Alternatively, the test can be related to the type of the nodes; in this case all nodes are considered and the test is one of the following expressions:

`text()`	to select text nodes
`comment()`	to select comment nodes
`cdata()`	to select CDATA nodes
`data()`	to select DATA nodes
`processing-instruction()`	to select processing instruction nodes
`node()`	to keep all nodes (independently of the type and name)

19.1.2.3 Abbreviated notation

Common combinations of axis-node tests have an abbreviated notation. The supported abbrevations are:

`.`	is equivalent to `self::node()`
`..`	is equivalent to `parent::node()`
`//`	(used in place of /) is the same as `descendant-or-self::node()`

19.1.2.4 Predicate

A *predicate* is a Boolean expression enclosed in square brakets. The expression evaluator supports Boolean, text and numerical values (encoded as floating point numbers). Type conversions are implicit and implied by the operators: for instance the additive operator `"+"` operates on numbers, as a consequence its operands are systematically converted to numbers. Constant strings must be quoted using either single or double quotes.

The notation `@attname` designates the attribute which name is `"attname"`: if used where a Boolean value is expected, it is true if the attribute is defined for the current node. Otherwise, this is the value of the attribute.

Supported arithmetic operators include +, -, *, div (division on floating point numbers, not integral division as in Mosel!), mod (modulo on floating point numbers). Boolean expressions can be composed using `and` and `or`; the usual comparators <, <=, >=, >, =, <>(or !=) can be applied to numbers. Note that equality testing (= and <>) is defined for all types. The following predefined functions can also be used in expressions:

`name()`	name of the node
`string()`	value of the node
`number()`	value of the node as a number
`boolean()`	value of the node as a Boolean
`position()`	position of the current node in the selected set (first node has position 1)
`not(boolexp)`	true if 'boolexp' is false, false otherwise
`true()`	value `true`
`false()`	value `false`
`string-length()/getsize()`	length of the node value
`string-length(strexp)/getsize(strexp)`	length of the text passed as parameter
`starts-with(strexp1,strexp2)`	true if text 'strexp1' starts with text 'strexp2'
`contains(strexp1,strexp2)`	true if text 'strexp1' contains text 'strexp2'
`round(numexp)`	rounded value of 'numexp'
`floor(numexp)`	floor value of 'numexp'
`ceiling(numexp)/ceil(numexpr)`	ceil value of 'numexp'
`abs(numexp)`	absolute value of 'numexp'

If the predicate `[expr]` is not a Boolean value, the whole expression is interpreted as `[position()=expr]`.

19.1.3 JSON document as an XML tree

In addition to XML documents *mmxml* can also load and generate JSON documents represented as XML trees such that the information contained in the document can be handled using the routines published by this module. The procedure `jsonload` parses a JSON file that it maps to the internal XML representation using the following conventions: every JSON syntactic entity is converted to an XML element the value of which corresponds to the associated JSON value. The type of the value is identified via the attribute `"jst"` that can be `"str"` (string), `"num"` (numeric), `"boo"` (Boolean), `"nul"` (null object), `"obj"` (object) or `"arr"` (array). Names of object components can be mapped to either the name of the XML element or to an attribute (the behaviour of the parser is selected via an option of `jsonload`).

For instance, consider the following JSON document:

```
[{
  "name": "bob",
  "age": 25,
  "student": true,
  "phone": [
   { "type": "home", "number": "1234567900" },
   { "type": "work", "number": "6789012345" }
  ]
}]
```

It will be represented by the following XML document when object member names are turned into XML element names:

```
<?xml version="1.0" encoding="iso-8859-1"?>
<jsv jst="arr">
  <jsv jst="obj">
    <name jst="str">bob</name>
    <age jst="num">25</age>
    <student jst="boo">true</student>
    <phone jst="arr">
      <jsv jst="obj">
        <type jst="str">home</type>
        <number jst="str">1234567900</number>
      </jsv>
      <jsv jst="obj">
        <type jst="str">work</type>
        <number jst="str">6789012345</number>
      </jsv>
    </phone>
  </jsv>
</jsv>
```

Note that with this representation the generated XML document is not necessarily valid XML (this mapping can for instance produce XML elements that have a number as name) and trying to export a JSON document using the `save` procedure may produce a file that cannot be processed by an XML parser. Using the second mode of operation avoids this problem: all elements are named `"jsv"` and object names are represented by attributes. The resulting XML document is larger than the one produced with the first mode:

```
<?xml version="1.0" encoding="iso-8859-1"?>
<jsv jst="arr">
  <jsv jst="obj">
    <jsv jst="str" name="name">bob</jsv>
    <jsv jst="num" name="age">25</jsv>
    <jsv jst="boo" name="student">true</jsv>
    <jsv jst="arr" name="phone">
      <jsv jst="obj">
        <jsv jst="str" name="type">home</jsv>
        <jsv jst="str" name="number">1234567900</jsv>
      </jsv>
      <jsv jst="obj">
        <jsv jst="str" name="type">work</jsv>
        <jsv jst="str" name="number">6789012345</jsv>
      </jsv>
    </jsv>
  </jsv>
</jsv>
```

Assuming an XML tree has been built using the above conventions, the procedure `jsonsave` can be used to generate a JSON document. The XML document may combine the two representations described above and in most cases the `jst` attribute can be omitted. Therefore, `jsonsave` will produce the same JSON document as the example shown at the start of this section from the following XML file:

```
<?xml version="1.0" encoding="iso-8859-1"?>
<jsv>
  <jsv>
    <name>bob</name>
    <jsv name="age">25</jsv>
    <student>true</student>
    <jsv name="phone">
      <jsv>
        <type>home</type>
        <jsv name="number" jst="str">1234567900</jsv>
      </jsv>
```

```
      <jsv>
        <jsv name="type">work</jsv>
        <jsv name="number" jst="str">6789012345</jsv>
      </jsv>
    </jsv>
  </jsv>
</jsv>
```

19.2 New functionality for the Mosel language

19.2.1 The type xmldoc

The type xmldoc represents an XML document stored in the form of a tree. Each node of the tree is identified by a *node number* (an integer) that is attached to the document (*i.e.* a node number cannot be shared by different documents and in two different documents the same number represents two different nodes). The *root* node of the document has number 0: the content of the document is stored as the children of this root node. In addition to structural properties (*e.g.* name, value, successor, parent) nodes have 2 formatting properties: vertical (setvspace) and horizontal (sethspace) spacing. These indications are used when the document is saved in text form for controling how the resulting text has to be organised (see save). The general formatting policy is defined by a set of document settings: indentation mode (setindentmode), indentation skip (setindentskip) and line length (setlinelen). Also used when exporting the documents are the XML version (setxmlversion), standalone status (setstandalone) and encoding (setencoding).

19.3 Procedures and functions

addnode

Purpose

Add a node to a document tree.

Synopsis

```
function addnode(doc:xmldoc, n:integer, where:integer, type:integer,
      name:string, value:text):integer
function addnode(doc:xmldoc, n:integer, where:integer, type:integer,
      nameval:string|text):integer
function addnode(doc:xmldoc, n:integer, type:integer, name:string,
      value:text):integer
function addnode(doc:xmldoc, n:integer, type:integer,
      nameval:string|text):integer
function addnode(doc:xmldoc, n:integer, type:integer):integer
function addnode(doc:xmldoc, n:integer, name:string,
      value:text|string|boolean|integer|real):integer
```

Arguments

`doc` Document to use

`n` Node number where to attach the new node

`where` How to attach the new node to the node `n`:

`XML_FIRST`	as the first element of the list where node `n` is located
`XML_LAST`	as the last element of the list where node `n` is located
`XML_NEXT`	after node `n`
`XML_FIRSTCHILD`	as the first child of node `n` (node `n` must be an *element*)
`XML_LASTCHILD`	as the last child of node `n` (node `n` must be an *element*)

When the function is used without this parameter, `XML_LASTCHILD` is assumed.

`type` Type of node to add:

`XML_ELT`	an element
`XML_TXT`	a text block
`XML_CDATA`	a CDATA section
`XML_COM`	a comment
`XML_DATA`	non interpreted data
`XML_PINST`	processing instruction

When the function is used without this parameter, `XML_ELT` is assumed.

`name` Name associated to the new node. Only *element* and *processing instruction* nodes have a name

`value` Value associated to the new node. An *element node* does not have any value: if this parameter is provided for a node of this type, an additional *text node* with the specified value is added as the first child of the new node

`nameval` If the type is `XML_ELT` or `XML_PINST` this parameter is used as the name of this node. Otherwise it is the value of the new node

Return value

Number of the newly created node within the document.

Example

The following code extract appends a new node 'employee' as last child to the node `APAC`. It shows how to use diffrent versions of `addnode` for the creation of descendants of the new node.

```
declarations
  DB: xmldoc
```

```
  APAC, NewPers, n, k: integer
end-declarations

APAC:= getnode(DB, "personnelList/region[@id='APAC']")
! Append a new node to 'APAC' and set its attribute 'id':
NewPers:= addnode(DB, APAC, XML_LASTCHILD, XML_ELT, "employee")
setattr(DB, NewPers, "id", "T432")
! Create a comment:
n:= addnode(DB, NewPers, XML_COM, "This is a new employee")
! Add 2 nodes containing the specified text (nodes):
n:= addnode(DB, NewPers, XML_ELT, "startDate", text(2012))
n:= addnode(DB, NewPers, XML_ELT, "name", "Tim")
! Add an empty node, then set its contents:
n:= addnode(DB, NewPers, XML_ELT, "address")
setvalue(DB, n, "Sydney")
! Add an empty node, then create its contents as a text node:
n:= addnode(DB, NewPers, XML_ELT, "language")
k:= addnode(DB, n, XML_TXT, "English")
```

XML resulting from this code:

```
<employee id="T432">
  <!--This is a new employee-->
  <startDate>2012</startDate>
  <name>Tim</name>
  <address>Sydney</address>
  <language>English</language>
</employee>
```

Further information

1. An element or processing instruction node must be named: trying to create a node of these types with an empty name will cause an error.
2. It is not possible to add attributes with this function. Use `setattr` for this purpose.

Related topics

`copynode`, `delnode`

Module

mmxml

copynode

Purpose

Copy a node.

Synopsis

```
function copynode(src:xmldoc, s:integer, dst:xmldoc, d:integer,
       where:integer):integer
```

Arguments

`src` Document of node to be copied

`s` Number of the node to copy

`dst` Destination document

`d` Node number where to attach the new node in the destination document

`where` How to attach the copy of the source node to the node `d`:

`XML_FIRST`	as the first element of the list where node `d` is located
`XML_LAST`	as the last element of the list where node `d` is located
`XML_NEXT`	after node `d`
`XML_FIRSTCHILD`	as the first child of node `d` (node `d` must be an *element*)
`XML_LASTCHILD`	as the last child of node `d` (node `d` must be an *element*)

Example

The following code extract shows how to move (copy node, then delete original) and edit a node with all its descendants

```
declarations
  DB: xmldoc
  APAC, NewPers, Pers: integer
end-declarations

! Retrieve destination region node
APAC:= getnode(DB, "personnelList/region[@id='APAC']")
! Retrieve employee record (node) for 'Lisa'
Pers:=
  getnode(DB, "personnelList/region/employee/name[string()='Lisa']/..")
! Employee Lisa moves to Delhi: copy node & delete in original location
NewPers:= copynode(DB, Pers, DB, APAC, XML_LASTCHILD)
delnode(DB, Pers)
! Update the 'address' information
setvalue(DB, getnode(DB, NewPers, "address"), "Delhi")
```

Further information

This routine copies the node as well as all of its descendants if it is an *element node*. Source and destination documents may be the same.

Related topics

addnode, delnode

Module

mmxml

delattr

Purpose

Delete an attribute of an element node.

Synopsis

```
procedure delattr(doc:xmldoc, n:integer, name:string)
```

Arguments

`doc`	Document to use
`n`	Element node to modify
`name`	Name of the attribute to remove

Example

See `testattr`.

Further information

This routine has no effect if the element does not have any attribute of the specified name.

Related topics

`setattr`

Module

mmxml

delnode

Purpose

Delete a node in a document tree.

Synopsis

```
procedure delnode(doc:xmldoc, n:integer)
```

Arguments

`doc`	Document to use
`n`	Number of the node to delete

Example

See `copynode`.

Further information

This routine deletes the node as well as all of its descendants if it is an *element node*.

Related topics

`addnode`, `copynode`

Module

mmxml

getattr

Purpose

Get the value of an attribute.

Synopsis

```
function getattr(doc:xmldoc, n:integer, name:string):text
function getboolattr(doc:xmldoc, n:integer, name:string):boolean
function getintattr(doc:xmldoc, n:integer, name:string):integer
function getrealattr(doc:xmldoc, n:integer, name:string):real
function getstrattr(doc:xmldoc, n:integer, name:string):string
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)
`name`	Name of the attribute

Return value

The value of the attribute or an empty string, 0 or `false` depending on the expected type.

Example

The following code extract prints the contents of 'name' (leftbound in a 10 character space) and the attributes 'id' of all 'employee' nodes, and the 'id' of their parent node.

```
declarations
  DB: xmldoc
  AllEmployees: list of integer
end-declarations

getnodes(DB, "personnelList/region/employee", AllEmployees)
forall(p in AllEmployees)
  writeln(textfmt(getvalue(DB, getnode(DB, p, "name")), -10),
          "(ID: ", getattr(DB,p,"id"), ") ",
          "region: ", getattr(DB, getparent(DB, p), "id"))
```

Output produced by this code will look as follows:

```
Lisa       (ID: L234) region: EMEA
James      (ID: J876) region: APAC
Sarah      (ID: S678) region: AM
```

Further information

1. Values of attributes are stored as `text` objects: the first version of the routine returns a reference to the object containing the attribute value. Modifying this text will also alter the attribute value. Using one of the alternative versions of this routine allows to avoid having to perform a type conversion. Note however that no validation is performed and a conversion error will result in a `0` for a number and `false` for a Boolean without raising any error.
2. A default value (empty string, 0 or false) is returned if the requested attribute is not defined. Use function `testattr` to check whether a given node has a particular attribute.

Related topics

`setattr`, `testattr`, `getfirstattr`

Module

mmxml

testattr

Purpose

Test existence of an attribute for a given element node.

Synopsis

```
function testattr(doc:xmldoc, n:integer, name:string):boolean
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)
`name`	Name of the attribute

Return value

`true` if the requested attribute is defined for the node.

Example

This example tests whether the attribute 'parttime' is defined for an employee, and if this is the case the attribute gets deleted after printing the name of the employee.

```
declarations
  DB: xmldoc
  AllEmployees: list of integer
end-declarations

getnodes(DB, "personnelList/region/employee", AllEmployees)
forall(p in AllEmployees | testattr(DB, p, "parttime")) do
  writeln(getvalue(DB, getnode(DB, p, "name")))
  delattr(DB, p, "parttime")
end-do
```

Related topics

`setattr`, `getattr`

Module

mmxml

getencoding

Purpose

Get the character encoding of the document.

Synopsis

```
function getencoding(doc:xmldoc):string
```

Argument

`doc` Document to use

Return value

Character encoding of the document

Related topics

`getstandalone`, `getxmlversion`

Module

mmxml

getname

Purpose

Get the name of a node.

Synopsis

```
function getname(doc:xmldoc, n:integer):string
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

The name of the node depending on the node type:

`XML_ELT`	name of the element section
`XML_TXT`	`"#text"`
`XML_CDATA`	`"#cdata-section"`
`XML_COM`	`"#comment"`
`XML_DATA`	`"#data"`
`XML_PINST`	processing instruction target
`XML_ATTR`	name of the attribute

Example

The following example collects the names of all element nodes occurring in a document.

```
declarations
  DB: xmldoc
  NodeList: list of integer
  NodeNames: set of string
end-declarations

getnodes(DB, "/descendant-or-self::node()", NodeList)
NodeNames:= union(r in NodeList | gettype(DB,r)=XML_ELT) {getname(DB,r)}
writeln("Names of element nodes: ", NodeNames)
```

Further information

Only element, attribute and processing instruction nodes have a name, for all other node types the above listed constant name is returned.

Related topics

gettype, getvalue, setname

Module

mmxml

getvalue

Purpose

Get the value of a node.

Synopsis

```
function getvalue(doc:xmldoc, n:integer):text
function getboolvalue(doc:xmldoc, n:integer):boolean
function getintvalue(doc:xmldoc, n:integer):integer
function getrealvalue(doc:xmldoc, n:integer):real
function getstrvalue(doc:xmldoc, n:integer):string
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

The value of the node.

Example

This code prints out the name of the employee with attribute id="T345".

```
declarations
  DB: xmldoc
end-declarations

writeln("Person with id='T345': ", getvalue(DB, getnode(DB,
  "personnelList/region/employee[@id='T345']/name") ))
```

Further information

1. Values of nodes are stored as `text` objects: the first version of the routine returns a reference to the object containing the value. Modifying this text will also alter the node value. Using one of the alternative versions of this routine allows to avoid having to perform a type conversion. Note however that no validation is performed and a conversion error will result in a `0` for a number and `false` for a Boolean without raising any error.
2. Element nodes have no value: the returned value corresponds to the value of the first child of type text of this element (or an empty string if no such child can be found).

Related topics

`gettype`, `getname`, `setvalue`

Module

mmxml

getfirstattr

Purpose

Get the first attribute of an element node.

Synopsis

```
function getfirstattr(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)

Return value

The node number of the first attribute of the element node provided or `-1` if there is no attribute.

Example

The following example displays all attributes of node `e`:

```
declarations
  DB: xmldoc
  a,e: integer
end-declarations

a:=getfirstattr(DB,e)
while(a>0) do
  writeln(getname(DB,a), "=", getvalue(DB,a))
  a:=getnext(DB,a)
end-do
```

Further information

Attributes are represented by nodes of type `XML_ATTR`: all node-related routines can be applied to attribute nodes.

Related topics

`getnext`, `getfirstchild`, `getlastchild`, `getparent`

Module

mmxml

getnext

Purpose

Get the successor of a node.

Synopsis

```
function getnext(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

The node number of the following node or `-1` if the current node is the last of the list.

Example

This example enumerates all child nodes within a specific region and displays the 'id' for all 'employee' nodes on a single line, adding a line break after the last name:

```
declarations
  DB: xmldoc
  APAC, Pers: integer
end-declarations

APAC:= getnode(DB, "personnelList/region[@id='APAC']")
Pers:= getfirstchild(DB, APAC)
LastPers:= getlastchild(DB, APAC)
while(Pers>-1) do
  if getname(DB, Pers)="employee" then
    write(" ", getattr(DB,Pers,"id"))
  end-if
  if Pers=LastPers then writeln; end-if
  Pers:= getnext(DB, Pers)
end-do
```

Further information

Node numbers returned by Mosel are not directly related to the order of nodes within the XML document (*i.e.* a larger node number does not imply that a node succeeds a node with a smaller number).

Related topics

`getfirstattr`, `getfirstchild`, `getlastchild`, `getparent`

Module

mmxml

getfirstchild

Purpose

Get the first child of an element node.

Synopsis

```
function getfirstchild(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)

Return value

The node number of the first child or `-1` if there is no child.

Example

See `getnext`.

Related topics

`getfirstattr`, `getnext`, `getlastchild`, `getparent`

Module

mmxml

getlastchild

Purpose

Get the last child of an element node.

Synopsis

```
function getlastchild(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)

Return value

The node number of the last child or `-1` if there is no child.

Example

See `getnext`.

Related topics

`getfirstattr`, `getfirstchild`, `getnext`, `getparent`

Module

mmxml

getnode

Purpose

Get the first node returned by a path specification.

Synopsis

```
function getnode(doc:xmldoc, n:integer, p:string|text):integer
function getnode(doc:xmldoc, n:integer):integer
function getnode(doc:xmldoc, p:string):integer
```

Arguments

`doc`	Document to use
`n`	Base node number (`0` when not provided)
`p`	Path to the node (`"*"` when not provided)

Return value

The node number of the first node selected by the path `p`; `-1` if no node can be found.

Example

The following example shows different forms of the `getnode` function.

```
  declarations
    DB: xmldoc
    Root, EMEA: integer
  end-declarations

! Get the first element that is not a comment or a processing instruction
  Root:= getnode(DB,"*")          ! Same as: getnode(DB,0,"*")

! Get the 'region' node with id=EMEA
  EMEA:= getnode(DB, "personnelList/region[@id='EMEA']")

! Check for employee record (node) for 'Sam' under 'EMEA'
  if getnode(DB, EMEA, "employee/name[string()='Sam']/..")<0 then
    writeln("No employee called 'Sam' in EMEA")
  end-if
```

Further information

1. Refer to section 19.1.2 for a detailed description of the syntax and semantic of XML paths.
2. This function is the same as `getfirstchild` when used without path specification.

Related topics

`getnodes`, `getfirstchild`

Module

mmxml

getnodes

Purpose

Get the list of nodes returned by a path specification.

Synopsis

```
procedure getnodes(doc:xmldoc, n:integer, p:string|text, l:list of integer)
procedure getnodes(doc:xmldoc, p:string, l:list of integer)
procedure getnodes(doc:xmldoc, n:integer, l:list of integer)
```

Arguments

`doc`	Document to use
`n`	Base node number (`0` when not provided)
`p`	Path to the node (`"*"` when not provided)
`l`	List where result is returned

Example

Here are a number of examples how to retrieve nodes with specific properties:

```
  declarations
    DB: xmldoc
    Employees, AllEmployees: list of integer
  end-declarations

! Get all employees in the Americas
  getnodes(DB, "personnelList/region[@id='AM']/employee", Employees)

! All employees who started before 2005
  getnodes(DB, "personnelList/region/employee/startDate[number()<2005]/..",
    Employees)

! All employees whose names start with "J"
  getnodes(DB, "personnelList/region/employee", AllEmployees)
  forall(n in AllEmployees) do
    getnodes(DB, n, "./name[starts-with(string(),'J')]/..", Employees)
    forall(p in Employees) save(DB, p, "")
  end-do

! Employees speaking at least 3 languages (=have a third "language" entry)
  getnodes(DB, "personnelList/region/employee/language[position()=3]/..",
    Employees)
```

Further information

1. Refer to section 19.1.2 for a detailed description of the syntax and semantic of XML paths.
2. This function resets the list it receives as parameter: the provided list is returned empty if no node can be found.

Related topics

getnode

Module

mmxml

getparent

Purpose

Get the parent of a node.

Synopsis

```
function getparent(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

The node number of the parent node or `-1` if `n=0` (root node has no parent).

Example

See `getattr`.

Related topics

`getfirstattr`, `getfirstchild`, `getlastchild`, `getnext`

Module

mmxml

gettype

Purpose

Get the type of a node.

Synopsis

```
function gettype(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

The type of the node:

`XML_ELT`	an element
`XML_TXT`	`a text`
`XML_CDATA`	`a CDATA section`
`XML_COM`	`a comment`
`XML_DATA`	`a data section`
`XML_PINST`	a processing instruction
`XML_ATTR`	an attribute
`-1`	if the node number is not valid

Example

See `getname`.

Further information

This function returns `-1` if the provided node number is not valid: this feature can be used to verify the validity of a node number before using it with other functions.

Related topics

`getname`, `getvalue`

Module

mmxml

getstandalone

Purpose

Get the standalone flag of the document.

Synopsis

```
function getstandalone(doc:xmldoc):integer
```

Argument

`doc` Document to use

Return value

Standalone flag:

`-1`	flag not specified
`0`	`standalone=no`
`1`	`standalone=yes`

Further information

The value of this flag is not used by `mmxml`. This is just an information to be saved in the header of the XML document. The default value for this flag is `-1`.

Related topics

`getencoding`, `getxmlversion`

Module

mmxml

getxmlversion

Purpose

Get the XML version of the document.

Synopsis

```
function getxmlversion(doc:xmldoc):string
```

Argument

`doc` Document to use

Return value

XML version as a text string

Further information

The XML version number is not used by `mmxml`. This is just an information to be saved in the header of the XML document. The default value for this option is `1.0`.

Related topics

`getencoding`, `getstandalone`

Module

mmxml

gethspace

Purpose

Get horizontal spacing of a node.

Synopsis

```
function gethspace(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

Number of spaces inserted before the node output

Further information

This spacing indicates the number of spaces to insert before displaying the node from the start of a new line when outputing the document. The horizontal spacing setting is only used when the indentation is in manual mode (see `setindentmode`).

Related topics

`getvspace`, `getindentmode`

Module

mmxml

getvspace

Purpose

Get vertical spacing of a node.

Synopsis

```
function getvspace(doc:xmldoc, n:integer):integer
```

Arguments

`doc`	Document to use
`n`	Node number

Return value

Number of carriage returns inserted before the node output

Further information

This spacing indicates the number of empty lines to insert before displaying the node when outputing the document. The vertical spacing setting is only used when the indentation is in manual mode (see `setindentmode`).

Related topics

`gethspace`, `getindentmode`

Module

mmxml

getindentmode

Purpose

Get indent mode of the document.

Synopsis

```
function getindentmode(doc:xmldoc):integer
```

Argument

`doc`	Document to use

Return value

Indent mode:

`XML_AUTO`	automatic indentation
`XML_NONE`	no formatting
`XML_MANUAL`	use vertical/horizontal spacing settings of each node

Related topics

`setindentmode`, `getindentskip`, `getlinelen`

Module

mmxml

getindentskip

Purpose

Get the size of an indentation step.

Synopsis

```
function getindentskip(doc:xmldoc):integer
```

Argument

`doc` Document to use

Return value

Number of spaces to add for each indentation

Related topics

`setindentskip`, `getindentmode`, `getlinelen`

Module

mmxml

getlinelen

Purpose

Get the length of a line.

Synopsis

```
function getlinelen(doc:xmldoc):integer
```

Argument

`doc` Document to use

Return value

Length of a line in characters for outputting the XML document

Related topics

`setlinelen`, `getindentmode`, `getindentskip`

Module

mmxml

getmaxnodes

Purpose

Get the number of nodes currently allocated for a document.

Synopsis

```
function getmaxnodes(doc:xmldoc):integer
```

Argument

`doc` Document to use

Return value

Number of nodes currently allocated

Further information

This function returns the amount of memory (in number of nodes) currently allocated for a given document. This amount may be larger than the amount actually in use.

Related topics

`setmaxnodes`, `getsize`

Module

mmxml

getsize

Purpose

Get the size of a document.

Synopsis

```
function getsize(doc:xmldoc):integer
```

Argument

`doc` Document to use

Return value

The number of nodes used by the document.

Related topics

`getmaxnodes`

Module

mmxml

jsonload

Purpose

Load a JSON document.

Synopsis

```
procedure jsonload(doc:xmldoc, fname:text)
procedure jsonload(doc:xmldoc, fname:text, mode:integer)
```

Arguments

`doc`	Document to use
`fname`	File name of the document to load
`mode`	How to handle JSON object names:
	`0` Object names are converted to XML element names (default)
	`1` Object names are saved as the attribute `"name"`

Further information

1. This routine replaces the content of the provided document object with the JSON file given as second argument. If the file cannot be accessed or if an error occurs during reading, the procedure generates an IO error (which may be intercepted if the control parameter `ioctrl` is true).
2. The parser converts the original JSON document into an XML representation (See Section 19.1.3). Using the version of the procedure without the `mode` argument is the same as using `0` for this parameter.

Related topics

`jsonsave`, `jsonparse`, `load`

Module

mmxml

jsonparse

Purpose

Parse a JSON document.

Synopsis

```
function jsonparse(afct:array(range) of string|function,ctx:ctxtype):
      integer
```

Arguments

`afct` Event function table. Each entry of this array is the name of or a reference to the function to call when the corresponding event occurs. The expected events are (all of these entries are optional):

`JSON_FCT_OPEN_OBJ`	Opening of an object
`JSON_FCT_CLOSE_OBJ`	Closing of an object
`JSON_FCT_OPEN_ARR`	Opening of an array
`JSON_FCT_CLOSE_ARR`	Closing of an array
`JSON_FCT_TEXT`	A textual value
`JSON_FCT_NUM`	A numerical value
`JSON_FCT_BOOL`	A Boolean value
`JSON_FCT_NULL`	The `null` value

`ctx` Value passed as firt argument of all event functions

Return value

`0` if successful, `1` in case of parsing error or a non-zero value returned by an event function

Example

This example displays values of object members `"name"` and `"age"` of a JSON document:

```
declarations
 afct:array(range) of string
  s_ctx=record
   cnt:integer
  end-record
  c:s_ctx
end-declarations

public function setvalue_all(ctx:s_ctx,name:text,type:integer,val:text):intege
 if name="name" or name="age" then
  writeln(name,":",val)
  ctx.cnt+=1
 end-if
end-function

afct(JSON_FCT_TEXT):="setvalue_all"   ! A value as a text
fopen("mydoc.json",F_INPUT)
rts:=jsonparse(afct,c)
fclose(F_INPUT)
writeln("line count:",c.cnt)
```

Further information

1. This function is an alternative approach to `jsonload` for processing JSON documents: instead of loading into memory the entire document this function calls a dedicated routine whenever it identifies a JSON entity. For instance a specific function is called when an object is open and another one when it is closed. It is up to the Mosel program to decide how to handle the document via these *event handling functions*.

2. To each event type corresponds a specific function signature. These functions return an integer that decides whether parsing should continue: a non-zero value will cause the parsing to cancel (this value is used as the return value of `jsonparse`). The expected function signatures are:

```
JSON_FCT_OPEN_OBJ  function open_object(ctx:ctxtype, name:text):integer
JSON_FCT_CLOSE_OBJ  function close_object(ctx:ctxtype):integer
JSON_FCT_OPEN_ARR  function open_array(ctx:ctxtype, name:text):integer
JSON_FCT_CLOSE_ARR  function close_array(ctx:ctxtype):integer
JSON_FCT_TEXT  function text_val(ctx:ctxtype, name:text, type:integer,
           val:text):integer
JSON_FCT_NUM  function num_val(ctx:ctxtype, name:text, val:real):integer
JSON_FCT_BOOL  function bool_val(ctx:ctxtype, name:text,
           val:boolean):integer
JSON_FCT_NULL  function null_val(ctx:ctxtype, name:text):integer
```

   In addition to the pre-defined arguments these functions take a *context* as their first parameter. This variable (that can be of any type) is provided to the `jsonparse` routine and can be used by the event functions for storing progress information.
   The `name` argument is not empty only when the value corresponds to an object member: in this case this parameter is the label of this member. The `type` argument passed to the *text_val* function indicates the type of the data (0 for `null`, 1 for text, 2 for numerical and 3 for Boolean): this function is used with the textual representation of the value when the required type-specific function is not available. For instance this function will be called with `type=3` if a Boolean value has been read and the entry `JSON_FCT_BOOL` is not defined in the function table.

3. An error message indicating the location of the error is displayed when the parsing fails or if an event function returns a negative value (a positive value also interrupts parsing but no message is displayed).

Related topics

`jsonload`

Module

mmxml

jsonsave

Purpose

Save a JSON document.

Synopsis

```
procedure jsonsave(doc:xmldoc, fname:text)
```

Arguments

`doc` Document to save

`fname` Destination file name

Further information

1. This routine generates a JSON file from the provided `xmldoc` object. It is assumed that the document is built according to the JSON conventions (See Section 19.1.3). The result is undefined if the conventions are not respected.
2. This procedure does not require that the elements of the tree are typed using the `"jst"` attribute: the type is deduced from the value of the node when this attribute is missing. Moreover, both object member naming conventions can be used: when outputing an object, the member name can be taken either from the element name or from the attribute `"name"`. If both are available, the attribute takes precedence.
3. An IO error will be raised if the destination file cannot be accessed.

Related topics

`jsonload`, `save`

Module

mmxml

load

Purpose

Load an XML document.

Synopsis

```
procedure load(doc:xmldoc, fname:text)
```

Arguments

`doc` Document to use

`fname` File name of the document to load

Example

This code reads in a document and displays its contents on screen applying automatic formatting instead of its original formatting.

```
declarations
  DB: xmldoc
end-declarations

! Reading data from an XML file
load(DB, "refexample.xml")

! Set indentation mode for XML output (default after load: MANUAL)
setindentmode(DB, XML_AUTO)

! Display document contents on screen
save(DB, "")
```

Further information

This routine replaces the content of the provided document object with the XML file given as second argument: all properties of the document are reset to their default value and the indentation mode is set to `XML_MANUAL` (see `setindentmode`). Vertical and horizontal spacing of each loaded node are set in order to preserve as much as possible the original formatting of the document. If the file cannot be accessed or if an error occurs during reading, the procedure generates an IO error (which may be intercepted if the control parameter `ioctrl` is true).

Related topics

`save`, `xmlparse`, `jsonload`

Module

mmxml

save

Purpose

Save an XML document.

Synopsis

```
procedure save(doc:xmldoc, fname:text)
procedure save(doc:xmldoc, n:integer, fname:text)
```

Arguments

`doc`	Document to save
`n`	Node number to use as root node (default: 0)
`fname`	Destination file name

Example

This example shows the two versions of this procedure.

```
declarations
   DB: xmldoc
   Pers: integer
 end-declarations

! Save XML document to file 'results.xml'
  save(DB, "results.xml")

! Display a subtree on screen
  Pers:= getnode(DB, "personnelList/region/employee[@id='T345']")
  save(DB, Pers, "")
```

Further information

1. This routine generates an XML file from the provided `xmldoc` object. The XML header is produced using the properties defined with `setencoding`, `setxmlversion` and `setstandalone`. No header is emitted if either the encoding or the version is an empty string.
2. When providing an alternative root node, only the specified part of the document tree is exported without any XML header.
3. The document is formatted according to the indentation mode and its associated settings (see `setindentmode`); XML control characters are encoded (see `xmlencode`).
4. An IO error will be raised if the destination file cannot be accessed.

Related topics

`load`, `save`

Module

mmxml

setattr

Purpose

Set the value of an attribute.

Synopsis

```
procedure setattr(doc:xmldoc, n:integer, name:string,
       v:text|string|boolean|integer|real)
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element)
`name`	Name of the attribute
`v`	New value for the attribute

Example

See `addnode`.

Further information

1. Attribute values are stored as `text` objects: the versions of this procedure accepting other types perform the conversion implicitly.
2. Attributes are nodes of type `XML_ATTR`: procedure `setvalue` may also be used to change the value of an attribute.
3. Setting an empty value to an attribute does not remove this attribute from the attribute list of the element. Use `delattr` for this purpose.

Related topics

`getattr`, `delattr`

Module

mmxml

setencoding

Purpose

Set the character encoding of the document.

Synopsis

```
procedure setencoding(doc:xmldoc, enc:string)
```

Arguments

`doc`	Document to use
`enc`	Name of the character encoding

Further information

The default character encoding is UTF-8.

Related topics

`save`, `setstandalone`, `setxmlversion`

Module

mmxml

setmaxnodes

Purpose

Set the number of allocated nodes for a document.

Synopsis

```
procedure setmaxnodes(doc:xmldoc, m:integer)
```

Arguments

`doc`	Document to use
`m`	Number of nodes to reserve

Further information

This procedure sets the amount of memory reserved for a document. Normally, *mmxml* allocates memory on demand but using this procedure it is possible to allocate at once a larger block of memory to possibly speedup the loading of very large documents. If the requested amount is smaller than what is required to represent the document currently held in the `doc` object, the memory block is reduced as much as possible such that the document can still be stored.

Related topics

`getmaxnodes`

Module

mmxml

setname

Purpose

Set the name of a node.

Synopsis

```
procedure setname(doc:xmldoc, n:integer,name:string)
```

Arguments

`doc`	Document to use
`n`	Node number (must be an element or processing instruction)
`name`	New name for the node

Further information

Only element and processing instruction nodes can be modified with this routine; for all other node types an error will be raised.

Related topics

`setvalue`

Module

mmxml

setvalue

Purpose

Set the value of a node.

Synopsis

```
procedure setvalue(doc:xmldoc, n:integer,
       v:text|string|integer|real|boolean)
```

Arguments

`doc`	Document to use
`n`	Node number
`v`	New value for the node

Example

See `copynode`.

Further information

1. Node values are stored as `text` objects: the versions of this procedure accepting other types perform the conversion implicitly.
2. Element nodes have no value: this procedure will modify the value of the first child text node of the element. If no such node exists, a new text node will be added to the beginning of the list of children.

Related topics

`setname`

Module

mmxml

sethspace

Purpose

Set horizontal spacing of a node.

Synopsis

```
procedure sethspace(doc:xmldoc, n:integer, s:integer)
```

Arguments

`doc`	Document to use
`n`	Node number
`s`	Number of spaces to put before the node output

Example

The following example reformats the XML document layout by adding an additional line before 'region' nodes and printing three consecutive tags within 'employee' on a single line. The indentmode is set to 'manual' in order to apply the user formatting (instead of automatic or none).

```
declarations
  DB: xmldoc
  NodeList, Employees: list of integer
end-declarations

! New line without indentation for Root
setvspace(DB, Root, 1)

! Add extra line in between regions, keeping original indentation
getnodes(DB, "personnelList/region", NodeList)
forall(r in NodeList) setvspace(DB, r, 2)

! Spacing/indentation for 'employee' tag
getnodes(DB, "personnelList/region/employee", Employees)
forall(p in Employees) do
  setvspace(DB, p, 1); sethspace(DB, p, 4)

  ! Within 'employee', display up to 3 consecutive tags on a single line
  getnodes(DB, p, "child::node()[position() mod 3=1]", NodeList)
  forall(r in NodeList) do
    setvspace(DB, r, 1); sethspace(DB, r, 6)
  end-do
  getnodes(DB, p, "child::node()[position() mod 3<>1]", NodeList)
  forall(r in NodeList) do
    setvspace(DB, r, 0); sethspace(DB, r, 1)
  end-do
end-do

! Set indentation mode to 'manual' to use our own formatting for display
setindentmode(DB, XML_MANUAL)
save(DB, "")
```

Further information

This spacing indicates the number of spaces to skip from the start of a new line before displaying the node when outputing the document. The horizontal spacing setting is only used when the indentation is in manual mode (see `setindentmode`).

Related topics

`setvspace`, `setindentmode`

Module

mmxml

setvspace

Purpose

Set vertical spacing of a node.

Synopsis

```
procedure setvspace(doc:xmldoc, n:integer, s:integer)
```

Arguments

`doc`	Document to use
`n`	Node number
`s`	Number of carriage return to put before the node output

Example

See `sethspace`.

Further information

This spacing indicates the number of empty lines to add before displaying the node when outputing the document. The vertical spacing setting is only used when the indentation is in manual mode (see `setindentmode`).

Related topics

`sethspace`, `setindentmode`

Module

mmxml

setindentmode

Purpose

Set indent mode for the document.

Synopsis

```
procedure setindentmode(doc:xmldoc, imod:integer)
```

Arguments

`doc` Document to use

`imod` Indent mode:

`XML_AUTO`	automatic indentation
`XML_NONE`	no formatting
`XML_MANUAL`	use vertical/horizontal spacing of each node

Example

See `sethspace`.

Further information

This parameter specifies how the XML document must be formatted by the `save` routine. Automatic indentation can be tuned by redefining the indent skip (`setindentskip`) and line length (`setlinelen`). If the indent mode is set to `XML_NONE`, the document is exported on a single line without formatting. Finally, with manual indenting, each node is placed according to its horizontal/vertical spacing as specified by `setvspace` and `sethspace`.

Related topics

`save`, `setindentskip`, `setlinelen`

Module

mmxml

setindentskip

Purpose

Set the size of an indentation step.

Synopsis

```
procedure setindentskip(doc:xmldoc, skip:integer)
```

Arguments

`doc`	Document to use
`skip`	Number of spaces to add for each indentation (at least 1; default is 2)

Example

This code reads in a document and displays its contents on screen applying automatic formatting with single space indentation and increased line length.

```
  declarations
    DB: xmldoc
  end-declarations

! Reading data from an XML file
  load(DB, "refexample.xml")

! Set indentation mode for XML output (default after load: MANUAL)
  setindentmode(DB, XML_AUTO)

! Set smaller indentation skip than default
  setindentskip(DB, 1)

! Increase default line length
  setlinelen(DB, 80)

! Display document contents on screen
  save(DB, "")
```

Further information

When the document is formatted automatically (see `setindentmode`) the number of spaces specified by this procedure is added to the current margin each time a new indent step is created.

Related topics

`save`, `setindentmode`, `setlinelen`

Module

mmxml

setlinelen

Purpose

Set the length of a line.

Synopsis

```
procedure setlinelen(doc:xmldoc, len:integer)
```

Arguments

`doc`	Document to use
`len`	Length of a line in characters (at least 1; default is 70)

Example

See `setindentskip`.

Further information

When outputing the document, a line break is inserted between nodes or while displaying a list of element attributes whenever more than the specified number of characters has been written.

Related topics

`save`, `setindentmode`, `setindentskip`

Module

mmxml

setstandalone

Purpose

Set the standalone flag of the document.

Synopsis

```
procedure setstandalone(doc:xmldoc, std:integer)
```

Arguments

`doc` Document to use

`std` Standalone flag:

`-1`	flag not specified
`0`	`standalone=no`
`1`	`standalone=yes`

Further information

The value of this flag is not used by `mmxml`. This is just an information to be saved in the header of the XML document. The default value for this flag is `-1`.

Related topics

`save`, `setencoding`, `setxmlversion`

Module

mmxml

setxmlversion

Purpose

Set the XML version of the document.

Synopsis

```
procedure setxmlversion(doc:xmldoc, xv:string)
```

Arguments

`doc`	Document to use
`xv`	XML version

Further information

The XML version number is not used by `mmxml`. This is just an information to be saved in the header of the XML document. The default value for this option is `1.0`.

Related topics

`save`, `setencoding`, `setstandalone`

Module

mmxml

xmlattr

Purpose

Get an attribute during parsing of an element.

Synopsis

```
procedure xmlattr(ndx:integer, name:text, val:text)
procedure xmlattr(aname:string, val:text)
```

Arguments

`ndx`	Attribute index
`name`	Attribute name (returned by the procedure)
`val`	Attribute value (returned by the procedure)
`aname`	Attribute name (provided to the procedure)

Further information

1. This procedure can only be used from the *open element* function while parsing an XML document with the `xmlparse` function.
2. With the first syntax, the attribute index `ndx` is returned by the procedure (both its name and value). This index value must range between `1` and the last index as passed to the *open element* function. With the second syntax the name of the attribute to retrieve is given to the procedure. An empty string is returned if this attribute is not defined for the current element.

Related topics

`xmlparse`

Module

mmxml

xmlencode

Purpose

Encode a text string for XML.

Synopsis

```
function xmlencode(t:text):text
```

Argument

`t` text to encode

Further information

Encode a text string for XML by replacing control characters (<, >, &, ', ") by their encoded equivalent.

Related topics

`xmldecode`

Module

mmxml

xmldecode

Purpose

Decode a text string for XML.

Synopsis

```
function xmldecode(t:text):text
```

Argument

`t` text to decode

Further information

Decode a text string from XML by replacing encoded sequences (< > & ' ") by the corresponding control characters.

Related topics

`xmlencode`

Module

mmxml

xmlparse

Purpose

Parse an XML document.

Synopsis

```
function xmlparse(afct:array(range) of
      string|function,mode:integer,ctx:ctxtype): integer
```

Arguments

`afct` Event function table. Each entry of this array is the name of or a reference to the function to call when the corresponding event occurs. The expected events are (all of these entries are optional):

`XML_FCT_DECL`	Document declarations
`XML_FCT_TXT`	A text node (same value as `ML_TEXT`)
`XML_FCT_CDATA`	A CDATA node
`XML_FCT_COM`	A commentary node
`XML_FCT_DATA`	A DATA node
`XML_FCT_PINST`	A processing instruction node
`XML_FCT_OPEN_ELT`	Opening of a new element node
`XML_FCT_CLOSE_ELT`	Closing of an element node

`mode` If `0`, spaces are preserved and returned as text elements. Otherwise all text elements are trimmed

`ctx` Value passed as first argument of all event functions

Return value

`0` if successful, `1` in case of parsing error or a non-zero value returned by an event function

Example

This example displays the structure of an XML document without loading it into memory.

```
! Display element name and update indentation
public function start_elt(spce:text,name:text,nba:integer):integer
 writeln(spce,name)
 spce+="  "
end-function

! Update indentation when element closes
function end_elt(spce:text):integer
 spce-="  "
end-function

declarations
 afct:array(range) of any
end-declarations

afct(XML_FCT_OPEN_ELT):="start_elt" ! define open element
afct(XML_FCT_CLOSE_ELT):=->end_elt  ! define close element
fopen("mydocument.xml",F_INPUT)
rts:=xmlparse(afct,1,text(""))
fclose(F_INPUT)
```

Further information

1. This function is an alternative approach to `load` for processing XML documents: instead of loading into memory the entire document this function calls a dedicated routine whenever it identifies an XML entity. For instance a specific function is called when an element is open and another one when it is closed. It is up to the Mosel program to decide how to handle the document via these *event handling functions*.

2. To each event type corresponds a specific function signature. These functions return an integer that decides whether parsing should continue: a non-zero value will cause the parsing to cancel (this value is used as the return value of `xmlparse`). The expected function signatures are:

   ```
   XML_FCT_DECL  function xmldecl(ctx:ctxtype, vers:text, enc:text,
              std:integer):integer
   XML_FCT_TXT  function text_node(ctx:ctxtype, type:integer,
              data:text):integer
   XML_FCT_CDATA  function cdata_node(ctx:ctxtype, type:integer,
              data:text):integer
   XML_FCT_COM  function comment_node(ctx:ctxtype, type:integer,
              data:text):integer
   XML_FCT_DATA  function data_node(ctx:ctxtype, type:integer,
              data:text):integer
   XML_FCT_PINST  function processing_instr(ctx:ctxtype, target:text,
              data:text):integer
   XML_FCT_OPEN_ELT  function open_element(ctx:ctxtype, name:text,
              nba:integer):integer
   XML_FCT_CLOSE_ELT  function close_element(ctx:ctxtype):integer
   ```

   In addition to the pre-defined arguments these functions take a *context* as their first parameter. This variable (that can be of any type) is provided to the `xmlparse` routine and can be used by the event functions for storing progress information.
   The type passed to the text node functions is the XML type corresponding to the function (namely `XML_TXT`, `XML_CDATA`, `XML_COM`, `XML_DATA`).
   The *open_element* function receives the name of the element as well as the number of defined attributes. To retrieve these attributes `xmlattr` can be used.

3. An error message indicating the location of the error is displayed when the parsing fails or if an event function returns a negative value (a positive value also interrupts parsing but no message is displayed).

Related topics

`load`

Module

mmxml

CHAPTER 20

mmxnlp

The *mmxnlp* module provides access to nonlinear solvers, extending the capabilities provided by the *mmxprs* and *mmnl* modules. In particular, this module allows existing linear or mixed integer (MIP) models to be upgraded to include nonlinearities, without requiring unnecessary changes to the formulation. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmxnlp'
```

Problem type and module hierarchy

Module *mmxprs* provides

- linear models and
- mixed integer linear models.

Module *mmnl* adds support for

- convex quadratic models,
- convex quadratic mixed integer models,
- convex, quadratically constrained models, and
- convex, quadratically constrained mixed integer models.

Module *mmxnlp* adds support for

- general nonlinear problems and
- general nonlinear mixed integer problems.

If the *mmxnlp* module is used for a model which does not require a general nonlinear solver, this should be equivalent to using the appropriate *mmxprs* or *mmnl* module directly.

20.1 New functionality for the Mosel language

20.1.1 The `userfunc` type

A nonlinear model may employ one or more black box evaluation functions, which can be used to provide function evaluations to the solver. These are represented in *mmxnlp* by the new `userfunc` type. The implementation of each `userfunc` must be described by calling one of:

- `userfuncMosel`: to declare that a user function is implemented as a Mosel function

Note that user functions returning multiple arguments are support by the *mmxnlp* module. The `F` construction allows a `userfunc` to be included in any nonlinear (`nlctr`) expression, and groups each occurrence of the userfunc with its parameters . During the solve, the parameters (which are of type nlctr themselves) will be evaluated at the current solution, and the real-valued results passed to the `userfunc` implementation. The function `userfuncinfo` can be used to find out which parameters the system has deduced it needs to pass to a particular `userfunc`.

20.1.2 The `tolset` type

The module provides a large number of configurable tolerances for users of the Xpress NonLinear SLP solver. A `tolset` describes a convergence tolerance set, which can be used for those nonlinear solvers supporting variable-specific convergence tolerances. The elements of a tolerance set are defined by using `settol`, and assigned to a variable or list of variables using `settolset`. For more details on tolerance sets, please refer to the *Xpress NonLinear Reference Manual*.

- `XNLP_TOL_TC`: The absolute closure tolerance
- `XNLP_TOL_TA`: The absolute delta tolerance
- `XNLP_TOL_RA`: The relative delta tolerance
- `XNLP_TOL_TM`: The absolute matrix tolerance
- `XNLP_TOL_RM`: The relative matrix tolerance
- `XNLP_TOL_TI`: The absolute impact tolerance
- `XNLP_TOL_RI`: The relative impact tolerance
- `XNLP_TOL_TS`: The relative slack impact tolerance
- `XNLP_TOL_RS`: The absolute slack impact tolerance

20.1.3 The `mpproblem.xprs.xnlp` problem type

When using the *mmxnlp* module, the type of the active Mosel problem is changed from mpproblem.xprs to the extended type mpproblem.xprs.xnlp. This means that all of the routines presented in this section operate in the context of the current Mosel problem.

20.2 *mmxnlp* and the other Mosel modules

mmxnlp is designed to provide seamless integration with other Mosel functionalities. However, the fundamentally different nature of nonlinear problems makes some compromises necessary; these are listed in this section.

20.2.1 Overloaded functions

The following functionality is modified or extended by the *mmxnlp* module:

- Retrieval of solution values with `getsol`, both for variables and nonlinear constraints. A detailed description of the behaviour of this function can be found in the documentation for the *mmxprs* and *mmnl* modules.

- Functions implemented in the *mmnl* module are extended for nonlinear solvers:
  - `setinitval`, `clearinitvals` and `copysoltoinit` to manage initial values.
  - Mathematical functions: `abs`, `exp`, `ln`, `log`, `sqrt`, `cos`, `sin`, `tan`, `arccos`, `arcsin`, `arctan`.
  - Mosel constraint and constraint visibility functions: `gettype`, `settype`, `ishidden` and `sethidden`.
- Functions implemented in the *mmxprs* module are extended for nonlinear solvers:
  - `maximize` and `minimize` to solve the problem.
  - `getprobstat` to return the problem solution status.
  - `fixglobal` for managing integer problems.
  - Exporting the current status (for debugging purposes) with `loadprob`, `writeprob` and `savestate`.

20.2.2 Module compatibility

The *mmquad* module is incompatible with the *mmxnlp* module, and should not be used together with it.

The *mmxprs* and *mmnl* modules are automatically loaded when using the *mmxnlp* module.

The *mmnl* module defines several discontinuous functions for use with decision variables (`mpvar`), which are not supported by the *mmxnlp* module. These constructions should instead be modelled with integer constraints. The functions are: `round`, `ceil`, `floor`, `idiv` and `mod`.

The following standard functionalities are not available for nonlinear problems:

- Functions for working with a basis: `loadbasis`, `readbasis` and `savebasis`.
- Logical constraints of the form `logctr`, and their operators: `implies`, `indicator`, `or`, `xor` and `and`.
- Functions for working with multiple MIP solutions, the solution pool and the solution enumerator: `selectsol`, `XPRS_enumduplpol`, `XPRS_enummaxsol` and `XPRS_enumsols`.
- Functions for cut management, including model cuts and delayed rows: `addcut`, `addcuts`, `loadcuts`, `storecut`, `storecuts`, `delcuts`, `dropcuts`, `getcnlist` and `getcplist`.
- Functions for determining irreducible infeasible sets, and for repairing infeasibility: `getiis`, `getiissense`, `getiistype`, `isiisvalid`, `resetiis` and `repairinfeas` and `getinfeas`.

20.3 Control parameters

When using *mmxnlp*, `getparam` and `setparam` are extended to additionally provide access to all the control and problem parameters of the Xpress NonLinear SLP solver. The module also provides the following controls of its own:

`XNLP_AUTOELIM`	When set to true, Mosel uses the model's semantics to break down nonlinear formulas and feed the information to the solver for nonlinear eliminations and to detect network structures in the model. p. 697
`XNLP_LOADASNL`	When set to true, quadratic expressions will be treated as being of general nonlinear type. If they are known to be non-convex, the overhead of attempting to treat the expression as convex initially is avoided. p. 697

XNLP_LOADNAMES	When set to true, names from the Mosel file will be passed to the underlying solver to improve the readability of messages it generates. This is an alias for XPRS_LOADNAMES. p. 697
XNLP_NLPSTATUS	The solution status of the problem. For a detailed description of this value, please see the documentation for the XSLP_NLPSTATUS attribute in the *Xpress NonLinear Reference Manual*. p. 698
XNLP_SOLVER	Solver selection when available. p. 698
XNLP_VERBOSE	When set to true, informative messages from any underlying nonlinear solver will be displayed. This is an alias for XPRS_VERBOSE. p. 698

XNLP_AUTOELIM

Description When set to true, Mosel uses the model's semantics to break down nonlinear formulas and feed the information to the solver for nonlinear eliminations and to detect network structures in the model.

Type Integer, read/write

Values

0	Disable
1	Enable

Default value 1

Module mmxnlp

XNLP_LOADASNL

Description When set to true, quadratic expressions will be treated as being of general nonlinear type. If they are known to be non-convex, the overhead of attempting to treat the expression as convex initially is avoided.

Type Integer, read/write

Values

0	Assume that quadratic expressions are convex
1	Assume that quadratic expressions are non-convex

Default value 0

Module mmxnlp

XNLP_LOADNAMES

Description When set to true, names from the Mosel file will be passed to the underlying solver to improve the readability of messages it generates. This is an alias for XPRS_LOADNAMES.

Type Integer, read/write

Values

0	Names are not loaded into the solver
1	Names are loaded into the solver

Default value 0

Module mmxnlp

XNLP_NLPSTATUS

Description The solution status of the problem. For a detailed description of this value, please see the documentation for the XSLP_NLPSTATUS attribute in the *Xpress NonLinear Reference Manual*.

Type Integer, read only

Values

0	Optimization unstarted
1	Locally optimal
2	Optimal
3	Locally infeasible
4	Infeasible
5	Unbounded
6	Unfinished

Default value 0

Module mmxnlp

XNLP_SOLVER

Description Solver selection when available.

Type Integer, read/write

Values

−1	Determine automatically, based on problem characteristics and availability of solvers
0	Xpress NonLinear (SLP)
1	Knitro

Default value -1

Module mmxnlp

XNLP_VERBOSE

Description When set to true, informative messages from any underlying nonlinear solver will be displayed. This is an alias for XPRS_VERBOSE.

Type Integer, read/write

Values

0	No solver logging
1	Solver log is displayed

Default value 0

Module mmxnlp

20.4 Procedures and functions

This section lists in alphabetical order the functions and procedures that are provided by the *mmxnlp* module.

addmultistart

Purpose

Loads a single or a set of multistart job(s) into the multistart job pool.

Synopsis

```
addmultistart(descr:string)
addmultistart(descr:string, controls:array(set of string) of real)
addmultistart(descr:string, initvalues:array(set of mpvar) of real)
addmultistart(descr:string, initvalues:array(set of mpvar) of real,
      controls: array(set of string) of real)
addmultistart(descr:string, controls:array(set of string) of real,
      initvalues:array(set of mpvar) of real)
addmultistart(descr:string, preset:integer)
addmultistart(descr:string, preset:integer, cnt:integer)
addmultistart(descr:string, preset:integer, initvalues:array(set of mpvar)
      of real, controls:array(set of string) of real)
addmultistart(descr:string, preset:integer, cnt:integer,
      initvalues:array(set of mpvar) of real, controls:array(set of string)
      of real)
```

Arguments

`descr`	Text description of the job. Used in reporting and in callbacks.
`controls`	An array containing the controls to be set for the loaded multistart job.
`initvalues`	An array containing initial values to be set for the loaded multistart job.
`preset`	The multistart preset of jobs to be loaded. Please see the *Xpress NonLinear Reference Manual* for the list of possible presets.
`cnt`	The upper bound on the number of jobs to be created, in case a preset is used.

Further information

Adds a job or a preset to the multistart job pool. Multistart jobs are automatically executed on the next minimize/maximize command, unless the `XSLP_MULTISTART` control is set to 0. Please refer to the *Xpress NonLinear Reference Manual* for a detailed description of multistart.

Module

mmxnlp

chgdeltatype

Purpose

Changes the type of a delta variable associated to an mpvar.

Synopsis

```
procedure chgdeltatype(col:mpvar, type:integer, value:real)
```

Arguments

`col` The column for which the delta is to be changed.

`type` The new type of the delta.

`value` Value associated to the new delta type.

Further information

Please refer to the *Xpress NonLinear Reference Manual* for more details about delta types.

Related topics

`setinitval`, `setinitsb`, `setdetrow`, `setenforcedctr`.

Module

mmxnlp

F

Purpose

Include a user function in a nonlinear constraint.

Synopsis

```
function F(UF:userfunc, arg:linctr):nlctr
function F(UF:userfunc, arg:nlctr):nlctr
function F(UF:userfunc, arg:list of nlctr):nlctr
function F(UF:userfunc, arg:array(any sets) of nlctr):nlctr
function F(UF:userfunc, arg:list of nlctr, returnarg:integer):nlctr
function F(UF:userfunc, arg:array(any sets) of nlctr,
      returnarg:integer):nlctr
```

Arguments

`UF`	A user function of type `userfunc`
`arg`	Argument to be passed to the user function
`returnarg`	Return argument to be substituted into the formula for multivalued user functions

Return value

A nonlinear expression which may form part of any `nlctr`.

Example

The following example shows how to implement a negative cosine function.

```
model "SimpleUF"
 uses "mmxnlp"
 declarations
  obj: nlctr
  x: mpvar
  MinusSine: userfunc
 end-declarations

! Creation and assignment of the user function
 MinusSine := userfuncMosel("MinusSineImplementation")
! which can then be embedded into any nonlinear expression
 obj := F(MinusSine,x)
 minimize(obj)

 public function MinusSineImplementation (x:real): real
  returned := -sin(x)
 end-function
end-model
```

Further information

User functions allow extremely complex, recursive or non-algebraic expressions to be included in nonlinear formulae. As such they may make use of simulators or other black box evaluators. The actual parameters to a user function depend upon the way it is bound to the model by the `F` function. Please see the chapter on user functions for more details. Each user function instance defined by the means of the `F` function must share the same argument syntax structure, however the actual formula content may differ: *e.g.* if a function takes an array of nonlinear expressions as input arguments, each instance of the function corresponding to the same definition based on the same F instance must have the same underlying array structure, although the expressions stored in them may differ. If a separate `F` instance is used using the same function implementation, this rule does not apply. Also note, that for Mosel to be able to correctly cross reference the sets used in the definition of an array, the sets must be named.

Related topics

`userfuncMosel`.

Module

mmxnlp

generateUFparallel

Purpose

Generates a parallel version of a Mosel user function that is implemented as a Mosel package.

Synopsis

```
procedure generateUFparallel(bimname:string, fctname:string)
```

Arguments

`bimname` Path to the compiled Mosel package implementing the user function.

`fctname` The public user function inside the package.

Further information

Please refer to the *Xpress NonLinear Reference Manual* for more details about this functionality.

Module

mmxnlp

printmodelmemory

Purpose

Print a summary of the current memory usage of the nonlinear module.

Synopsis

```
procedure printmodelmemory
```

Further information

This procedure has no effect unless XNLP_VERBOSE is set. It is provided solely for the purpose of model analysis and debugging.

Related topics

`validate`, `printmodelscaling`, `userfuncinfo`.

Module

mmxnlp

printmodelscaling

Purpose

Print a summary of the scaling of the model, as loaded into the solver.

Synopsis

```
procedure printmodelscaling
```

Further information

This procedure has no effect unless XNLP_VERBOSE is set. It is provided solely for the purpose of model analysis and debugging.

Related topics

`validate`, `printmodelmemory`, `userfuncinfo`.

Module

mmxnlp

setcallback

Purpose

Set nonlinear callback functions and procedures.

Synopsis

```
procedure setcallback(cbtype:integer, cb:string)
```

Arguments

`cbtype` Type of the callback:

`XSLP_CB_ITERSTART`	SLP iteration start callback
`XSLP_CB_ITEREND`	SLP iteration end callback
`XSLP_CB_ITERVAR`	Nonlinear variable convergence check callback
`XSLP_CB_CASCADESTART`	Cascading start callback
`XSLP_CB_CASCADEVAR`	Variable cascaded callback
`XSLP_CB_CASCADEEND`	Cascading end callback
`XSLP_CB_START`	SLP solve start callback
`XSLP_CB_END`	SLP solve end callback
`XSLP_CB_PRENODE`	MISLP node setup callback
`XSLP_CB_INTSOL`	New integer solution found callback
`XSLP_CB_OPTNODE`	MISLP node solved and (SLP) optimal callback
`XSLP_CB_CONSTRUCT`	Construct start callback
`XSLP_CB_MSJOBSTART`	A new multistart job is about to be solved callback
`XSLP_CB_MSJOBEND`	A multistart job has been solved callback
`XSLP_CB_MSWINNER`	Winner multistart job callback

`cb` Name of the callback function/procedure; the parameters and the type of the return value (if any) vary depending on the type of the callback:

`function cb:integer`	XSLP_CB_ITERSTART
`function cb:integer`	XSLP_CB_ITEREND
`function cb(var:mpvar) : integer`	XSLP_CB_ITERVAR
`function cb:integer`	XSLP_CB_CASCADESTART
`function cb(var:mpvar):integer`	XSLP_CB_CASCADEVAR
`function cb:integer`	XSLP_CB_CASCADEEND
`function cb:integer`	XSLP_CB_START
`function cb:integer`	XSLP_CB_END
`function cb:integer`	XSLP_CB_PRENODE
`function cb:integer`	XSLP_CB_INTSOL
`function cb:integer`	XSLP_CB_OPTNODE
`function cb:integer`	XSLP_CB_CONSTRUCT
`function cb(description:string):integer`	XSLP_CB_MSJOBSTART
`function cb(description:string):integer`	XSLP_CB_MSJOBEND
`function cb(description:string):integer`	XSLP_CB_MSWINNER

Module

mmxnlp

setcomplementary

Purpose

Set two variables as being complementary.

Synopsis

```
procedure setcomplementary(var1:mpvar, var2:mpvar)
```

Arguments

`var1` The first variable of the variable pair to be set as complementing

`var2` The first variable of the variable pair to be set as complementing

Further information

A complementing variable pair implements the constraint that is equivalent with the product of the variables being zero. However, the solvers may be able to treat such constraints in a special, more efficient ways, which may make a difference if the complementarity constraints are the problematic part of the model. Note that Knitro only allows non-overlapping complementary variables, and in the presence of overlaps Xpress will default to use SLP. Complementary variables must have a lower bound of zero.

Related topics

`setinitval`, `setinitsb`, `setdetrow`, `setenforcedctr`.

Module

mmxnlp

setdefvar

Purpose

Set a variable to be purely defined by a constriant.

Synopsis

```
procedure setdefvar(var:mpvar, row:linctr)
procedure setdefvar(var:mpvar, row:nlctr)
```

Arguments

`var` The variable being made defined by the constraint.

`row` The constraint that defines the value of the variable.

Further information

The variable will be made free (its bounds removed) since it's value is now defined by the contraint's value. Ideally, the variable should appear linearly in the constriant, in which case unless a circular reference is detected it will used for eliminate on in the nonlinear presolver. The purpose of the construct is to break large nonliner expressions.

Related topics

`setdetrow`

Module

mmxnlp

setdetrow

Purpose

Set the determining row for a variable.

Synopsis

```
procedure setdetrow(var:mpvar, row:linctr)
procedure setdetrow(var:mpvar, row:nlctr)
procedure setdetrow(row:linctr, var:mpvar)
procedure setdetrow(row:nlctr, var:mpvar)
```

Arguments

`var` The variable for which the determining row is provided

`row` The row that determines the value of the variable.

Further information

A row which is determining for a variable defines the value of that variable. This means that the variable is a derived value which is calculated in another part of the model. Some solvers will use such designations to refine their search, and in particular in sequential linear programming, a process called *cascading* makes use of determining rows. Please refer to the *Xpress NonLinear Reference Manual* (chapter 'Cascading') for more information.

Related topics

`setinitval`, `setinitsb`, `setenforcedctr`.

Module

mmxnlp

setenforcedctr

Purpose

Mark a nonlinear constraint as enforced.

Synopsis

```
procedure setenforcedctr(row:nlctr)
```

Argument

`row` The constraint to be set enforced

Further information

A constraint which is marked as enforced will not have penalty error vectors introduced upon it by solvers which use such techniques. This may be useful for constraints which are hard to satisfy.

Related topics

`setinitval`, `setinitsb`, `setdetrow`.

Module

mmxnlp

setinitsb

Purpose

Provide the initial step bound for a variable.

Synopsis

```
procedure setinitsb(var:mpvar, value:real)
```

Arguments

`var` The variable for which the step bound is provided

`value` Value to be used as initial value

Further information

The initial step bounds define in turn the size of the initial trust region. Please refer to the *Xpress NonLinear Reference Manual* for more information.

Related topics

`setinitval`, `setdetrow`, `setenforcedctr`.

Module

mmxnlp

settol

Purpose

Define a particular tolerance in a tolerance set.

Synopsis

```
procedure settol(tset:tolset, which:integer, value:real)
```

Arguments

`tset` The tolerance set to be modified

`which` The tolerance which is being defined

`value` The new value of the tolerance

Further information

The tolerances which may be defined by this method are:

`XNLP_TOL_TC` The absolute closure tolerance

`XNLP_TOL_TA` The absolute delta tolerance

`XNLP_TOL_RA` The relative delta tolerance

`XNLP_TOL_TM` The absolute matrix tolerance

`XNLP_TOL_RM` The relative matrix tolerance

`XNLP_TOL_TI` The absolute impact tolerance

`XNLP_TOL_RI` The relative impact tolerance

`XNLP_TOL_TS` The relative slack impact tolerance

`XNLP_TOL_RS` The absolute slack impact tolerance

Please refer to the *Xpress NonLinear Reference Manual*, and particularly the chapter 'Convergence criteria', for more information on these tolerances.

Related topics

`setinitval`, `setinitsb`, `setdetrow`, `setenforcedctr`.

Module

mmxnlp

settolset

Purpose

Assigns a tolerance set to a variable, or list of variables.

Synopsis

```
procedure settolset(var:mpvar, tset:tolset)
procedure settolset(vars:list of mpvar, tset:tolset)
```

Arguments

`var`	Variable to which the tolerance set is to be assigned
`vars`	List pf variable to which the tolerance set is to be assigned
`tset`	The tolerance set to be assigned to the variable(s)

Related topics

`settol`.

Module

mmxnlp

userfuncinfo

Purpose

Print the inferred prototype of the given user function.

Synopsis

```
procedure userfuncinfo(UF:userfunc)
```

Argument

`UF` The user function to be analyzed

Further information

The type and signature of a user function are inferred from its use in calls to the `F` function in the current model. This procedure has no effect unless XNLP_VERBOSE is set. It is provided solely for the purpose of model analysis and debugging.

Related topics

`validate`, `printmodelmemory`, `printmodelscaling`.

Module

mmxnlp

userfuncMosel

Purpose

Create a user function from a Mosel function.

Synopsis

```
function userfuncMosel(fctname:string):userfunc
function userfuncMosel(fctname:string, options:integer):userfunc
```

Arguments

`fctname` Name of the Mosel function to wrap

`options` Options describing special properties of the user function

Return value

A `userfunc` object that can be used in the `F` functions to be embedded in formulas.

Further information

User functions allow extremely complex, recursive or non-algebraic expressions to be included in nonlinear formulae. As such they may make use of simulators or other black box evaluators. The actual parameters to a user function depend upon the way it is bound to the model by the `F` function. Please see the chapter on user functions for more details.

There is support for user functions providing their own derivatives. Currently, user functions taking an array of `nlctr` and returning a single function values may provide their own derivatives. To mark a function as returning it's own derivatives, use option `XNLP_DERIVATIVES` or `XNLP_DELTAS` to indicate that the solver should suggest perturbation values for the variables.

Related topics

`F`.

Module

mmxnlp

validate

Purpose

Print a summary of the feasibility of the current solution.

Synopsis

```
procedure validate
```

Further information

This procedure has no effect unless XNLP_VERBOSE is set. It is provided solely for the purpose of model analysis and debugging.

Related topics

`printmodelmemory`, `printmodelscaling`, `userfuncinfo`.

Module

mmxnlp

20.5 Error codes issued by mmxnlp

1 ***Out of memory***

The system has run out of memory.

2 ***No purchase authorization found***

No license found

3 ***Failed to initialize XSLP***

Cannot initialize the XPRS library. There may be a licensing problem

4 ***Unsupported XSLP version***

The version of the 'XSLP' library is incompatible with the current module. The Xpress installation may be corrupt

5 ***Failed to create the XSLP problem object***

Cannot create the XSLP optimizer problem. There may be a licensing problem

6 ***Unexpected mmxnlp user function signature***

The provided user functions' signature does not match any expected format.

7 ***Unexpected external token in mmxnlp***

An unexpected external token found by the 'mmxnlp' module. Please contact support.

8 ***Unsupported operator***

The provided operator is not supported by 'mmxnlp'.

9 ***Failed to load problem***

Could not load the problem into the optimizer.

10 ***Variable bound conflict in problem***

Inconsistent bounds provided for the variable.

11 ***Failed to load user function***

The user function could not be loaded into the optimizer.

12 ***Error evaluating user function***

Error while evaluation the user function. The user function likely to have returned an error code.

13 ***Unknown tolerance set***

The provided tolerance set is invalid.

14 ***List tpype error in user function***

The list provided to the user function is not valid for the function.

15 ***Failed to create save file***

The savefile could not be created.

16 ***Error in optimization***

An error has occured during optimization.

17 ***Cannot reoptimize using a different objective (use named linctr or nlctr)***

The objective has unexpectedly changed

18 ***Internal error in mmxnlp. Please contact FICO support***

An internal error has occurred. Please contact support.

20 ***Incompatible array definitions for user function arguments***

The user function received incompatible arrays.

21 ***Non-Mosel user functions only take 'list of nlctr' type arguments***

User functions that are not implemented as a Mosel function can only take list of 'nlctr' arguments (no arrays).

22 ***Invalid argument list for external function***

The provided argument list is not valid for the external function.

23 ***Provided user function is not returning a single real***

The provided user function was expected to return a single real value.

24 ***Provided user function is not returning an array indexed by integers***

The provided user function was expected to return an array of reals indexed by integers.

25 ***User function must be loaded before it's properties can be retrieved***

The user function must be loaded before it's properties are interrogated. Please use 'loadprob' to load the model including the user function.

26 ***Unexpected variable found. Please reload problem first using 'loadprob'***

An unexpected variable has been used. Please reload the problem to load the variable.

27 ***Operation only supported on the main problem (e.g. not inside multi-start callbacks)***

This operation is only supported in the main problem. It cannot be used on worker problems.

28 ***Math error while evaluating expression***

A mathematical error has occurred while evaluating the expression.

CHAPTER 21

mmxprs

The *mmxprs* module provides access to FICO® Xpress Optimizer from within a Mosel model and as such it requires the Xpress Optimizer library (XPRS) to be installed on the system. To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'mmxprs'
```

A large number of optimization-related routines are provided, ranging from those for finding a solution to the problem, to those for setting callbacks and cut manager functions. Whilst a description of their usage is provided in this manual, further details relating to the usage of these may be found by consulting the *Xpress Optimizer Reference Manual*.

21.1 New functionality for the Mosel language

21.1.1 The problem type `mpproblem.xprs`

This module exposes its functionality through an extension to the `mpproblem` problem type. As a consequence, all routines presented here are executed in the context of the current problem. In particular, the setting of a control parameter is applied only to the current problem and each problem has its own set of settings and solution information. However, when a new problem instance is created, the value of the control parameters `XPRS_colorder`, `XPRS_enummaxsol`, `XPRS_enumduplpol`, `XPRS_loadnames` and `XPRS_verbose` are initialised with the settings of the main problem.

21.1.2 The type `basis`

The module *mmxprs* defines the type `basis` to represent solution basis in the Mosel Language. This new type is used to store a basis computed by the optimizer during its solution process (`savebasis`). A basis can then be loaded again into the optimiser with `loadbasis`, inspected (by getting the basis status of each variable/constraint it includes with `getbstat`) or modified (by changing this basis status using `setbstat`). The type `basis` supports assignment and test of equality. This comparison only checks whether two basis contain the same information, it does not indicate whether the basis are equivalent.

21.1.3 The type `mpsol`

The type `mpsol` characterises a *solution* of an MP problem by associating a value to each decision variable (type `mpvar`) of the problem. Initialising such an object can be achieved by saving the current solution found by the optimiser (`savesol` or `savemipsol`) or by building it one variable at a time (`setsol`). Various routines requiring solution information support the solution object. For instance `getsol` may be used to evaluate an expression on a specific solution; `loadmipsol` and `addmipsol` accept this object as input. A solution might be saved into a file using `writesol` and the resulting file

can be loaded into the optimiser with readsol. The type mpsol supports assignment and test of equality.

21.1.4 The type boolvar

An entity of type boolvar is a *pseudo boolean decision variable*. This type supports operators and, or and not for building logical expressions and can be combined with ordinary Boolean variables. A *logical constraint* is specified either by associating a pseudo boolean variable to a logical expression using the following syntax:

```
boolvar = logical_expression
```

or by forcing the truth value (*i.e.* true or false) of an expression as follows:

```
logical_expression = boolean
```

When a logical expression is used on its own as a statement it is implicitly turned into a constraint (forced to true) and added to the constraint store.

Each boolvar is represented in the MIP problem by two binary variables (mpvar): one for the value itself and another one for its negation. These decision variables can be accessed from the model using the function getvar such that they can be used in linear constraints. The solution value of a boolvar is of type boolean and can be obtained using getsol.

21.1.5 The type logctr

The type logctr represents either a *logical expression* over linear constraints, a logical expression/constraint over pseudo boolean decision variables (boolvar) or an *indicator constraint* (see indicator). Logical expressions can be built using standard operators (and, or, not) or with the help of the dedicated functions implies and xor (for logical expressions over linear constraints only). These logical constructs are handled like linear constraints: they are associated to the current problem, can be (re)defined via assignments and hidden using sethidden. Note however that logical constructs are not shown by exportprob although the *mmxprs* routine writeprob will report them.

If logical expressions over linear constraints are employed in a model, the loading of the problem into the optimizer requires the use of the helper package "advmod":

```
uses 'advmod'
```

This package is not necessary when a model uses only logical constraints over pseudo boolean variables or indicator constraints directly.

21.2 Control parameters

This module extends the getparam function and the setparam procedure in order to access all the control and problem parameters of Optimizer (for example the problem attribute LPSTATUS is mapped to the *mmxprs* control parameter XPRS_lpstatus). In addition to these, the following control parameters are also defined:

XPRS_colorder	Reorder matrix columns before loading the problem.	p. 722
XPRS_enumduplpol	Handling of duplicate solutions during an enumeration.	p. 723
XPRS_enummaxsol	Maximum number of solutions to be saved during an enumeration.	p. 722

Example:

```
setparam("XPRS_verbose", true)      ! Turn on message printing
pstat:= getparam("XPRS_lpstatus")   ! Get the problem LP optimization status
writeln("Best bound=", getparam("XPRS_bestbound")) ! Display the best bound value
```

XPRS_colorder

Description Reorder matrix columns before loading the problem.

Type Integer, read/write

Values

0	Mosel implicit ordering
1, 3	Reorder using a numeric criterion
2	Alphabetical order of the variable names (this requires the names to be available)
4	Random ordering

Default value 0

Module mmxprs

XPRS_enumsols

Description Number of solutions found during the last enumeration. The value of this parameter is –1 is no enumeration has been run.

Type Integer, read only

Affects routines maximize, minimize.

Module mmxprs

XPRS_enummaxsol

Description Maximum number of solutions to be saved during an enumeration.

Type Integer, read/write

Default value 10

Affects routines maximize, minimize.

Module mmxprs

XPRS_enumduplpol

Description Handling of duplicate solutions during an enumeration. Refer to the MSP control parameter `MSP_DUPLICATESOLUTIONSPOLICY` for further information.

Type Integer, read/write

Values

`0`	All solutions kept
`1`	Continuous
`2`	Discrete and continuous separate
`3`	Discrete only

Default value 3

Affects routines `maximize`, `minimize`.

Module mmxprs

XPRS_fullversion

Description The full Optimizer version number in the form *major.minor.build* (*e.g.*`"20.01.03"`).

Type String, read only

Module mmxprs

XPRS_loadnames

Description Enable/disable loading of MPS names into the Optimizer.

Type Boolean, read/write

Values

`true`	Enable loading of names
`false`	Disable loading of names

Default value `false`

Affects routines `loadprob`, `maximize`, `minimize`.

Module mmxprs

XPRS_maxupdc

Description By default any call to `setcoeff` is recorded only in the Mosel representation of the problem and requires a full reload of the matrix when the problem is solved. When this parameter is non-zero these changes to the problem are also reported to the matrix loaded into the optimiser such that the following solving operation does not require a regeneration of the matrix (as long as the problem has not been updated by another operation). The value of the parameter is the number of changes to be sent to the optimiser at once, pending operations are executed before solving the problem or exporting it via `writeprob`. They are also run whenever the parameter is updated.

Type Integer, read/write

Values Any non-negative integer

Default value 0

Affects routines setcoeff, setmatcoeff, maximize, minimize.

Module mmxprs

XPRS_problem

Description The Optimizer problem (XPRSprob), MIP solution pool (XPRSmipsolpool) and MIP solution enumerator (XPRSmipsolenum) pointers separated by spaces. This attribute is only required in applications using both Mosel and the Optimizer at the C level.

Type String, read only

Module mmxprs

XPRS_probname

Description Read/set the problem name used by the Optimizer to build its working files (this name may contain a full path). If set to the empty string (default value), a unique name with a path to the temporary directory of the operating system is generated.

Type String, read/write

Module mmxprs

XPRS_verbose

Description Enable/disable message printing by the Optimizer.

Type Boolean, read/write

Values
- true Enable message printing
- false Disable message printing

Default value false

Module mmxprs

21.3 Procedures and functions

This section lists in alphabetical order the functions and procedures that are provided by the *mmxprs* module.

addmipsol

Purpose

Add a MIP solution to the optimizer.

Synopsis

```
procedure addmipsol(solid:string,s:array(set of mpvar) of real)
procedure addmipsol(solid:string,ms:mpsol)
```

Arguments

`solid` Identifier to be assigned to the solution

`s` An array containing the solution

`ms` A solution object

Further information

1. This function is used to provide the expectations of the modeler on the values of selected variables in possible MIP solutions. It is different to `loadmipsol` in that it is not necessary to provide full, feasible MIP solutions. The values provided will be used by the Optimizer to attempt to generate full MIP solutions. The `addmipsol` function can therefore be used to trial the feasibility of certain variable value assignments without the need to fix them in the problem formulation itself.

2. The solution value array `s` is created by assigning values to discrete variables in the problem, such as `s(x):= 1` (where `x` is a decision variable of type `mpvar`). It is also possible to use a solution that has previously been saved using the procedure `savemipsol`.

3. If the provided solution is found to be infeasible, a limited local search heuristic will be run in an attempt to find a close feasible integer solution.

4. The current problem definition must be loaded into the Optimizer for `addmipsol` to have any effect. If this has not recently been done, *e.g.*, by calling `maximize` or `minimize`, the problem must be explicitly loaded using `loadprob`.

5. The function returns immediately after passing the solution to the Optimizer. The solution is placed in a pool until the optimizer is able to analyze the solution during a MIP solve.

6. The `SOLNOTIFY` callback function can be used to discover the outcome of a loaded solution, based on the identifier assigned to the solution (see `setcallback`).

Related topics

`savemipsol`, `loadmipsol`.

Module

mmxprs

basisstability

Purpose

Get basis stability information.

Synopsis

```
function basisstability(type:integer,norm:integer,scaled:boolean):real
```

Arguments

`type` Which information to return. Possible values:

- `0` Condition number of the basis
- `1` Stability measure for the solution relative to the current basis
- `2` Stability measure for the duals relative to the current basis
- `3` Stability measure for the right hand side relative to the current basis
- `4` Stability measure for the basic part of the objective relative to the current basis

`norm` Which norm to use. Possible values:

- `0` Use the infinity norm
- `1` Use the 1 norm
- `2` Use the Euclidian norm for vectors, and the Frobenius norm for matrices

`scaled` If `false`, work on the unscaled matrix

Return value

Basis stability information.

Module

mmxprs

calcsolinfo

Purpose

Calculates a property of an `mpsol` solution.

Synopsis

```
function calcsolinfo(solution:mpsol, option:integer):mpsol
```

Arguments

`solution`	The solution to be checked	
`option`	Which information to return. Possible values:	
	`XPRS_SOLINFO_ABSPRIMALINFEAS`	Calculate the maximum absolute primal infeasibility
	`XPRS_SOLINFO_RELPRIMALINFEAS`	Calculate the maximum relative primal infeasibility
	`XPRS_SOLINFO_MAXMIPFRACTIONAL`	Calculate the maximum fractionality of the integer variables

Related topics

`refinemipsol`.

Module

mmxprs

clearmipdir

Purpose

Delete all defined MIP directives.

Synopsis

```
procedure clearmipdir
```

Further information

This procedure clears the list of directives defined so far.

Related topics

`setmipdir`.

Module

mmxprs

clearmodcut

Purpose

Delete all defined model cuts.

Synopsis

```
procedure clearmodcut
```

Further information

This procedure clears the list of model cuts defined so far.

Related topics

`setmodcut`.

Module

mmxprs

command

Purpose

Execute an Optimizer command or enter interactive mode of the Optimizer.

Synopsis

```
procedure command(cmd:string)
procedure command
```

Argument

`cmd` Command or sequence of commands separated by `"\n"` character

Example

Solve a MIP problem and then enter interactive mode:

```
command("minim\nglobal")
command
```

Further information

1. When used without parameter, this procedure enters an interactive mode of the Optimizer similar to the console mode: model execution is suspended and Optimizer commands can be typed directly. Model execution resumes after command `quit` has been typed or the input stream has reached an end of file. Using the alternate form of the procedure with an argument, one can send a command (or sequence of commands) to the Optimizer: this may be useful to execute commands for which there is no *mmxprs* interface.
   During the execution of this procedure, callbacks set up in the model are effective and the problem solution status of *mmxprs* is updated upon termination. Note that, commands altering the problem must be avoided (like `readprob`, change of name of the problem, *etc.*) in order to preserve consistency between Mosel and Optimizer representations of the problem.

2. When Mosel is running in restricted mode (see Section 1.3.4), the restriction `NoExec` disables this routine.

Module

mmxprs

copysoltoinit

Purpose

Copy solution values to initial values of an NL problem.

Synopsis

```
procedure copysoltoinit(ms:mpsol)
```

Argument

`ms` A solution object

Further information

1. This procedure copies the solution values of decision variables from the provided solution `ms` to their initial values for the next run. Doing so it overrides any previously set initial values for the involved variables. However, the settings for decision variables that are not included in the solution `ms` remain unchanged.

2. This operation can only be performed on a non-linear problem described using the module `mmnl`.

Related topics

`copysoltoinit`, `clearinitvals`, `setinitval`.

Module

mmxprs

crossoverlpsol

Purpose

Crosses over a previously loaded LP solution to a basic solution.

Synopsis

```
function crossoverlpsol:boolean
```

Return value

Operation status:

`FALSE` No valid starting solution provided prior to call using `loadlpsol`

`TRUE` Crossover called

Further information

This procedure calls the crossover procedure for an already loaded LP solution followed by the usual simplex solve afterwards. The solution, solution status and all attributes are set up to match the solve and are available the usual way.

Related topics

`loadlpsol`.

Module

mmxprs

defdelayedrows

Purpose

Define the set of constraints to be treated as delayed rows.

Synopsis

```
procedure defdelayedrows(cset:set of linctr)
```

Argument

`cset` Set of constraints to load or `{}` to reset a previous setting

Further information

This procedure stores a reference to the provided set that is used when the problem is loaded into the optimizer. This set can be modified after the call to this procedure: the optimizer will use the current content of the set at the time of loading the problem.

Module

mmxprs

defsecurevecs

Purpose

Define the sets of variables and constraints that must not be removed by presolve.

Synopsis

```
procedure defsecurevecs(vset:set of mpvar,cset:set of linctr)
```

Arguments

`vset` Set of decision variables to preserve or `{}` to reset a previous setting

`cset` Set of constraints to preserve or `{}` to reset a previous setting

Further information

This procedure stores references to the provided sets that are used when the problem is loaded into the optimizer. These sets can be modified after the call to this procedure: the optimizer will use the current content of the sets at the time of loading the problem.

Module

mmxprs

estimatemarginals

Purpose

Estimate better marginal values for variables and constraints for degenerate problems.

Synopsis

```
procedure estimatemarginals(sbvars:array(vars: set of mpvar) of real)
procedure estimatemarginals(dualslb:array(constriants: set of linctr) of
      real, dualsub:array(constriants: set of linctr) of real)
procedure estimatemarginals(sbvars:array(vars: set of mpvar) of real,
      efforlimit:integer, delta:real)
procedure estimatemarginals(dualslb:array(constriants: set of linctr) of
      real, dualsub:array(constriants: set of linctr) of real,
      effortlimit:integer)
```

Arguments

`sbvars`	An array of reals that will be populated with the approximations for the marginal values. The approximation is carried out for the variables included in the `variables` set.
`dualslb`	An array of reals that will be populated with the approximations for the lower bounds for the row marginal values. The approximation is carried out for the constraints in the `constraints` set.
`dualsub`	An array of reals that will be populated with the approximations for the upper bounds for the row marginal values. The approximation is carried out for the constraints in the `constraints` set.
`efforlimit`	Effort limit spent to approximate the effect of the move of a variable, expressed as an upper limit of simplex iterations per variable.
`delta`	The size of the perturbation applied to force a movement in the variable.

Further information

1. This procedure can be used to estimate the marginal values of variables in degenerate problems. In degenerate problems, the reduced costs and row duals do not always provide a good representation of the effect on the objective when forcing a move in a variable. Also, in degenerate problems, the reduced costs and row duals may depend on the final basis found, and multiple correct alternatives might exists. This function attempts to identify better marginal values by simulating a move in the variables.
2. Prior to calling estimatemarginals, the current LP problem must have been solved to optimality and an optimal basis must be available.
3. It is important to note that the procedure provides an estimate only.
4. This procedure relies on the `XPRSstrongbranch` and `XPRSestimaterowdualranges` functions, refer to the *Xpress Optimizer Reference Manual* for more information.

Module

mmxprs

fixglobal

Purpose

Fix values of discrete entitites according to the current solution.

Synopsis

```
procedure fixglobal
procedure fixglobal(options:integer)
```

Argument

`options` Options sent to the library routine `XPRSfixglobals`

Example

Solve the MIP problem, reload the problem after solving, fix discrete entities to their solution values, and finally solve the LP for the continous variables in order to be able to use `getrange`.

```
minimize(obj)
fixglobal
minimize(XPRS_LIN, obj)
writeln(getrange(XPRS_UPACT,x))
```

Further information

1. This procedure fixes the non-continuous variables to their value of the current solution. A call to this function is required when performing sensitivity analysis on MIP problems using `getrange`.
2. The first form of the procedure corresponds to `fixglobal(0)`.

Related topics

`getrange`.

Module

mmxprs

getbstat

Purpose

Get the status of a variable or constraint in a basis.

Synopsis

```
function getbstat(b:basis,v:mpvar):integer
function getbstat(b:basis,c:linctr):integer
```

Arguments

`b` A basis

`v` A decision variable

`c` A linear constraint

Return value

Basis status. For a variable:

`-1` Variable is not in the basis

`0` Variable is non-basic at lower bound, or superbasic at zero if the variable has no lower bound

`1` Variable is basic

`2` Variable is non-basic at upper bound

`3` Variable is super-basic

For a constraint:

`-1` Constraint is not in the basis

`0` Slack, surplus or artificial is non-basic at lower bound

`1` Slack, surplus or artificial is basic

`2` Slack or surplus is non-basic at upper bound

`3` Slack or surplus is super-basic

Related topics

`savebasis`, `setbstat`, `resetbasis`.

Module

mmxprs

getcomputeallowed

Purpose

Query in what circumstances the current Mosel instance can send optimizations to the Insight Compute Interface.

Synopsis

```
function getcomputeallowed:integer
```

Return value

Value controlling in what circumstances solves may be sent to Insight Compute Interface. Will be one of the following constants:

`XPRS_ALLOW_COMPUTE_ALWAYS`	Always allow solves to be sent to Compute.
`XPRS_ALLOW_COMPUTE_NEVER`	Never allow solves to be sent to Compute.
`XPRS_ALLOW_COMPUTE_DEFAULT`	Allow solves to be sent to Compute only from non-OEM applications.

Related topics

`setcomputeallowed`.

Module

mmxprs

getdualray

Purpose

Get a dual ray for an infeasible problem.

Synopsis

```
function getdualray(ray:array(set of linctr) of real):boolean
```

Argument

`ray` An array of reals over all constraints in the problem (as loaded) in which the dual ray is returned.

Return value

This procedure returns the dual ray found for the problem if the problem is found to be dual unbounded (thus primal infeasible) and one is available.

Further information

1. The return value of the function is true if a dual ray is available, and false otherwise.
2. The dimension and base set of the `ray` argument will be set up by the function.

Example

```
declarations
 all_constraints : set of linctr
 dual_ray : array(all_constraints) of real
end-declarations
if getprobstat <> XPRS_INF then
  writeln("Problem not infeasible.")
else
  HasRay := getdualray(dual_ray)
  if HasRay then
   writeln("Dual ray:")
   forall (c in all_constraints)
     writeln(getname(c), " ", dual_ray(c))
  else
   writeln("No dual ray was found")
  end-if
end-if
```

Related topics

getprimalray

Module

mmxprs

getiis

Purpose

Compute then get the Irreductible Infeasible Sets (IIS).

Synopsis

```
procedure getiis(vset:set of mpvar,cset:set of linctr)
procedure getiis(numiis:integer,vset:set of mpvar,cset:set of linctr)
procedure getiis(numiis:integer,ctrtype:array(linctr) of integer)
procedure getiis(numiis:integer,duals:array(linctr) of real)
procedure getiis(numiis:integer,isolrow:array(linctr) of boolean)
procedure getiis(numiis:integer,bndtype:array(mpvar) of integer)
procedure getiis(numiis:integer,rdcs:array(mpvar) of real)
procedure getiis(numiis:integer,isolcol:array(mpvar) of boolean)
```

Arguments

`vset`	Set to return the decision variables of the IIS or `{}` if not required
`cset`	Set to return the constraints of the IIS or `{}` if not required
`numiis`	Ordinal number of the IIS
`ctrtype`	Array to return the sense or type of rows in the IIS (`XPRS_IIS_LEQ`, `XPRS_IIS_GEQ`, `XPRS_IIS_EQ` , `XPRS_IIS_SOS1`, `XPRS_IIS_SOS2` or `XPRS_IIS_INDIC`)
`duals`	Array to return the dual multipliers associated with the rows of the IIS
`isolrow`	Array to return the isolation status of the the rows of the IIS
`bndtype`	Array to return the encoded sense and type of bounds in the IIS
`rdcs`	Array to return the dual multipliers associated with the bounds of the IIS
`isolcol`	Array to return the isolation status of the the bounds of the IIS

Further information

1. This procedure computes the IIS and stores the result in the provided parameters. The first form of the routine (`numiis` not specified) computes all IIS and returns the last set found.
2. The `bndtype` values have to be decoded using `getiissense` and `getiistype`. The first routine may return `XPRS_IIS_LEQ` (upper bound), `XPRS_IIS_GEQ` (lower bound), `XPRS_IIS_RNG` (lower and upper bound) or `XPRS_IIS_EQ` (fixed bound). The second one may give `XPRS_IIS_BIN` (binary), `XPRS_IIS_INT` (integer), `XPRS_IIS_PINT` (partial integer), `XPRS_IIS_SEC` (semi continuous) or `XPRS_IIS_SINT` (semi continuous integer).
3. The sets passed to this procedure are reset before being used.

Related topics

`resetiis`, `isiisvalid`, `getinfeas`.

Module

mmxprs

getiissense

Purpose

Decode the sense part of an IIS bound type information.

Synopsis

```
function getiissense(i:bndtype):integer
```

Argument

`bndtype` A bound type as returned by `getiis`

Return value

Sense part of an IIS bound type.

Related topics

`getiis`, `getiistype`.

Module

mmxprs

getiistype

Purpose

Decode the type part of an IIS bound type information.

Synopsis

```
function getiistype(i:bndtype):integer
```

Argument

`bndtype` A bound type as returned by `getiis`

Return value

Type part of an IIS bound type.

Related topics

`getiis`, `getiissense`.

Module

mmxprs

getinfcause

Purpose

Returns the variable or constraint causing infeasibility.

Synopsis

```
procedure getinfcause(vars:set of mpvar,ctrs:set of linctr)
```

Arguments

`vars` Set to return the infeasible variable or `{}` if not required

`ctrs` Set to return infeasible constraint or `{}` if not required

Further information

1. This function can be used to get the variable or constraint responsible for an infeasibility detected either during matrix generation (invalid bound) or when presolving the problem.
2. The sets passed to this procedure are reset before being used.

Related topics

`getinfeas`.

Module

mmxprs

getinfeas

Purpose

Returns sets of infeasible primal and dual variables.

Synopsis

```
procedure getinfeas(mx:set of mpvar,mslack:set of linctr,mdual:set of
      linctr,mdj:set of mpvar)
```

Arguments

`mx`	Set to return the infeasible variables or `{}` if not required
`mslack`	Set to return infeasible constraints or `{}` if not required
`mdual`	Set to return dual infeasible constraints or `{}` if not required
`mdj`	Set to return the dual infeasible variables or `{}` if not required

Related topics

`getiis`.

Module

mmxprs

getlb

Purpose

Get the lower bound of a variable.

Synopsis

```
function getlb(x:mpvar):real
```

Argument

`x` A decision variable

Return value

Lower bound of the variable.

Further information

This function returns the lower bound of a variable that is currently held by the Optimizer. The bound value may be changed directly in the Optimizer using `setlb`. Changes to the variable in Mosel are not taken into account by this function unless the problem has been reloaded since (procedure `loadprob`).

Related topics

`getub`, `setlb`, `setub`.

Module

mmxprs

getloadedlinctrs

Purpose

Get the linear constraints loaded into the optimiser.

Synopsis

```
procedure getloadedlinctrs(sc:set of linctr)
```

Argument

`sc` A set of linear constraints

Further information

The result of the operation is added to the current content of the provided set (*i.e.* the set is not cleared).

Related topics

`getloadedmpvars`

Module

mmxprs

getloadedmpvars

Purpose

Get the decision variables loaded into the optimiser.

Synopsis

```
procedure getloadedmpvars(sv:set of mpvar)
```

Argument

`sv` A set of decision variables

Further information

The result of the operation is added to the current content of the provided set (*i.e.* the set is not cleared).

Related topics

`getloadedlinctrs`

Module

mmxprs

getmatcoeff

Purpose

Get the coefficient of a variable or the constant term of a constraint directly from the Optimizer.

Synopsis

```
function getmatcoeff(c:linctr, x:mpvar):real
function getmatcoeff(c:linctr):real
```

Arguments

`c` A linear constraint

`x` A decision variable

Return value

The coefficient of the varible or the constant term.

Further information

1. This function behaves like `getcoeff` except that it gets the information from the matrix loaded into the Optimizer.
2. The routine will fail if no problem has been loaded into the Optimizer or if the constraint or the variable is not part of the current matrix.

Related topics

`getcoeff`, `setmatcoeff`, `maximize`, `minimize`.

getname

Purpose

Get the name of a decision variable or constraint of the problem.

Synopsis

```
function getname(x:mpvar):string
function getname(c:linctr):string
function getname(nl:nlctr):string
```

Arguments

`x`	A decision variable used in the problem
`c`	A constraint (or SOS) of the problem
`nl`	A non linear constraint of the problem

Return value

Name of the given object.

Further information

1. This function returns the name of a decision variable or constraint of the problem that would be used for matrix exportation. The parameter of this function must be part of the problem — for instance a hidden constraint cannot be assigned a name.
2. This function requires that the matrix has been generated (*e.g.* by a call to `exportprob` or `loadprob`). When used with a non linear constraint it is further required for the problem to be loaded into the optimiser and the parameter `XPRS_loadnames` must be `true`.

Module

mmxprs

getprimalray

Purpose

Get a primal ray for an unbounded problem.

Synopsis

```
function getprimalray(ray:array(set of mpvar) of real):boolean
```

Argument

`ray` An array of reals over all constraints in the problem (as loaded) in which the primal ray is returned.

Return value

This procedure returns the primal ray found for the problem if the problem is found to be primal unbounded (thus dual infeasible) and one is available.

Further information

1. The return value of the function is true if a primal ray is available, and false otherwise.
2. The dimension and base set of the `ray` argument will be set up by the function.

Example

```
declarations
 all_variables : set of mpvar
 primal_ray : array(all_variables) of real
end-declarations
if getprobstat <> XPRS_UNB then
  writeln("Problem is not unbounded.")
else
  HasRay := getprimalray(primal_ray)
  if HasRay then
   writeln("Primal ray:")
   forall (c in all_variables)
     writeln(getname(c), " ", primalray(c))
  else
   writeln("No primal ray was found")
  end-if
end-if
```

Related topics

getdualray

Module

mmxprs

getprobstat

Purpose

Get the Optimizer problem status.

Synopsis

```
function getprobstat:integer
```

Return value

Status of the problem currently held in the Optimizer:

`XPRS_OPT`	Solved to optimality
`XPRS_UNF`	Unfinished
`XPRS_INF`	Infeasible
`XPRS_UNB`	Unbounded
`XPRS_OTH`	Unsolved or objective worse than cutoff

Example

The following procedure displays the current problem status:

```
procedure print_status
 declarations
  status: string
 end-declarations

 case getprobstat of
  XPRS_OPT: status:="Optimum found"
  XPRS_UNF: status:="Unfinished"
  XPRS_INF: status:="Infeasible"
  XPRS_UNB: status:="Unbounded"
  XPRS_OTH: status:="Failed"
  else status:="???"
 end-case

 writeln("Problem status: ", status)
end-procedure
```

Further information

More detailed information than what is provided by this function can be obtained with function `getparam`, retrieving the problem attributes `XPRS_presolvestate`, `XPRS_lpstatus`, and `XPRS_mipstatus` (see the *Xpress Optimizer Reference Manual*).

Related topics

`getparam`.

Module

mmxprs

getrange

Purpose

Get a range value for a variable or constraint.

Synopsis

```
function getrange(w:integer, x:mpvar):real
function getrange(w:integer, c:linctr):real
```

Arguments

`w` Which information to return. Possible values for a variable:

`XPRS_UPACT`	For a variable which is at one of its bounds, the largest value which that bound can take while the current basis remains optimal
`XPRS_LOACT`	For a variable which is at one of its bounds, the smallest value which that bound can take while the current basis remains optimal
`XPRS_UUP`	The change in objective value per unit increase in the variable activity, assuming the the current basis remains optimal
`XPRS_UDN`	The change in objective value per unit decrease in the variable activity, assuming the the current basis remains optimal
`XPRS_UCOST`	The largest value which this variable's objective coefficient can take while the current basis remains optimal
`XPRS_LCOST`	The smallest value which this variable's objective coefficient can take while the current basis remains optimal

Possible values for a constraint:

`XPRS_UPACT`	The largest value which the constraint RHS can take while the current basis remains optimal
`XPRS_LOACT`	The smallest value which the constraint RHS can take while the current basis remains optimal
`XPRS_UUP`	The change in objective value per unit increase in the constraint RHS, assuming the the current basis remains optimal
`XPRS_UDN`	The change in objective value per unit decrease in the constraint RHS, assuming the the current basis remains optimal

`x` A variable of the problem

`c` A constraint of the problem

Return value

Range information depending on the value of `w`.

Further information

This function returns ranging information to be used for sensitivity analysis after the problem has been optimized. On MIP problems, discrete entities have to be "fixed" using the procedure `fixglobal` before this function can be called.

Related topics

`fixglobal`.

Module

mmxprs

getscale

Purpose

Retrieves scaling information about the currently loaded problem.

Synopsis

```
procedure getscale(options:integer, scaling:array(set of integer) of
      integer)
```

Arguments

`options` Bitmap, matrix data to include: +1 for coefficients, +2 for RHS and +4 for objective

`scaling` Array where scaling information is returned.

Further information

The indices of the returned array indicate buckets of powers of 10. For example, if scaling(3) is 11, then there are 11 elements in the range of [100, 1000]. The scaling array needs to be declared dynmaic.

Module

mmxprs

getsensrng

Purpose

Get sensitivity ranges for objective function coefficients, RHS coefficients, variable upper bounds or variable lower bounds.

Synopsis

```
function getsensrng(w:integer, x:mpvar):real
function getsensrng(w:integer, c:linctr):real
```

Arguments

`w` Which information to return. Possible values:

`XPRS_UP`	Upper sensitivity range
`XPRS_DN`	Lower sensitivity range
`XPRS_UP+XPRS_UBND`	Upper sensitivity range of the upper bound of the variable
`XPRS_DN+XPRS_UBND`	Lower sensitivity range of the upper bound of the variable
`XPRS_UP+XPRS_LBND`	Upper sensitivity range of the lower bound of the variable
`XPRS_DN+XPRS_LBND`	Lower sensitivity range of the lower bound of the variable

`x` A variable of the problem

`c` A constraint of the problem

Return value

Sensivity range information depending on the value of `w`.

Further information

This function returns sensitivity ranges for RHS coefficients (if used with a constraint); and for objective function coefficients, upper bounds or lower bounds (if used with a variable). `getsensrng` can be called only if an optimal LP solution is available and the problem is not MIP presolved.

Module

mmxprs

getsize

Purpose

Get the size of a solution.

Synopsis

```
function getsize(ms:mpsol):integer
```

Argument

`ms` A solution object

Return value

The number of variables stored in the solution.

Related topics

`getvars`.

Module

mmxprs

getsol

Purpose

Get the solution value of an expression from a solution object.

Synopsis

```
function getsol(ms:mpsol,v:mpvar):real
function getsol(ms:mpsol,c:linctr):real
function getsol(ms:mpsol,nl:nlctr):real
function getsol(bv:boolvar):boolean
function getsol(ms:mpsol,bv:boolvar):boolean
function getsol(lc:logctr):boolean
function getsol(ms:mpsol,lc:logctr):boolean
```

Arguments

`ms`	A solution object
`v`	A decision variable
`bv`	A pseudo boolean decision variable
`c`	A linear constraint
`nl`	A non linear constraint
`lc`	A logical constraint

Return value

Solution value or 0 (or `false` for a logical parameter).

Further information

This function returns an evaluation of an expression using the provided solution object as solution values for the decision variables.

Related topics

`setsol`, `savesol`, `savemipsol`.

Module

mmxprs

getvar

Purpose

Get the decision variable associated to a pseudo boolean.

Synopsis

```
function getvar(bv:boolvar):mpvar
```

Argument

`bv` A pseudo boolean decision variable

Return value

The decision variable associated to the given parameter.

Further information

Each pseudo boolean variable is associated to two decision variables of type `mpvar`. This function makes it possible to retrieve these variables: it can be applied to both the variable itself (*e.g.* `getvar(bv)`) and its negation (*e.g.* `getvar(not bv)`).

Module

mmxprs

getub

Purpose

Get the upper bound of a variable.

Synopsis

```
function getub(x:mpvar):real
```

Argument

`x` A decision variable

Return value

Upper bound of the variable.

Further information

The bound value may be changed directly in the optimizer using `setub`. Changes to the variable in Mosel are not taken into account by this function unless the problem has been reloaded since (procedure `loadprob`).

Related topics

`getlb`, `setlb`, `setub`.

Module

mmxprs

getvars

Purpose

Get the set of variables of a solution.

Synopsis

```
procedure getvars(ms:mpsol,s:set of mpvar)
```

Arguments

`ms`	A solution object
`s`	A set of decision variables

Further information

This procedure returns in the parameter `s` the set of variables used by a solution object. Note that this procedure replaces the content of the set.

Related topics

`getsize`.

Module

mmxprs

hasfeature

Purpose

Check if a specific feature is supported by the currently used license.

Synopsis

```
function hasfeature(feature:string):boolean
```

Argument

`feature` The name of the feature to check, as it would appear in the Xpress license file

Return value

`true` if the requested feature is supported, `false` otherwise.

Module

mmxprs

implies

Purpose

Create an *implies* expression.

Synopsis

```
function implies(c1:log_or_linctr,c2:log_or_linctr):logctr
```

Arguments

`c1` A linear constraint (`linctr`) or logical expression (`logctr`)

`c2` A linear constraint (`linctr`) or logical expression (`logctr`)

Return value

A new `logctr` representing the expression.

Example

The following example shows several ways of stating the logical relation 'if $x_1 \geq 10$ then $x_1 + x_2 \geq 12$ and not $x_2 \leq 5$'. The implied constraint `L` is itself a logical constraint, built up by using the operators `and` and `not` in combination with linear constraints.

```
declarations
 R=1..2
 C: array(range) of linctr        ! Linear constraints
 L: logctr                        ! Logical constraint
 x: array(R) of mpvar             ! Decision variables
end-declarations

C(1):= x(1)>=10                   ! Define (temporary) linear ctrs
C(2):= x(2)<=5
C(3):= x(1)+x(2)>=12

implies(C(1), C(3) and not C(2))  ! State the implication
forall(j in 1..3) C(j):=0         ! Delete the auxiliary ctrs

! The same implication constraint can be stated by:
implies(x(1)>=10, x(1)+x(2)>=12 and not x(2)<=5)

! Or also by:
L:= x(1)+x(2)>=12 and not x(2)<=5 ! Define (temporary) logical ctr
implies(x(1)>=10, L)              ! State the implication
L:= 0                             ! Delete the auxiliary ctr
```

Further information

1. This function creates a `logctr` constraint representing an *implies* condition: *if c1 is valid then c2 is enforced*.
2. The helper package 'advmod' must be loaded if this function is used:

```
uses 'advmod'
```

Related topics

`indicator`, `xor`

Module

mmxprs

indicator

Purpose

Create an *indicator constraint*.

Synopsis

```
function indicator(type:integer,y:mpvar,ctr:linctr|nlctr):logctr
```

Arguments

`type` The indicator type:
- `-1` for indicator *y=0 -> ctr*
- `1` for indicator *y=1 -> ctr*

`y` The variable associated to the constraint

`ctr` An inequality constraint

Return value

A new `logctr` representing the indicator.

Example

This example shows how to define two indicator constraints. The second constraint labeled `L` is stated with the help of an auxiliary linear constraint definition. This temporary constraint `C` needs to be deleted from the problem after having been used in the definition of the indicator constraint. The notation `b(1)=1 -> ...` should be read as 'if b(1) takes the value 1 then ... must hold'

```
declarations
 R=1..2, S=1..3
 C: linctr              ! Linear constraint
 L: logctr              ! Logical (indicator) constraint
 x: array(S) of mpvar   ! Decision variables
 b: array(R) of mpvar   ! Indicator variables
end-declarations

forall(i in R)
  b(i) is_binary        ! Indicator variables must be binaries

C:= x(2)+x(3)<=5        ! Constraint to transform into indicator ctr.

! Define 2 indicator constraints
indicator(1, b(1), x(1)+x(2)>=12)    ! b(1)=1 -> x(1)+x(2)>=12
L:= indicator(-1, b(2), C)           ! b(2)=0 -> x(2)+x(3)<=5

C:=0                    ! Delete the auxiliary constraint definition
```

Related topics

implies, xor

Module

mmxprs

isiisvalid

Purpose

Check whether an IIS number exists.

Synopsis

```
function isiisvalid(numiis:integer):boolean
```

Argument

`numiis` Ordinal number of the IIS

Return value

`true` if `numiis` corresponds to an existing IIS.

Related topics

`resetiis`, `getiis`.

Module

mmxprs

isintegral

Purpose

Check whether a variable (or set of variables) solution value is integral.

Synopsis

```
function isintegral(x:mpvar):boolean
function isintegral(s:set of mpvar):boolean
```

Arguments

`x` A decision variable

`s` A set of decision variables

Return value

`true` if the variable (or all variables of the set) is integral.

Further information

This function checks whether the current solution value of a variable is integral with respect to the tolerance value of the optimizer (`XPRS_MIPSOL`). When used with a set, the function returns `true` if all variables of the set satisfy the condition.

Module

mmxprs

loadbasis

Purpose

Load a previously saved basis.

Synopsis

```
procedure loadbasis(b:basis)
```

Argument

`b` A basis

Example

The following saves a basis, changes the problem, and then loads it into the Optimizer, reloading the old basis:

```
declarations
 MinCost:linctr
 mybasis:basis
end-declarations

savebasis(mybasis)
 ...
loadprob(MinCost)
loadbasis(mybasis)
```

Further information

1. This procedure loads a basis into the optimizer that has previously been saved using procedure `savebasis` or constructed using `setbstat`.
2. The problem must be loaded in the Optimzer for `loadbasis` to have any effect. If this has not recently been carried out using `maximize` or `minimize` it must be explicitly loaded using `loadprob`.

Related topics

`loadprob`, `savebasis`, `setbstat`, `getbstat`, `resetbasis`.

Module

mmxprs

loadlpsol

Purpose

Load an LP solution into the optimizer.

Synopsis

```
procedure loadlpsol(x:array(set of mpvar) of real, slack:array(set of
      linctr) of real, dual:array(set of linctr) of real, dj:array(set of
      mpvar) of real)
procedure loadlpsol(x:array(set of mpvar) of real, dual:array(set of linctr)
      of real)
procedure loadlpsol(x:array(set of mpvar) of real)
```

Arguments

`x`	An array containing the primal solution
`slack`	An array containing the constraint slacks
`dual`	An array containing the dual multipliers
`dj`	An array containing the reduced cost values

Related topics

`crossoverlpsol`.

Module

mmxprs

loadmipsol

Purpose

Load a MIP solution into the optimizer.

Synopsis

```
function loadmipsol(s:array(set of mpvar) of real):integer
function loadmipsol(solnum:integer):integer
function loadmipsol(ms:mpsol):integer
```

Arguments

`s`	An array containing the solution
`solnum`	Solution number (between 1 and `XPRS_enumsols`)
`ms`	A solution object

Return value

Operation status:

`-1`	Solution rejected because an error occurred
`0`	Solution accepted. When loading a solution before a MIP solve, the solution is always accepted. It is placed in temporary storage until the MIP solve is started.
`1`	Solution rejected because it is infeasible
`2`	Solution rejected because it is cut off
`3`	Solution rejected because the LP reoptimization was interrupted

Example

The following saves a MIP solution, modifies the problem, and then loads it into the Optimizer, reloading the MIP solution:

```
declarations
 MinCost:linctr
 mysol: array(set of mpvar) of real
 result: integer
end-declarations

savemipsol(mysol)
 ...                          ! Make some changes
loadprob(MinCost)
result:= loadmipsol(mysol)
if result<>0 then writeln("Loading MIP solution failed"); end-if
minimize(MinCost)
```

Further information

1. This function loads a MIP solution into the optimizer that has previously been saved using procedure `savemipsol` or constructed by some external heuristic. In the latter case a value needs to be assigned to each discrete variable in the problem, such as `mysol(x):= 1` (where `x` is a decision variable of type `mpvar`).
2. The values for the continuous variables in the `s` array are ignored and are calculated by fixing the integer variables and reoptimizing.
3. The second form of the routine can be called after a search for *n-best* solutions has been performed by the optimiser: the selected solution is used as input.
4. The current problem definition must be loaded into the Optimizer for `loadmipsol` to have any effect. If this has not recently been done, *e.g.*, by calling `maximize` or `minimize`, the problem must be explicitly loaded using `loadprob`.
5. If the MIP solution is accepted by the Optimizer it causes the `MIPABSCUTOFF` control to be set accordingly. The provided MIP solution may help guiding the MIP heuristics but the branch-and-bound search will start from the initial LP relaxation solution as usual.

Related topics

`savemipsol`, `addmipsol`.

Module

mmxprs

loadprob

Purpose

Load a problem into the optimizer.

Synopsis

```
procedure loadprob(obj:linctr)
procedure loadprob(obj:linctr, extravar:set of mpvar)
procedure loadprob(qobj:qexp)
procedure loadprob(qobj:qexp, extravar:set of mpvar)
procedure loadprob(nlobj:nlctr)
procedure loadprob(nlobj:nlctr, extravar:set of mpvar)
procedure loadprob(rbobj:robustctr)
procedure loadprob(rbobj:robustctr, extravar:set of mpvar)
```

Arguments

`obj`	Objective function constraint
`qobj`	Quadratic objective function (with module *mmquad*)
`nlobj`	Non linear objective function (with module *mmnl*)
`rbobj`	Robust objective function (with module *mmrobust*)
`extravar`	Extra variables to include

Further information

1. This procedure explicitly loads a problem into the optimizer. It gets called automatically by the optimization procedures `minimize` and `maximize` if the problem has been modified in Mosel since the last call to the optimizer. Nevertheless in some cases, namely before loading a basis, it may be necessary to reload the problem explicitly using this procedure. The parameter `extravar` is a set of variables to be included into the problem even if they do not appear in any constraint (*i.e.* they become empty columns in the matrix).

2. Support for quadratic programming requires the module *mmnl*.

3. Support for general nonlinear programming requires the module *mmxnlp*.

4. Support for robust programming requires the module *mmrobust*.

Related topics

`maximize`, `minimize`.

Module

mmxprs

maximize, minimize

Purpose

Maximize/minimize the current problem.

Synopsis

```
procedure maximize(alg:integer, obj:linctr)
procedure maximize(obj:linctr)
procedure maximize(alg:integer, qobj:qexp)
procedure maximize(qobj:qexp)
procedure maximize(alg:integer, nlobj:nlctr)
procedure maximize(nlobj:nlctr)
procedure maximize(rbobj:robustctr)
procedure maximize(alg:integer, rbobj:robustctr)
```

Arguments

`alg` Algorithm choice:

`XPRS_BAR`	Newton-Barrier to solve LP
`XPRS_DUAL`	Dual simplex
`XPRS_NET`	Network solver
`XPRS_LIN`	Only solve LP ignoring all discrete entities
`XPRS_PRI`	Primal simplex
`XPRS_ENUM`	Start a search for the *n-best* MIP solutions
`XPRS_LPSTOP`	Stop the MIP solution process after solving the first LP
`XPRS_CONT`	Continue a previously interrupted solution process
`XPRS_LOCAL`	Solve the linearization of the problem (mmxnlp only)
`XPRS_COREPB`	Solve the linear part of the problem (mmxnlp only)
`XPRS_TUNE`	Enable the tuner

`obj` Objective function constraint

`qobj` Quadratic objective function (with module *mmquad*)

`nlobj` Non linear objective function (with module *mmnl*)

`rbobj` Robust objective function (with module *mmrobust*)

Example

The following maximizes `Profit` using the dual simplex algorithm and stops before the branch-and-bound search:

```
declarations
 Profit:linctr
end-declarations

maximize(XPRS_DUAL+XPRS_LPSTOP, Profit)
```

The following minimizes `MinCost` using the Newton-Barrier algorithm and ignoring all discrete entities

```
declarations
 MinCost:linctr
end-declarations

minimize(XPRS_BAR+XPRS_LIN, MinCost)
```

Further information

1. This procedure calls the Optimizer to maximize/minimize the current problem (excluding all hidden constraints) using the given constraint as objective function. Optionally, the algorithm to be used can be defined. By default, the branch-and-bound search is executed automatically if the problem contains any discrete entities. Where appropriate, several algorithm choice parameters may be combined (using plus signs).
2. If `XPRS_LIN` is specified, then the discreteness of all discrete entities is ignored, even during the presolve procedure.
3. If `XPRS_LPSTOP` is specified, then just the LP at the top node is solved and no Branch-and-Bound search is initiated. But the discreteness of the discrete entities *is* taken into account in presolving the LP at the top node. Note also that `getprobstat` still returns information related to the MIP problem when this option is used although only an LP solve has been executed and the solution information returned by `getsol` corresponds to the current LP solution. However, if the the MIP is solved to optimality during this call, the MIP optimal solution will be returned by `getsol`.
4. If `XPRS_CONT` is used after a solve has completed, the routine returns immediately without altering the current problem status.
5. If `XPRS_ENUM` is specified, the optimiser starts a search for the *n-best* MIP solutions. The maximum number of solutions to store may be specified using the `XPRS_enummaxsol` (default: 10). After the execution of the enumeration, the number of solutions found during the search is returned by the control parameter `XPRS_enumsols`. The procedure `selectsol` can then be used to select one of these solutions.
6. If `XNLP_LOCAL` is specified for a non-linear problem having been loaded using mmxnlp and which have been solved using XSLP, then the current linearization will be reoptimized.
7. If `XPRS_TUNE` is specified the problem will be tuned and then solved with the best control settings identified by the tuner. For a user guide about the tuner, please refer to the documentation of the Xpress Optimizer.
8. If `XNLP_COREPB` is specified for a non-linear problem having been loaded using mmxnlp, then only the linear part of the problem will be loaded and optimized. This is usefull for checking if the linear part of the problem is well posed.
9. Support for quadratic programming requires the module *mmnl*.
10. Support for general nonlinear programming requires the module *mmxnlp*.
11. Support for robust programming requires the module *mmrobust*.

Related topics

`postsolve`, `loadprob`, `selectsol`, `XPRS_maxupdc`.

Module

mmxprs

postsolve

Purpose

Postsolve the current matrix.

Synopsis

```
procedure postsolve
```

Further information

After an optimisation operation has been interrupted before its completion, the matrix held into the optimiser remains in a *presolved* state. In this state direct matrix operations (like fixing bounds) cannot be applied: this routine restores the problem in its original state that is just after it was loaded into the optimiser. As an alternative to postsolving the matrix, the problem may be entirely reloaded using `loadprob`.

Related topics

`maximize`, `minimize`.

Module

mmxprs

readbasis

Purpose

Read a basis from a file.

Synopsis

```
procedure readbasis(fname:string,options:string)
```

Arguments

`fname`	Extended file name
`options`	String of options

Further information

This procedure reads in a basis from a file by calling the function `XPRSreadbasis` of the Optimizer. Note that basis save/read procedures can be used only if the constraint and variable names have been loaded into the Optimizer (control parameter `XPRS_loadnames` set to true) and all constraints are named. For more detail on the options and behavior of this procedure refer to the *Xpress Optimizer Reference Manual*.

Related topics

`writebasis`.

Module

mmxprs

readdirs

Purpose

Read directives from a file.

Synopsis

```
procedure readdirs(fname:string)
```

Argument

`fname` Extended file name

Further information

This procedure reads in directives from a file by calling the function `XPRSreaddirs` of the Optimizer. Note that directives save/read procedures can be used only if variable names have been loaded into the Optimizer (parameter `XPRS_loadnames` set to true).

Related topics

`writedirs`.

Module

mmxprs

readsol

Purpose

Read a solution from a file.

Synopsis

```
procedure readsol(fname:string,options:string)
```

Synopsis

```
procedure readsol(fname:string,options:string)
procedure readsol(sol:array(mpvar) of real,fname:string,options:string)
procedure readsol(sol:mpsol,fname:string,options:string)
procedure readsol(sol:mpvar,fname:string,options:string)
```

Arguments

`fname`	Extended file name
`options`	String of options
`sol`	Object to load the solution into

Further information

This procedure reads in a solution from a file by calling the function `XPRSreadslxsol` of the Optimizer. Note that solution save/read procedures can be used only if the constraint and variable names have been loaded into the Optimizer (control parameter `XPRS_loadnames` set to true) and all constraints are named. For more detail on the options and behavior of this procedure refer to the *Xpress Optimizer Reference Manual*.

Related topics

`writesol`.

Module

mmxprs

refinemipsol

Purpose

Executes the MIP solution refiner on an `mpsol` solution.

Synopsis

```
function refinemipsol(solution:mpsol):mpsol
function refinemipsol(solution:mpsol, options:integer):mpsol
```

Arguments

`solution`	The solution to be refined
`options`	Options passed to the solution refiner. Please refer to `XPRSrefinemipsol` for the available options

Related topics

`calcsolinfo`.

Module

mmxprs

rejectintsol

Purpose

Reject the solution provided to the PREINTSOL callback.

Synopsis

```
procedure rejectintsol
```

Further information

This procedure cannot be called from outside of the PREINTSOL callback.

Related topics

`setcallback`.

Module

mmxprs

repairinfeas

Purpose

Relaxing bounds to repair infeasibility.

Synopsis

```
procedure repairinfeas(alrp:array(linctr) of real, agrp:array(linctr) of
      real, albp:array(mpvar) of real, aubp:array(mpvar) of real)
procedure repairinfeas(alrp:array(linctr) of real, agrp:array(linctr) of
      real, albp:array(mpvar) of real, aubp:array(mpvar) of real,
      phs2:string, delta:real,optfg:string)
procedure repairinfeas(flags:string, lrp:real, grp:real, lbp:real, ubp:real,
      delta:real)
procedure repairinfeas(flags:string)
procedure repairinfeas(alrp:array(linctr) of real, agrp:array(linctr) of
      real, albp:array(mpvar) of real, aubp:array(mpvar) of
      real,alrb:array(linctr) of real,agrb:array(linctr) of
      real,albb:array(mpvar) of real,aubb:array(mpvar) of
      real,phs2:string,delta:real,optfg:string)
```

Arguments

`alrp` Array of preferences for relaxing the less or equal side of row

`agrp` Array of preferences for relaxing the greater or equal side of row

`albp` Array of preferences for relaxing lower bounds

`aubp` Array of preferences for relaxing upper bounds

`alrb` Array of upper bounds to be imposed on the amount of relaxation allowed for the less or equal side of row

`agrb` Array of upper bounds to be imposed on the amount of relaxation allowed for the greater or equal side of row

`albb` Array of upper bounds to be imposed on the amount of relaxation allowed for lower bounds

`aubb` Array of upper bounds to be imposed on the amount of relaxation allowed for upper bounds

`phs2` A 1-character string controling the second phase optimization

`lrp` Preference for relaxing the less or equal side of row

`grp` Preference for relaxing the greater or equal side of row

`lbp` Preference for relaxing lower bounds

`ubp` Preference for relaxing upper bounds

`delta` Relaxation multiplier for the second phase-1

`flags` A 3-character string defining the p/o/g flags

`optfg` Flags to be passed to the optimizer

Further information

1. This routine is an interface to the Optimizer functions `XPRSrepairweightedinfeas` and `XPRSrepairinfeas`. Please refer to the *Xpress Optimizer Reference Manual* for further details.
2. The 2 first forms call the Optimizer routine `XPRSrepairweightedinfeas`. Missing preferences are treated as `0`; the default value for `phs2` is `"d"` and the default value for `delta` is `0.001`.
3. The third and fourth forms call the Optimizer routine `XPRSrepairinfeas`. If `flags` is not specified (empty string), a default value of `"cog"` is used. If preferences and `delta` are not given, all preferences are set to `1` and `delta` is `0.001`.
4. The last form calls the Optimizer routine `XPRSrepairweightedinfeasbounds`, allowing to bound the amount of relaxation applied on a per row or bound basis. Only positive bounds are applied; a zero or negative bound is ignored and the amount of relaxation allowed for the corresponding row or bound is not limited. The effect of a zero bound on a row or bound would be equivalent with not relaxing it, and can be achieved by setting its preference array value to zero instead, or not including it in the preference arrays. The default value for `phs2` is `"d"`.
5. Negative preferences translate to quadratic penalties applied for the corresponding rows or bounds.

Module

mmxprs

resetbasis

Purpose

Reset a basis.

Synopsis

```
procedure resetbasis(b:basis)
```

Argument

`b` A basis

Further information

This function clears the information stored in a `basis` object.

Related topics

`loadbasis`, `savebasis`, `setbstat`, `resetbasis`.

Module

mmxprs

resetiis

Purpose

Reset the search for IIS.

Synopsis

```
procedure resetiis
```

Further information

This procedure resets the search for IIS and clears all information already computed related to IIS.

Related topics

getiis.

Module

mmxprs

resetsol

Purpose

Reset a solution.

Synopsis

```
procedure resetsol(ms:mpsol)
procedure resetsol(ms:mpsol,v:mpvar)
procedure resetsol(ms:mpsol,bv:boolvar)
```

Arguments

`ms`	A solution object
`v`	A decision variable
`bv`	A pseudo boolean decision variable

Further information

When used with a single argument this procedure clears the information stored in the specified solution object (this is equivalent to calling `reset`). With two arguments the designated entity is removed from the solution object (no operation is performed if the corresponding variable was not yet part of the solution).

Related topics

`setsol`, `savesol`, `savemipsol`, `getsize`.

Module

mmxprs

savebasis

Purpose

Save the current basis.

Synopsis

```
procedure savebasis(b:basis)
```

Argument

`b` A basis

Further information

This function saves the current basis into the provided `basis` object.

Related topics

`loadbasis`, `setbstat`, `getbstat`, `resetbasis`.

Module

mmxprs

savemipsol

Purpose

Save the current solution into the provided array or solution object.

Synopsis

```
procedure savemipsol(s:array(set of mpvar) of real)
procedure savemipsol(ms:mpsol)
```

Arguments

`s`	An array to return the solution
`ms`	A solution object

Further information

1. This procedure saves the current solution into the provided array. The resulting datastructure may be used as input for the `loadmipsol` function.
2. If the index set of the array is dynamic, the procedure may extend it in order to have all variables of the problem. Otherwise the solution is saved only for the variables included in this set.
3. Only non-continuous variables are saved when this procedure is used with an `mpsol` argument. Use `savesol` to save the values of all variables.

Related topics

`loadmipsol`, `savesol`.

Module

mmxprs

savesol

Purpose

Save the current solution into a solution object.

Synopsis

```
procedure savesol(ms:mpsol)
```

Argument

`ms` A solution object

Further information

This procedure saves the current solution into the provided solution object. As opposed to the `savemipsol` routine all variables are saved independently of their type.

Related topics

`savemipsol`.

Module

mmxprs

savestate

Purpose

Save current state of the Optimizer to a file.

Synopsis

```
procedure savestate(fname:string)
```

Argument

`fname` Extended file name

Further information

The produced file (Optimizer SVF file format) can then be used as input to Optimizer console using *optimizer*'s command `RESTORE`.

Module

mmxprs

selectsol

Purpose

Select one of the solutions found by solution enumerator.

Synopsis

```
procedure selectsol(solnum:integer)
```

Argument

`solnum` Solution number (between 1 and `XPRS_enumsols`)

Further information

1. This routine can be called after a search for *n-best* solutions has been performed by the optimizer in order to select a particular solution.
2. Once a solution has been selected, the functions `getsol` (applied to decision variables) and `getobjval` return values related to this solution.

Module

mmxprs

setarchconsistency

Purpose

Sets the value of the optimizer architecture control.

Synopsis

```
procedure setarchconsistency(controlvalue:integer)
```

Argument

`controlvalue` Value of the optimizer architecture control

Further information

Please refer to the *Xpress Optimizer Reference Manual* for more details.

Module

mmxprs

setbstat

Purpose

Set the status of a variable or constraint in a basis.

Synopsis

```
procedure setbstat(b:basis,v:mpvar,s:integer)
procedure setbstat(b:basis,c:linctr,s:integer)
```

Arguments

`b` A basis

`v` A decision variable

`c` A linear constraint

`s` Basis status. For a variable:

`-1`	Remove the variable from the basis
`0`	Variable is non-basic at lower bound, or superbasic at zero if the variable has no lower bound
`1`	Variable is basic
`2`	Variable is non-basic at upper bound
`3`	Variable is super-basic

For a constraint:

`-1`	Remove the constraint from the basis
`0`	Slack, surplus or artificial is non-basic at lower bound
`1`	Slack, surplus or artificial is basic
`2`	Slack or surplus is non-basic at upper bound
`3`	Slack or surplus is super-basic

Related topics

`savebasis`, `getbstat`, `resetbasis`.

Module

mmxprs

setcallback

Purpose

Set optimizer callback functions and procedures.

Synopsis

```
procedure setcallback(cbtype:integer, cb:string)
procedure setcallback(cbtype:integer, pr:procedure|function)
```

Arguments

`cbtype` Type of the callback:

`XPRS_CB_LPLOG`	Simplex log callback
`XPRS_CB_CUTLOG`	Cut log callback
`XPRS_CB_GLOBALLOG`	Global log callback
`XPRS_CB_BARLOG`	Barrier log callback
`XPRS_CB_CHGNODE`	User select node callback
`XPRS_CB_PRENODE`	User preprocess node callback
`XPRS_CB_OPTNODE`	User optimal node callback
`XPRS_CB_INFNODE`	User infeasible node callback
`XPRS_CB_INTSOL`	User integer solution callback
`XPRS_CB_NODECUTOFF`	User cut-off node callback
`XPRS_CB_NEWNODE`	New node callback
`XPRS_CB_BARITER`	Barrier iteration callback
`XPRS_CB_CUTMGR`	Cut manager (branch-and-bound node) callback
`XPRS_CB_CHGBRANCH`	User choose branching variable callback
`XPRS_CB_PREINTSOL`	Integer solution callback called before acceptation
`XPRS_CB_GAPNOTIFY`	Gap notify callback
`XPRS_CB_SOLNOTIFY`	Integer notify callback called each time a solution added with `addmipsol` is processed
`XPRS_CB_PRESOLVE`	A callback fired after presolve is performed
`XPRS_CB_COMPUTERESTART`	A callback fired when a solve in compute mode had to be restarted
`XPRS_CB_CHECKTIME`	Check time callback

`cb` Name of the callback function/procedure (that must be public); the parameters and the type of

the return value (if any) vary depending on the type of the callback:

`function cb:boolean`	XPRS_CB_LPLOG
`function cb:boolean`	XPRS_CB_CUTLOG
`function cb:boolean`	XPRS_CB_GLOBALLOG
`function cb:boolean`	XPRS_CB_BARLOG
`function cb(node:integer):integer`	XPRS_CB_CHGNODE
`function cb:boolean`	XPRS_CB_PRENODE
`function cb:boolean`	XPRS_CB_OPTNODE
`procedure cb`	XPRS_CB_INFNODE
`procedure cb`	XPRS_CB_INTSOL
`procedure cb(node:integer)`	XPRS_CB_NODECUTOFF
`procedure cb(parent:integer,new:integer,branch:integer)`	XPRS_CB_NEWNODE
`function cb:integer`	XPRS_CB_BARITER
`function cb:boolean`	XPRS_CB_CUTMGR
`procedure cb(e:integer,u:integer,d:real)`	XPRS_CB_CHGBRANCH
`procedure cb(isheur:boolean,cutoff:real)`	XPRS_CB_PREINTSOL
`procedure cb(rt:real,at:real,aot:real,abt:real)`	XPRS_CB_GAPNOTIFY
`procedure cb(solid:string,status:integer)`	XPRS_CB_SOLNOTIFY
`procedure cb`	XPRS_CB_PRESOLVE
`procedure cb`	XPRS_CB_COMPUTERESTART
`function cb:boolean`	XPRS_CB_CHECKTIME

`pr` A subroutine reference compatible with the corresponding callback (see above).

Example

The following example defines a procedure to handle solution printing and sets it to be called whenever an integer solution is found using the integer solution callback:

```
public procedure printsol
 declarations
  objval:real
 end-declarations

 objval:= getparam("XPRS_lpobjval")
 writeln("Solution value: ", objval)
end-procedure

setcallback(XPRS_CB_INTSOL, "printsol")
```

Further information

1. This procedure sets the optimizer callback functions and procedures. For a detailed description of these callbacks the user is referred to the *Xpress Optimizer Reference Manual*.
2. Passing an empty string (`""`) as the function name disables the corresponding callback.
3. The arguments of the Mosel subroutines implementing callback functions correspond to the arguments documented in the *Xpress Optimizer Reference Manual*, with the exception of arguments that are used for passing back information to the solver: these are replaced by the subroutine return values. For the logging callbacks, the return value `true` interrupts the solving. For the `PRENODE` and `OPTNODE` callbacks the return value `true` declares the current node to be infeasible. The return value of the `BARITER` callback is the selected barrier action (see `XPRSaddcbbariteraction` in the *Xpress Optimizer Reference Manual* for details). The cut manager routine is called repeatedly at each node until it returns `false`.
4. Whilst the solution values can be accessed from Mosel in any callback function/procedure, all other information such as the problem status or the value of the objective function must be obtained directly from the Optimizer using function `getparam`.
5. The function `setucbdata` can be used to return information to the optimizer from the callback 'CHGBRANCH'.
6. The functions `rejectintsol` and `setcbcutoff` can be used to return information to the optimizer from the callback 'PREINTSOL'.
7. The function `setgndata` can be used to return information to the optimizer from the callback 'GAPNOTIFY'.
8. When the mmxnlp model is used, this function can also be used to set the callbacks relevant to non-linear problems only. Please see the documentation of the mmxnlp module for the list of extra callbacks.

Module

mmxprs

setcomputeallowed

Purpose

Controls in what circumstances the current Mosel instance can send optimizations to the Insight Compute Interface.

Synopsis

```
procedure setcomputeallowed(allowed:integer)
```

Argument

`allowed` Value controlling in what circumstances solves may be sent to Insight Compute Interface. Must be one of the following constants:

`XPRS_ALLOW_COMPUTE_ALWAYS`	Always allow solves to be sent to Compute.
`XPRS_ALLOW_COMPUTE_NEVER`	Never allow solves to be sent to Compute.
`XPRS_ALLOW_COMPUTE_DEFAULT`	Allow solves to be sent to Compute only from non-OEM applications.

Further information

1. This procedure affects all models running in the current Mosel instance.
2. If the user enables Insight 5 Compute Interface but the value passed to this function does not allow the Insight Compute Interface to be used, any solves will terminate with an immediate error. This function can be used to prevent solves from being sent to Insight Compute but cannot be used to force solves to be performed locally. The purpose of this function is to allow applications that do not want to support Insight Compute Interface to prevent it being used.

Related topics

`getcomputeallowed`.

Module

mmxprs

setcbcutoff

Purpose

Set the cutoff to be returned to the Optimizer by the PREINTSOL callback.

Synopsis

```
procedure setcbcutoff(cutoff:real)
```

Argument

`cutoff` New cutoff value for the current solution

Further information

This procedure cannot be called from outside of the PREINTSOL callback.

Related topics

`setcallback`.

Module

mmxprs

setgndata

Purpose

Update data to be returned to the Optimizer by the GAPNOTIFY callback.

Synopsis

```
procedure setgndata(what:integer, target:real)
```

Arguments

`what` What target to update. Possible values:

`XPRS_GN_RELTARGET`	Relative gap
`XPRS_GN_ABSTARGET`	Absolute gap
`XPRS_GN_ABSOBJTARGET`	Absolute gap on objective
`XPRS_GN_ABSBOUNDTARGET`	Absolute gap on bound

`target` New target value

Further information

This procedure stores the provided information that will be returned to the optimizer when the callback terminates. This procedure cannot be called from outside of the GAPNOTIFY callback.

Related topics

`setcallback`.

Module

mmxprs

setlb

Purpose

Set the lower bound of a variable.

Synopsis

```
procedure setlb(x:mpvar,r:real)
```

Arguments

`x` A decision variable

`r` Lower bound value

Further information

This procedure changes the lower bound of a variable directly in the Optimizer, that is, the bound is modified in the problem that is currently loaded in the Optimizer but does not get recorded in the problem definition held in Mosel. If the problem has not yet been loaded into the Optimizer then the new bound value is ignored. Reloading the problem into the Optimizer after a call to `setlb` will reset the lower bound for the variable to the value computed by Mosel, that is, the bound value resulting from `setlb` is overwritten.

Related topics

`getlb`, `getub`, `loadprob`, `setub`.

Module

mmxprs

setmatcoeff

Purpose

Set the coefficient of a variable or the constant term directly in the Optimizer.

Synopsis

```
procedure setmatcoeff(c:linctr, x:mpvar, r:real)
procedure setmatcoeff(c:linctr, r:real)
```

Arguments

`c` A linear constraint

`x` A decision variable

`r` Coefficient or constant term

Further information

1. This procedure behaves like `setcoeff` except that it updates only the matrix loaded into the Optimizer, the problem representation of Mosel is not changed. Reloading the problem into the Optimizer will restore the matrix to the Mosel representation of the problem.
2. The routine will fail if no problem has been loaded into the Optimizer or if the constraint or the variable is not part of the current matrix.
3. After a call to this procedure the control parameter `XPRS_maxupdc` gets the value 1 if it was set to 0 before.

Related topics

`setcoeff`, `setlb`, `setub`, `maximize`, `minimize`, `XPRS_maxupdc`, `getmatcoeff`.

setmipdir

Purpose

Set a directive on a variable or Special Ordered Set.

Synopsis

```
procedure setmipdir(x:mpvar,t:integer,r:real)
procedure setmipdir(x:mpvar,t:integer)
procedure setmipdir(c:linctr,t:integer,r:real)
procedure setmipdir(c:linctr,t:integer)
```

Arguments

`x` A decision variable

`c` A linear constraint (of type SOS)

`r` A real value

`t` Directive type, which may be one of:

`XPRS_PR`	`r` is a priority (integer value between 1 and 1000 where 1 is the highest priority, 1000 the lowest)
`XPRS_UP`	Force up first
`XPRS_DN`	Force down first
`XPRS_PU`	`r` is an up pseudo cost
`XPRS_PD`	`r` is a down pseudo cost
`XPRS_BR`	Force branching even if satisfied

Further information

This procedure sets a directive on a discrete entity. Note that the priority value is converted into an integer. The directives are loaded into the Optimizer at the same time as the problem itself.

Related topics

`clearmipdir`, `readdirs`, `writedirs`.

Module

mmxprs

setmodcut

Purpose

Mark a constraint as a model cut.

Synopsis

```
procedure setmodcut(c:linctr)
```

Argument

`c` A linear constraint

Further information

This procedure marks the given constraint as a model cut. The list of model cuts is sent to the Optimizer when the matrix is loaded.

Related topics

`clearmodcut`.

Module

mmxprs

setsol

Purpose

Define the value associated to a decision variabe in a solution object.

Synopsis

```
procedure setsol(ms:mpsol,v:mpvar,s:real)
procedure setsol(ms:mpsol,bv:boolvar,t:boolean)
```

Arguments

`ms`	A solution object
`v`	A decision variable
`bv`	A pseudo boolean decision variable
`s`	The solution value as a real
`t`	The solution value as a boolean

Further information

1. This procedure associates a solution value to a decision variable in a solution object. If the variable is already included in the solution, its value is replaced. Otherwise the solution is extended with the new variable.

2. When the function is applied to a pseudo boolean variable, the values for the two decision variables associated to the entity are updated (value and its negation).

Related topics

`getsol`, `resetsol`, `savesol`, `savemipsol`.

Module

mmxprs

setub

Purpose

Set the upper bound of a variable.

Synopsis

```
procedure setub(x:mpvar,r:real)
```

Arguments

`x` A decision variable

`r` Upper bound value

Further information

This procedure changes the upper bound of a variable directly in the Optimizer, that is, the bound is modified in the problem that is currently loaded in the Optimizer but does not get recorded in the problem definition held in Mosel. If the problem has not yet been loaded into the Optimizer then the new bound value is ignored. Reloading the problem into the Optimizer after a call to `setub` will reset the upper bound for the variable to the value computed by Mosel, that is, the bound value resulting from `setub` is overwritten.

Related topics

`getlb`, `getub`, `loadprob`, `setlb`.

Module

mmxprs

setucbdata

Purpose

Update data to be returned to the Optimizer by the CHGBRANCH callback.

Synopsis

```
procedure setucbdata(x:mpvar, u:integer, e:real)
procedure setucbdata(s:linctr, u:integer, e:real)
procedure setucbdata(n:integer, u:integer, e:real)
```

Arguments

`x` A decision variable

`s` An SOS

`n` A column or SOS number as provided by the optimizer

`u` Direction for branching. Possible values:

- `0` Upward branch made second (branch on column)
- `1` Upward branch made first (branch on column)
- `2` Upward branch made second (branch on SOS)
- `3` Upward branch made first (branch on SOS)

`e` Estimated degradation at the node

Further information

This procedure stores the provided information that will be returned to the optimizer when the callback terminates. This procedure cannot be called from outside of the CHGBRANCH callback.

Related topics

`setcallback`.

Module

mmxprs

stopoptimize

Purpose

Interrupt the optimizer algorithms.

Synopsis

```
procedure stopoptimize(why:integer)
```

Argument

`why` The reason for stopping. Possible reasons:

`XPRS_STOP_TIMELIMIT`	Time limit hit
`XPRS_STOP_CTRLC`	Control C hit
`XPRS_STOP_NODELIMIT`	Node limit hit
`XPRS_STOP_ITERLIMIT`	Iteration limit hit
`XPRS_STOP_MIPGAP`	MIP gap is sufficiently small
`XPRS_STOP_SOLLIMIT`	Solution limit hit
`XPRS_STOP_USER`	User interrupt

Further information

This procedure can be called from any callback. It is ignored if used from outside an optimization process.

Module

mmxprs

unloadprob

Purpose

Unload the problem held in the optimizer.

Synopsis

```
procedure unloadprob
```

Further information

1. This procedure "unloads" the optimizer by releasing all the resources it has allocated for its processing (internal representation, solution information, working files).
2. This procedure resets the control parameters `XPRS_EXTRACOLS`, `XPRS_EXTRAROWS`, `XPRS_EXTRAELEMS` to their default values.

Related topics

`maximize`, `minimize`, `loadprob`.

Module

mmxprs

uselastbarsol

Purpose

Sets up the last barrier solve's solution as the current one if one is available

Synopsis

```
function uselastbarsol:boolean
```

Return value

Operation status:

`FALSE` No barrier solution is available

`TRUE` The barrier solution is now the active solution

Further information

This fucntion allows to access the barrier solution before a crossover was performed. The solution, solution status and objective are set up to match the barrier solution and are available the usual way.

Module

mmxprs

writebasis

Purpose

Write the current basis to a file.

Synopsis

```
procedure writebasis(fname:string,options:string)
```

Arguments

`fname`	Extended file name
`options`	String of options

Further information

This procedure writes the current basis to a file by calling the Optimizer function `XPRSwritebasis`. Note that basis save/read procedures can be used only if the constraint and variable names have been loaded into the Optimizer (parameter `XPRS_loadnames` set to `true`) and all constraints are named. For more detail on the options and behavior of this procedure, refer to the *Xpress Optimizer Reference Manual*.

Related topics

`readbasis`.

Module

mmxprs

writedirs

Purpose

Write current directives to a file.

Synopsis

```
procedure writedirs(fname:string)
```

Argument

`fname` Extended file name

Further information

This procedure writes the current directives to a file using the Optimizer file format.

Related topics

`clearmipdir`, `setmipdir`, `readdirs`.

Module

mmxprs

writeprob

Purpose

Write the current problem to a file.

Synopsis

```
procedure writeprob(fname:string, options:string)
procedure writeprob(fname:string, options:string, fnamed:string)
```

Arguments

`fname`	Extended file name for the matrix
`options`	String of format options (default: full precision)
`fnamed`	Extended file name for the directives

Example

Load the current problem into the Optimizer and save it to an MPS file `"mypb.mps"` in hexadecimal format ('x') and to the file `"mypb.lp"` in LP format ('l') using scrambled names ('s'):

```
loadprob(myobj)
setparam("xprs_objsense",1) ! for 'minimize'
writeprob("mypb.mps","x")
writeprob("mypb.lp","ls")
```

Further information

This procedure writes the current problem held in the Optimizer to a file by calling the Optimizer function `XPRSwriteprob` and `XPRSwritedirs` if a file name for the directives is also specified. Note that the matrix written by this procedure may be different from the one produced by `exportprob` since it may include the effects of presolve or cuts generated by the Optimizer. For more detail on the options and behavior of this procedure, refer to the *Xpress Optimizer Reference Manual*.

Related topics

`exportprob`, `writedirs`.

Module

mmxprs

writesol

Purpose

Write a solution to a file.

Synopsis

```
procedure writesol(fname:string,options:string)
procedure writesol(ms:mpsol,sname:string,fname:string,options:string)
```

Arguments

`fname`	Extended file name
`options`	String of options
`ms`	A solution object
`sname`	Solution name

Further information

1. When using the first syntax this procedure writes the current solution to a file by calling the Optimizer function `XPRSwriteslxsol`. For more detail on the options and behavior of this procedure, refer to the *Xpress Optimizer Reference Manual*.
2. With the second syntax, the file is generated from a solution object. In this case, the solution name has to be provided (default name is `"solution"`) and the only supported option is `"x"` to output the numbers in hexadecimal.
3. Solution save/read procedures can be used only if the constraint and variable names have been loaded into the Optimizer (parameter `XPRS_loadnames` set to `true`) and all constraints are named.

Related topics

`readsol`.

Module

mmxprs

xor

Purpose

Create an *exclusive or* expression.

Synopsis

```
function xor(c1:log_or_linctr,c2:log_or_linctr):logctr
```

Arguments

`c1` A linear constraint (`linctr`) or logical expression (`logctr`)

`c2` A linear constraint (`linctr`) or logical expression (`logctr`)

Return value

A new `logctr` representing the expression.

Example

This example shows how to state an exclusive 'or' constraint that expresses the disjunction between two tasks with start time s_j and fixed duration D_j. A non-exclusive 'or' relation can be stated by using the `or` operator as shown in the last line (constraint `L`).

```
declarations
 R=1..2
 C: array(range) of linctr  ! Linear constraints
 L: logctr                  ! Logical constraint
 s: array(R) of mpvar       ! Decision variables (start times)
 D: array(R) of real        ! Data (durations)
end-declarations

C(1):= s(1)+D(1)>=s(2)      ! Define (temporary) linear constraints
C(2):= s(2)+D(2)>=s(1)

xor(C(1), C(2))             ! State an exclusive 'or'
forall(j in 1..2) C(j):=0   ! Delete the auxiliary constraints

! The same 'xor' constraint can be stated by:
xor(s(1)+D(1)>=s(2), s(2)+D(2)>=s(1))

! A non-exclusive 'or' relation is stated by using the 'or' operator:
L:= s(1)+D(1)>=s(2) or s(2)+D(2)>=s(1)
```

Further information

1. This function creates a `logctr` constraint representing an *exclusive or* condition: *either c1 or c2 is valid, not both*.
2. The helper package 'advmod' must be loaded if this function is used:

```
uses 'advmod'
```

Related topics

`indicator`, `implies`

Module

mmxprs

xprsmemoryuse

Purpose

Retrieve memory usage statistics.

Synopsis

```
function xprsmemoryuse(what:string):real
```

Argument

`what` The information to retrieve. Possible values are `"available"`, `"current"`, `"peak"`, `"system"` and `"total"`

Return value

An amount of memory expressed in bytes or `-1` if the provided identifier is not valid.

Further information

The provided identifier corresponds to an Optimizer problem attribute (*e.g.* `"peak"` refers to the attribute `XPRS_PEAKMEMORY`). This argument is not case sensitive and the parameter name may be directly used (*e.g.* `"XPRS_TOTALMEMORY"` is the same as `"total"`).

Related topics

`memoryuse`

Module

mmxprs

21.4 Cut Pool Manager

This section contains the functions and procedures of the Xpress Optimizer cut manager. For a detailed description of the cut manager and its functionality the user is referred to the *Xpress Optimizer Reference Manual*. To run the cut manager from Mosel, it may be necessary to (re)set certain control parameters of the optimizer. For example, switching off presolve and automatic cut generation, and reserving space for extra rows in the matrix may be useful:

```
setparam("XPRS_presolve", 0);       ! Switch presolve off...
setparam("XPRS_presolveops", 2270); ! ...or use secure setting for presolve
setparam("XPRS_cutstrategy", 0);    ! Switch automatic cut generation off
setparam("XPRS_extrarows", 5000);   ! Reserve space for 5000 extra rows in
                                    ! the matrix
```

The callback functions and procedures that are relevant to the cut manager are initialized with function `setcallback`, in common with the other Optimizer callbacks.

It should be noted that cuts are not stored by Mosel but sent immediately to the Optimizer. Consequently, if a problem is reloaded into the Optimizer, any previously defined cuts will be lost. In Mosel, cuts are defined by specifying a linear expression (*i.e.* an unbounded constraint) and the operator sign (inequality/equality). If instead of a linear expression a constraint is given, it will also be added to the system as an additional constraint.

`addcut`	Add a cut to the problem in the optimizer.	p. 816
`addcuts`	Add an array of cuts to the problem in the optimizer.	p. 817
`delcuts`	Delete cuts from the problem in the optimizer.	p. 818
`dropcuts`	Drop a set of cuts from the cut pool.	p. 819
`getcnlist`	Get the set of cuts active at the current node.	p. 820
`getcplist`	Get a set of cut indices from the cut pool.	p. 821
`loadcuts`	Load a set of cuts into the problem in the optimizer.	p. 822
`storecut`	Store a cut into the cut pool.	p. 823
`storecuts`	Store an array of cuts into the cut pool.	p. 824

addcut

Purpose

Add a cut to the problem in the optimizer.

Synopsis

```
procedure addcut(cuttype:integer, type:integer, linexp:linctr)
```

Arguments

`cuttype` Integer number for identification of the cut

`type` Cut type (equation/inequality), which may be one of:

- `CT_GEQ` Inequality (greater or equal)
- `CT_LEQ` Inequality (less or equal)
- `CT_EQ` Equality

`linexp` Linear expression (= unbounded constraint)

Further information

This procedure adds a cut to the problem in the Optimizer. The cut is applied to the current node and all its descendants.

Related topics

`addcuts`, `delcuts`.

Module

mmxprs

addcuts

Purpose

Add an array of cuts to the problem in the optimizer.

Synopsis

```
procedure addcuts(cuttype:array(range) of integer, type:array(range) of
      integer, linexp:array(range) of linctr)
```

Arguments

`cuttype` Array of integer number for identification of the cuts

`type` Array of cut types (equation/inequality):

- `CT_GEQ` Inequality (greater or equal)
- `CT_LEQ` Inequality (less or equal)
- `CT_EQ` Equality

`linexp` Array of linear expressions (= unbounded constraints)

Further information

This procedure adds an array of cuts to the problem in the Optimizer. The cuts are applied to the current node and all its descendants. Note that the three arrays that are passed as parameters to this procedure must have the same index set.

Related topics

`addcut`, `delcuts`.

Module

mmxprs

delcuts

Purpose

Delete cuts from the problem in the optimizer.

Synopsis

```
procedure delcuts(keepbasis:boolean, cuttype:integer,
      interpret:integer,delta:real, cuts:set of integer)
procedure delcuts(keepbasis:boolean, cuttype:integer, interpret:integer,
      delta:real)
```

Arguments

`keepbasis`	`false`	Cuts with non-basic slacks may be deleted
	`true`	Ensures that the basis will be valid
`cuttype`	Integer number for identification of the cut(s)	
`interpret`	The way in which the cut type is interpreted:	
	`-1`	Delete all cuts
	`1`	Treat cut types as numbers
	`2`	Treat cut types as bitmaps (delete cut if any bit matches any bit set in `cuttype`)
	`3`	Treat cut types as bitmaps (delete cut if all bits match those set in `cuttype`)
`delta`	Only delete cuts with an absolute slack value greater than `delta`. To delete all the cuts set this parameter to a very small value (*e.g.* `-MAX_REAL`)	
`cuts`	Set of cut indices, if not specified all cuts of type `cuttype` are deleted	

Further information

This procedure deletes cuts from the problem loaded in the Optimizer. If a cut is ruled out by any of the given criteria it will not be deleted.

Related topics

`addcut`, `addcuts`.

Module

mmxprs

dropcuts

Purpose

Drop a set of cuts from the cut pool.

Synopsis

```
procedure dropcuts(cuttype:integer, interpret:integer, cuts:set of integer)
procedure dropcuts(cuttype:integer, interpret:integer)
```

Arguments

`cuttype` Integer number for identification of the cut(s)

`interpret` The way in which the cut type is interpreted:

`-1`	Drop all cuts
`1`	Treat cut types as numbers
`2`	Treat cut types as bitmaps (delete cut if any bit matches any bit set in `cuttype`)
`3`	Treat cut types as bitmaps (delete cut if all bits match those set in `cuttype`)

`cuts` Set of cut indices in the cut pool, if not specified all cuts of type `cuttype` are deleted

Further information

This procedure drops a set of cuts from the cut pool. Only those cuts which are not applied to active nodes in the branch-and-bound tree will be deleted.

Related topics

`storecut`, `storecuts`.

Module

mmxprs

getcnlist

Purpose

Get the set of cuts active at the current node.

Synopsis

```
procedure getcnlist(cuttype:integer,interpret:integer, cuts:set of integer)
```

Arguments

`cuttype` Integer number for identification of the cut(s), -1 to return all active cuts

`interpret` The way in which the cut type is interpreted:

`-1`	Get all cuts
`1`	Treat cut types as numbers
`2`	Treat cut types as bitmaps (get cut if any bit matches any bit set in `cuttype`)
`3`	Treat cut types as bitmaps (get cut if all bits match those set in `cuttype`)

`cuts` Set of cut indices

Further information

This procedure gets the set of active cut indices at the current node in the Optimizer. The set of cut indices is returned in the parameter `cuts`.

Related topics

`getcplist`.

Module

mmxprs

getcplist

Purpose

Get a set of cut indices from the cut pool.

Synopsis

```
procedure getcplist(cuttype:integer,interpret:integer,delta:real, cuts:set
      of integer,viol:array(range) of real)
```

Arguments

`cuttype` Integer number for identification of the cut(s)

`interpret` The way in which the cut type is interpreted:

`-1`	Get all cuts
`1`	Treat cut types as numbers
`2`	Treat cut types as bitmaps (get cut if any bit matches any bit set in `cuttype`)
`3`	Treat cut types as bitmaps (get cut if all bits match those set in `cuttype`)

`delta` Only return cuts with an absolute slack value greater than `delta`

`cuts` Set of cut indices in the cut pool

`viol` Array where the slack variables for the cuts will be returned

Further information

This procedure gets a set of cut indices from the cut pool. The set of indices is returned in the parameter `cuts`.

Related topics

`getcnlist`.

Module

mmxprs

loadcuts

Purpose

Load a set of cuts from the cut pool into the problem in the optimizer.

Synopsis

```
procedure loadcuts(cuttype:integer, interpret:integer, cuts:set of integer)
procedure loadcuts(cuttype:integer, interpret:integer)
```

Arguments

`cuttype` Integer number for identification of the cut(s)

`interpret` The way in which the cut type is interpreted:

- `-1` Load all cuts
- `1` Treat cut types as numbers
- `2` Treat cut types as bitmaps (load cut if any bit matches any bit set in `cuttype`)
- `3` Treat cut types as bitmaps (load cut if all bits match those set in `cuttype`)

`cuts` Set of cut indices in the cut pool, if not specified all cuts of type `cuttype` are loaded

Further information

This procedure loads a set of cuts into the Optimizer. The cuts remain active at all descendant nodes.

Related topics

`storecut`, `storecuts`.

Module

mmxprs

storecut

Purpose

Store a cut into the cut pool.

Synopsis

```
function storecut(nodupl:integer, cuttype:integer, type:integer,
       linexp:linctr):integer
```

Arguments

`nodupl` Flag indicating how to deal with duplicate entries:

`0`	No check
`1`	Check for duplicates among cuts of the same cut type
`2`	Check for duplicates among all cuts

`cuttype` Integer number for identification of the cut

`type` Cut type (equation/inequality):

`CT_GEQ`	Inequality (greater or equal)
`CT_LEQ`	Inequality (less or equal)
`CT_EQ`	Equality

`linexp` Linear expression (= unbounded constraint)

Return value

Index number of the cut stored in the cut pool.

Further information

This function stores a cut into the cut pool without applying it to the problem at the current node. The cut has to be loaded into the problem with procedure `loadcuts` in order to become active at the current node.

Related topics

`dropcuts`, `loadcuts`, `storecuts`.

Module

mmxprs

storecuts

Purpose

Store an array of cuts into the cut pool.

Synopsis

```
procedure storecuts(nodupl:integer, cuttype:array(range) of integer,
       type:array(range) of integer,
       linexp:array(range) of linctr,
       ndx_a:array(range) of integer)
procedure storecuts(nodupl:integer, cuttype:array(range) of integer,
       type:array(range) of integer,
       linexp:array(range) of linctr,
       ndx_s:set of integer)
```

Arguments

`nodupl` Flag indicating how to deal with duplicate entries:

`0`	No check
`1`	Check for duplicates among cuts of the same cut type
`2`	Check for duplicates among all cuts

`cuttype` Array of integer number for identification of the cuts

`type` Array of cut types (equation/inequality):

`CT_GEQ`	Inequality (greater or equal)
`CT_LEQ`	Inequality (less or equal)
`CT_EQ`	Equality

`linexp` Array of linear expressions (= unbounded constraints)

`ndx_a` Interval of index numbers of stored cuts

`ndx_s` Set of index numbers of stored cuts

Further information

This function stores an array of cuts into the cut pool without applying them to the problem at the current node. The cuts have to be loaded into the problem with procedure `loadcuts` in order to become active at the current node. The cut manager returns the indices of the stored cuts in the form of an array `ndx_a` or a set of integers `ndx_s`. Note that the four arrays that are passed as parameters to this procedure must have the same index set.

Related topics

`dropcuts`, `loadcuts`, `storecut`.

Module

mmxprs

CHAPTER 22

python3

The *python3* Mosel module (*"python3.dso"*) makes it possible to easily exchange data between Mosel and Python® and to execute Python scripts from within Mosel.

Python is an interpreted programming language for general-purpose programming that has also become popular for scientific and numeric computing. The reference implementation (CPython) is available as Free Software under the terms of the Python Software Foundation License, which is compatible with the GNU General Public License. "Python" is a registered trademark of the Python Software Foundation.

To use this module, the following line must be included in the header of the Mosel model file:

```
uses "python3"
```

22.1 Introduction

This module implements functionality for exchanging data between a Mosel model and Python 3 (CPython) and for calling Python 3 scripts.

The *python3* module defines an I/O driver for exchanging data using the `initializations from` and `initializations to` Mosel constructs.

It is the Mosel run-time library that loads and runs the Python interpreter, not the other way round.

The purpose of the module is to make the extensive scientific and numeric capabilities of Python available from Mosel. This module does not implement an interactive Python shell. However, the interaction of the Mosel model and the Python interpreter is similar to an interactive shell: transferring data to Python and executing Python scripts changes the state of the interpreter.

22.1.1 Prerequisites

This module does not include Python binaries. In order to use Python you need a working installation of Python 3 targeting the same platform as Mosel (you won't be able to use, *e.g.*, the Windows 32-bit version of Python from the Windows 64-bit version of Mosel). *The supported Python versions are 3.7 to 3.9*. Version 3.8.0 is not and cannot be supported, because of Python issue #37633. For Windows users it is recommended to get the binaries from www.python.org. Advanced users, who want to use multiple Python environments on a single machine, can download and install the Anaconda Python distribution from www.anaconda.com. On recent versions of Mac OS, Python 3 should be pre-installed. Advanced users can also install the binaries from the Python or Anaconda website or via Homebrew. On Linux, Python 3 is usually part of your distribution and provided in a package called "python3" that can be installed via the package manager. Note that Python 3 is not part of the Red Hat 6 standard repository. In order to use the latest Python release on Red Hat 6, we recommend to download the latest Anaconda Python distribution for Linux from the Anaconda website. It is not recommended to compile Python from source.

The Mosel module *python3* tries to automatically locate the correct Python libraries on your system, applying the following rules. If the environment variable *PYTHONHOME* is specified, it will load the libraries of the Python installation in that directory. Otherwise, it searches for the Python executable in the directories specified in the *PATH* environment variable. If the Python executable has been found, the module will try to load the libraries of the Python installation of that Python executable. If the libraries could not be loaded with the help of the environment variables, then on Windows they are loaded from the latest Python installation specified in the registry (keys: *HKEY_CURRENT_USER* and *HKEY_LOCAL_MACHINE\SOFTWARE\Python\PythonCore\3.*\InstallPath*). If the previous steps failed, then the *python3* module will load the most recent libraries from the standard library search paths. On Windows it looks for `python3*.dll` and `python3.dll`, on Linux for `libpython3.*[m].so` and `libpython3.so`, and on Mac OSX for `libpython3.*[m].dylib` and `libpython3.dylib`.

If you have multiple installations of Python, or if Python could not be located automatically, or if the initialization of Python fails, you will need to set the environment variable *PYTHONHOME* to point to your Python installation directory or set *PATH* to include the location of the Python executable.

Note that the loading of Python is not influenced by Mosel statements like `setparam("workdir",...)` or `setenv("PYTHONHOME",...)` in the Mosel model that uses the Python module since these don't affect the process environment used for Python loading. The environment variables must be set before launching the Mosel instance that serves for executing Python scripts in order to influence the loading of Python.

As an example, if Python 3.x is installed on Windows in `"C:\Program Files\Python3x"` then this directory is also the correct value for the *PYTHONHOME* environment variable or alternatively, add this directory to the *PATH* environment variable.

The module supports the conversion between Mosel types and pandas and NumPy types. The supported pandas versions are 0.25 to 1.3 and the supported NumPy versions are 1.16 to 1.21. NumPy 1.19.4 is not supported on Windows, because of a problem in the Windows runtime (#1207405).

22.1.2 Windows Anaconda Setup

Set the `PYTHONHOME` system environment variable to the base directory of Anaconda or to the home directory of a specific Anaconda environment, *e.g.*, `C:\ProgramData\Anaconda3\envs\py373`. The NumPy module that ships with Anaconda requires the Math Kernel Library (MKL). It is necessary to add

```
%PYTHONHOME%\Library\bin
```

to the `PATH` system environment variable such that NumPy can find the DLLs of that library. If NumPy cannot find the library, the import of NumPy and pandas will fail with an error message similar to:

```
Traceback ...
    from . import _mklinit
ImportError: DLL load failed: The specified module could not be found.
```

If you change the system environment variables, then it is necessary to restart Workbench such that the changes take effect. If you run an Insight 5 Execution Worker, setting the system environment variables `PYTHONHOME` or `PATH` has no effect on the Insight app, because Insight does not pass those variables to the Insight app. Section *Xpress Insight 5 configuration* provides information about how to set those variables in Insight.

22.1.3 Linux Anaconda Setup

Set the `PYTHONHOME` environment variable to the base directory of Anaconda or to the home directory of a specific Anaconda environment, *e.g.*, `/opt/anaconda3/envs/py373`. The pandas module that ships

with Anaconda may require a version of the C++ standard library which is more recent than the one that ships with your operating system. The required library ships with Anaconda and the loading of that library can be forced by adding

```
$PYTHONHOME/lib/libstdc++.so
```

to the `LD_PRELOAD` environment variable. If an incompatible version gets loaded, then the initialization of pandas will fail with an error message similar to:

```
ImportError: /lib64/libstdc++.so.6: version `GLIBCXX_3.4.21' not found
```

If you run an Insight 5 Execution Worker, setting the system environment variables `PYTHONHOME` or `LD_PRELOAD` has no effect on the Insight app, because Insight does not pass those variables to the Insight app. Section *Xpress Insight 5 configuration* provides information about how to set those variables in Insight.

22.1.4 Python initialization

The Python environment is automatically initialized at the point where a Mosel model uses for the first time any function that requires it. So we can have the following small example that just executes a Python script:

```
model "Python script example"
  uses "python3"
  pyrun("my-python-script.py")
end-model
```

Alternatively it is possible to explicitly initialize Python using the `pyinit` function. If the initialization fails, activate additional logging by setting the parameter `pyinitverbose` to `true` before initializing Python and double check the values of your environment variables (see previous sections).

At the end of the model execution, the Python environment will automatically be released. It is also possible to explicitly release the environment using `pyunload`. This can be useful for freeing resources allocated by Python.

It is only possible to initialize one Python interpreter per Mosel instance. For that reason it is not possible to initialize and use the Python interpreter in two models in parallel if both models are run in the same Mosel instance. However, you can initialize and use multiple interpreters in concurrent models if each model is run in a separate Mosel instance.

22.1.5 Data types

The types of data that can be exchanged with Python are the Mosel types `boolean`, `integer`, `real`, `string` and `text`, plus arrays, lists and sets of these. Nested compositions are supported. Mosel lists and sets are exported to Python lists and sets. Both, dense and sparse Mosel arrays are supported and by default they are mapped to dictionaries of the corresponding element type. If the pandas interface is initialized, then arrays and lists of arrays can also be mapped to pandas Series and DataFrames. Moreover, Mosel arrays can be initialized from NumPy ndarrays and Mosel scalars be initialized from NumPy scalars (see `pyinitpandas` and `pyusepandas` for more details).

The following example shows how to invert a matrix with NumPy:

```
declarations
  I, J: range
  A, A_inverse: array(I, J) of real
end-declarations
```

```
writeln("Run Python script that defines invert_matrix function.")
pyinitpandas
pyrun("invert_matrix.py")

I := 0..2
J := 0..2
A :: [1,0,3,
      0,1,2,
      0,0,1]

writeln("Invert matrix with NumPy.")
pycall("invert_matrix", A_inverse, A)

writeln("Matrix A_inverse:")
writeln("A_inverse: ", A_inverse)
```

At the beginning of this code snippet the pandas interface is initialized via a call to `pyinitpandas`. This enables the conversion of Mosel arrays from and to pandas Series and from NumPy arrays from this point onwards—this statement will typically occur at the beginning of the program, but standard *python3* functionality can already be used before to it. After the pandas initialization a Python example script in a separate file `invert_matrix.py` is executed, which defines the `invert_matrix` Python function. This function is then invoked via the `pycall` procedure. The first parameter of this procedure is the Python function name, the second one is the Mosel array that will be used for storing the result, and the last parameter is the input parameter for the Python function. The Python function takes a pandas Series with a two-dimensional MultiIndex as input and returns a two-dimensional NumPy ndarray:

```
def invert_matrix(series):
    # Get pivot table of MultiIndex Series as DataFrame.
    df = series.unstack()

    # Compute and return inverse matrix as NumPy ndarray.
    return inv(df)
```

See the model `invert-matrix.mos` for a full example. At first, the function creates a pivot table of the MultiIndex Series, such that the resulting DataFrame looks like a two-dimensional matrix. This matrix-like DataFrame is used as an input value for the NumPy `inv` function, which returns a two-dimensional ndarray, which is then passed to Mosel.

Note that sparse Mosel arrays are exported to sparse Python dictionaries or pandas Series. In this example, the Mosel matrix `A` is dense, hence the pandas Series is also dense, that is, for each index tuple `(i, j)` in the cross product of `I` and `J` the pandas Series has a value.

When initializing a Mosel array, list, or set from a Python type, the initialization of the Mosel type is additive, which means that the elements of the Python type are added to the existing Mosel array, list, or set. In the example above, the pandas Series is dense such that all elements of the Mosel array will be overwritten. However, if the pandas Series (or dictionary) is sparse and the Mosel array is non-zero, it is necessary to manually clear its contents before initializing it with values from the sparse Python type. In that situation, the Mosel array should be cleared with `reset`. See Section 22.6.1 for an example with a sparse array and `reset`: `io_example.mos`.

22.2 Xpress Insight 4 configuration

The *python3* module can only be used when Mosel restrictions are disabled (`MOSEL_RESTR=0`). When the restrictions are disabled, any executed Mosel and Python code have the same rights (in particular for file system access) as the operating system user that runs the Insight Execution Worker. In order to use the *python3* module in an Insight app, it is necessary to relax the Mosel restrictions in the Insight Execution Worker configuration file. On Windows, the default location of the worker configuration file is `%XPRESSDIR%\bin\xprmsrv.cfg`. After relaxing the Mosel restrictions, we strongly recommend that the Insight administrator makes sure of the following points:

- The operating system user that runs the Insight Execution Worker should only be granted the minimal rights that are necessary for running the Insight app.
- Access to the workers should be protected by a password and additionally by IP filters (see the example extract of the configuration file `xprmsrv.cfg` below).
- If the network is not trusted, the workers should only accept SSH connections: Set `TCP_PORT=-1` (configurable via `xprmsrv.cfg`) and use `xssh` instead of the `xsrv` protocol (Execution Worker configuration in the Insight admin interface).
- Only trusted users should be granted the right to upload trusted Insight apps to the Insight Server.

And the Insight app developer needs to address the following points:

- The app should not execute any untrusted Python scripts that an end user may have uploaded as an app attachment (see `pyrun` function).
- The app should not concatenate untrusted strings entered by the end user (*e.g.* Insight scalars or arrays) into a Python evaluation string, because this could allow an attacker to inject and execute custom Python code. For example, the first function input parameter of `pycall`, `pyexec` and `pyget` is a Python evaluation string. Note that it is safe to transfer untrusted data between Mosel and Python variables. The developer just needs to avoid using untrusted strings directly in a Python evaluation string parameter.

If the Insight Execution Worker runs on the same machine as the Insight Server, it is recommended to modify the configuration settings in `xprmsrv.cfg` as follows:

```
...
# INFO: It is recommended to replace +ALL by -ALL in XPRMSRV_ACCESS when MOSEL_RESTR=0.
XPRMSRV_ACCESS=+127.0.0.1 -ALL
[insight]
# INFO: It is recommended to protect the worker with a password when MOSEL_RESTR=0.
PASS=my_password
# IMPORTANT: Replace the existing MOSEL_RESTR line to disable the Mosel restrictions.
MOSEL_RESTR=0
PYTHONHOME=C:\ProgramData\Anaconda3
PATH=${PYTHONHOME}\Library\bin;${PATH}
...
```

Restart the **Execution Worker** after changing the configuration file. Then log into the Insight admin interface, go to *Execution Services*, edit the Execution Worker, enter the password in the password edit field and save the changes.

Depending on your system configuration, the `PYTHONHOME` environment variable is optional. The `PATH` entry is only necessary for Anaconda on Windows. You can also specify the `PYTHONHOME` and `PATH` environment variables as system environment variables. Note that it is *not* sufficient to specify them for your personal user account, because the Insight service runs as a different user.

22.3 Xpress Insight 5 configuration

The *python3* module can only be used when Mosel restrictions are disabled (`MOSEL_RESTR=0`). When the restrictions are disabled, any executed Mosel and Python code have the same rights (in particular for file system access) as the operating system user that runs the Insight Execution Worker. In order to use the *python3* module in an Insight Mosel app, it is necessary to relax the Mosel restrictions in the Insight Execution Worker `application.properties` file. On Windows, the default location of the worker properties file is `C:\ProgramData\FICO\XpressInsight\Worker\config\application.properties`. To disable the restrictions, add the following line:

```
insight.worker.execution.environment.MOSEL_RESTR=0
```

After relaxing the Mosel restrictions, we strongly recommend that the Insight administrator makes sure of the following points:

- The operating system user that runs the Insight Execution Worker should only be granted the minimal rights that are necessary for running the Insight app.
- Only trusted users should be granted the right to upload trusted Insight apps to the Insight Server.

And the Insight app developer needs to address the following points:

- The app should not execute any untrusted Python scripts that an end user may have uploaded as an app attachment (see `pyrun` function).
- The app should not concatenate untrusted strings entered by the end user (*e.g.* Insight scalars or arrays) into a Python evaluation string, because this could allow an attacker to inject and execute custom Python code. For example, the first function input parameter of `pycall`, `pyexec` and `pyget` is a Python evaluation string. Note that it is safe to transfer untrusted data between Mosel and Python variables. The developer just needs to avoid using untrusted strings directly in a Python evaluation string parameter.

The Insight worker controls the environment variables under which the model runs. In particular, it clears all environment variables except for a list of allowed variables related to Xpress. For this reason, it may be necessary to set certain environment variables in the worker `application.properties` file, such that the *python3.dso* Mosel module can find and use Python. For example:

```
...
# MANDATORY: Replace the existing MOSEL_RESTR line to disable the Mosel restrictions.
insight.worker.execution.environment.MOSEL_RESTR=0

# IMPORTANT: Use one of the following example blocks to configure a Python environment:

# Windows: No configuration needed for using the latest Python.org
#          installation that is registered in the Windows registry.

# Configuration for a specific installation from Python.org.
insight.worker.execution.environment.PATH=C:\\Program Files\\Python39

# Alternative configuration for a specific installation from Python.org.
insight.worker.execution.environment.PYTHONHOME=C:\\Program Files\\Python39

# Configuration for the base environment of Anaconda on Windows.
insight.worker.execution.environment.PYTHONHOME=C:\\ProgramData\\Anaconda3
insight.worker.execution.environment.PATH=\
${insight.worker.execution.environment.PYTHONHOME}\\Library\\bin
...
```

Restart the **Execution Worker** after changing the properties file.

Depending on your system configuration, the `PYTHONHOME` environment variable is optional. Adding `${PYTHONHOME}\Library\bin` to the `PATH` is only necessary for Anaconda on Windows. Note that it is *not* sufficient to add these as either system or user environment variables as the worker only uses the environment variables configured in its `application.properties` file and the allowed Xpress related variables.

22.4 Control parameters

The following parameters are defined by the module *python3*:

pyinitverbose	Show additional log messages when initializing Python.	p. 831
pyusepandas	Enable and control pandas and NumPy conversion.	p. 831

pyinitverbose

Description Set this parameter to `true` to activate some additional logging of how the module looks for and finds your Python environment. The log messages are written to the model's output stream.

Type Boolean, read/write

Default value false

See also `pyinit`, `pyinitpandas`

Module python3

pyusepandas

Description If this parameter is `true`, then the next usage of any Python functionality will trigger the initialization of the pandas interface. When the interface is initialized, Mosel scalars can also be initialized from NumPy scalars, arrays can also be initialized from NumPy ndarrays and pandas Series, and lists of arrays can be initialized from pandas DataFrames. Once initialized, the pandas interface will remain initialized even after switching `pyusepandas` off. In particular, it will still be possible to initialize Mosel types from pandas and NumPy types.

When converting data from Mosel to Python, the target type depends on the value of `pyusepandas`: When the parameter is `true`, Mosel arrays and lists of arrays are converted to pandas Series and DataFrames; when it is `false`, then Mosel arrays will be converted to Python dictionaries. Mosel lists of arrays cannot be initialized to a Python type when this parameter is disabled.

Type Boolean, read/write

Default value false

See also `pyinitpandas`, *Driver python*

Module python3

22.5 Procedures and functions

The procedures and functions of the *python3* module fail in case of Python compile-time or run-time errors.

pycall	Call a Python object, *e.g.* a function, with optional input arguments and convert the result to a Mosel variable.	p. 833
pyexec	Execute Python statements from a string.	p. 835
pyget	Get the result of a Python expression as Mosel variable.	p. 836
pygetdf	Initialize a list of Mosel arrays from the columns of a pandas DataFrame.	p. 837
pyinit	Initialize the Python interpreter.	p. 839

`pyinitpandas`	Set `pyusepandas` parameter to true and initialize the pandas interface. p. 840	
`pyrun`	Run a Python script and wait until it is finished.	p. 841
`pyset`	Assign a Mosel value to a global Python variable.	p. 842
`pysetdf`	Convert a list of Mosel arrays to a pandas DataFrame.	p. 843
`pyunload`	Release the Python interpreter and its resources.	p. 844

pycall

Purpose

Call a Python object, *e.g.* a function, with optional input arguments and convert the result to a Mosel variable.

Synopsis

```
procedure pycall(expr:string,result:array|set|list[, arg1...])
procedure pycallvoid(expr:string[, arg1...])
function pycallbool(expr:string[, arg1...]):boolean
function pycallint(expr:string[, arg1...]):integer
function pycallreal(expr:string[, arg1...]):real
function pycallstr(expr:string[, arg1...]):string
function pycalltext(expr:string[, arg1...]):text
```

Arguments

`expr`	Global name of a callable Python object or Python expression that evaluates to a callable object
`result`	Result Mosel array, set or list
`arg1, arg2,...`	Optional input arguments for the object call

Example 1

The following example calls the Python `print` and `max` functions. The Mosel input arguments are automatically converted to Python objects and the return value of `max` is converted to a Mosel real.

```
pycallvoid("print", "Python objects:", true, 1, 2.2, [3,4], {5})
writeln("max: ", pycallreal("max", [1.1, 7.7, 4.4]))
```

Example 2

The following example uses pandas to compute the mean value of two Mosel arrays. The Mosel input arrays are passed as a single list of arrays with compatible array indices and are automatically converted to a single pandas DataFrame. The return value of the `mean` function is a pandas Series and its elements will be written to the Mosel `Result` array.

```
declarations
  Input1, Input2, Result: array(range) of real
end-declarations

Input1 :: (0..4)[1, 2, 3, 4, 5]
Input2 :: (0..4)[7, -1, -3, 1, 2]
pyinitpandas
pyexec("def mean(df, axis): return df.mean(axis)")
pycall("mean", Result, [Input1, Input2], 1)
writeln("mean: ", Result)
```

It is recommended to define small global wrapper functions like in this example, instead of calling functions or methods with the help of an expression like `"pandas.Series.mean"`. The global function can be found directly without having to perform an expensive Python string evaluation to retrieve the callable object.

Further information

1. At first, the function interprets the expression string as a global Python object name and tries to access it by getting it from the attributes of the Python `__main__` module. If this fails, the expression is evaluated by Python. Then the expression result object will be called with the optional input arguments. Finally, the result of the object call is stored in or returned as a Mosel variable. This is equivalent to the Python expression:

   ```
   expr(arg1, ...)
   ```

   It is a fatal error if the expression cannot be evaluated or if the object call or the type conversion between Python and Mosel fails.

2. The first version of the `pycall` routine stores the result in an array, set or list. Its behavior is additive: it writes the new elements to the existing Mosel array, set or list without clearing previously existing elements. Use `reset` to manually clear an array, set or list before calling this function.

3. See the I/O *Driver python* Section for further details about type conversions.

4. Do not concatenate untrusted strings from the end user into the `expr` string. See Section *Xpress Insight 5 configuration* for more information.

Related topics

`pyexec`, `pyget`, *Driver python*

Module

python3

pyexec

Purpose

Execute Python statements from a string.

Synopsis

```
procedure pyexec(code:string)
```

Argument

`code` Python statements to execute

Example

The following model runs Python statements from a string:

```
model "Python script from string"
  uses "python3"
  writeln("Python version:")
  pyexec("import platform; print(platform.python_version())")
end-model
```

Further information

1. This function compiles and runs a Python script from a string buffer and waits for its termination. It is a fatal error if the compilation fails or if a Python run-time error occurs.
2. Use the I/O *Driver python* and the functions `pyget` and `pyset` to transfer data between Mosel and Python. Use `pyget` to evaluate a single expression with return value and use `pycall` to call a single function with input arguments or return value.
3. Do not concatenate untrusted strings from the end user into the `code` string. See Section *Xpress Insight 5 configuration* for more information.

Related topics

`pycall`, `pyget`, `pyrun`, *Driver python*

Module

python3

pyget

Purpose

Get the result of a Python expression as Mosel variable.

Synopsis

```
procedure pyget(expr:string,var:array|set|list)
function pygetbool(expr:string):boolean
function pygetint(expr:string):integer
function pygetreal(expr:string):real
function pygetstr(expr:string):string
function pygettext(expr:string):text
```

Arguments

`expr` Python expression to evaluate

`var` Destination Mosel array, set or list

Example

The following example evaluates a Python dictionary expression and writes the result to a Mosel array. It then retrieves a real value from Python:

```
declarations
  Arr: dynamic array(set of integer) of real
end-declarations

pyexec("import math")
Arr(0) := 0.1; Arr(1) := 1.1          ! Old array data
reset(Arr)                            ! Clear old array data
pyget("{1: math.pi, 2: math.e}", Arr) ! Add new data to array

writeln("Arr: ", Arr)
writeln("pi:  ", pygetreal("math.pi"))
```

Further information

1. At first, the function interprets the expression as a global variable name and tries to access the variable by getting it from the attributes of the Python `__main__` module. If this fails, the expression is evaluated by Python and the result is written to or returned as a Mosel variable. It is a fatal error if the expression evaluation or the type conversion fails.
2. The first version of the `pyget` routine is additive: it writes the new elements to the existing Mosel array, set or list without clearing previously existing elements. Use `reset` to manually clear an array, set or list before calling this function.
3. See the I/O *Driver python* Section for further details about type conversions. Use `pycall` to call a single function with input arguments or return value.
4. Do not concatenate untrusted strings from the end user into the `expr` string. See Section *Xpress Insight 5 configuration* for more information.

Related topics

`pycall`, `pygetdf`, `pyset`, *Driver python*

Module

python3

pygetdf

Purpose

Initialize a list of Mosel arrays from the columns of a pandas DataFrame.

Synopsis

```
procedure pygetdf(expr:string,result:list of array)
procedure pygetdf(expr:string,result:list of array,labels:list of string)
```

Arguments

`expr`	Python expression that evaluates to a pandas DataFrame
`result`	Mosel list of arrays to be initialized from pandas DataFrame
`labels`	Labels of the pandas DataFrame columns used for initialization

Example

In this example, two Mosel arrays with the same index sets are initialized from a DataFrame. With the first call to `pygetdf`, the arrays are initialized based on the order of the DataFrame columns, with the second they are initialized using column labels.

```
declarations
    I, J: set of integer
    Numbers: dynamic array(I, J) of integer
    Labels: dynamic array(I, J) of string
end-declarations

pyinitpandas
pyexec(`
import pandas as pd
df = pd.DataFrame(
    data=[[11, "eleven"], [23, "twenty-three"], [42, "forty-two"]],
    index=pd.MultiIndex.from_tuples([(1, 1), (2, 3), (4, 2)]),
    columns=["number", "label"])
print(df)
`)

pygetdf("df", [Numbers, Labels])
writeln("I: ", I, "\nJ: ", J)
writeln("Numbers: ", Numbers, "\nLabels:  ", Labels)

reset(Numbers); reset(Labels)
pygetdf("df", [Labels, Numbers], ["label", "number"])
writeln("Numbers: ", Numbers, "\nLabels:  ", Labels)
```

Further information

1. The first version of the procedure initializes the arrays based on the order of the DataFrame columns. The second version uses column labels to select the DataFrame columns that are used for the initialization.
2. At first, the procedure interprets the expression as a global variable name and tries to access the variable by getting it from the attributes of the Python `__main__` module. If this fails, the expression is evaluated by Python and the result is used for the Mosel array initialization. It is a fatal error if the expression evaluation or the type conversion fails.
3. The initialization of the result arrays is additive: new elements are written to the existing arrays without clearing previously existing elements. Use `reset` to manually clear the arrays before calling this procedure.
4. DataFrame conversion is supported in all module functions that accept lists of arrays. In particular, it is supported by `pycall` and the I/O *Driver python* .
5. Do not concatenate untrusted strings from the end user into the `expr` string. See Section *Xpress Insight 5 configuration* for more information.

Related topics

`pyget`, `pysetdf`, `pyinitpandas`

Module

python3

pyinit

Purpose

Initialize the Python interpreter.

Synopsis

```
procedure pyinit
```

Example

The following example initializes Python:

```
pyinit
```

Further information

1. The use of this procedure is optional: Python is automatically initialized upon first use.
2. You can only initialize one Python interpreter per Mosel instance. The initialization will fail if you attempt to initialize two interpreters in the same Mosel instance. Use `pyunload` to release the interpreter and its resources. The interpreter cannot be reinitialized in the same Mosel instance after unloading it.
3. In order to use multiple interpreters in parallel, it is necessary to create a new Mosel instance for each additional interpreter. Use the `connect` function from the *mmjobs* module to create a new instance.
4. If the initialization of Python fails, activate additional logging by setting the parameter `pyinitverbose` to `true` before initializing Python, double check the values of your environment variables (see the *Introduction* section) and check the *Troubleshooting* section.

Related topics

`connect`, `pyinitverbose`, `pyinitpandas`, `pyunload`

Module

python3

pyinitpandas

Purpose

Set `pyusepandas` parameter to true and initialize the pandas interface.

Synopsis

```
procedure pyinitpandas
```

Example

The following example first prints a Mosel array as Python dictionary and then initializes the pandas interface and prints the array as pandas Series:

```
declarations
    A: array(range) of real
end-declarations

A :: (-1..2)[-1.1, 0, 1.1, 2.2]
pycallvoid("print", "A as Python dict:\n", A)
pyinitpandas
pycallvoid("print", "A as pandas Series:\n", A)
```

Further information

1. This procedure is equivalent to the following two commands:

   ```
   setparam("pyusepandas", true)
   pyinit
   ```

   See the documentation of `pyusepandas` and `pyinit` for further information. The I/O *Driver python* section provides an overview of the additionally available type mappings after having initialized the pandas interface.

2. At first, the procedure sets the parameter `pyusepandas` to true, then it initializes the Python interpreter if it has not yet been initialized and finally it initializes the pandas interface if it has not yet been initialized. Once initialized, the pandas functionality will continue to be available even after switching `pyusepandas` off. See `pyusepandas` for more information.

Related topics

`pyinit`, `pyinitverbose`, `pyunload`, `pyusepandas`, *Driver python*

Module

python3

pyrun

Purpose

Run a Python script and wait until it is finished.

Synopsis

```
procedure pyrun(filename:string)
```

Argument

`filename` Regular file name of a Python script

Example

The following model runs a Python script:

```
model "Python script example"
  uses "python3"
  pyrun("my-python-script.py")
end-model
```

Further information

1. The function compiles and runs a Python script and waits for its termination. It is a fatal error if the compilation fails or if a Python run-time error occurs.
2. Use the I/O *Driver python* and the functions `pyget` and `pyset` to transfer data between Mosel and Python.
3. Do not run untrusted scripts, *e.g.*, scripts provided by the end user. See Section *Xpress Insight 5 configuration* for more information.

Related topics

`pycall`, `pyexec`, *Driver python*

Module

python3

pyset

Purpose

Assign a Mosel value to a global Python variable.

Synopsis

```
procedure
        pyset(varname:string,var:boolean|integer|real|string|text|array|list|set)
```

Arguments

`varname` Global Python variable name

`var` Mosel value to be assigned to Python variable

Example

The following example writes a Mosel array to a Python dictionary and a Mosel list to a Python list:

```
declarations
  MosArray: array(set of string) of real
end-declarations

pyset('py_list', [1, 2, 3])    ! Mosel list -> Python list.
pyexec('print("py_list:", py_list)')

MosArray('e') := M_E; MosArray('pi') := M_PI

setparam('pyusepandas', false) ! Mosel array -> Python dictionary.
pyset('py_dict', MosArray)
pyexec('print("py_dict:", py_dict)')

setparam('pyusepandas', true)  ! Mosel array -> Pandas Series.
pyset('pd_series', MosArray)
pyexec('print("pd_series:", pd_series, sep="\n")')
```

Further information

1. The procedure creates or overwrites the global variable by writing the new value to the attributes of the Python `__main__` module. If the variable name is not a valid Python variable identifier the procedure will succeed anyway and write the value to the module attributes using the name specified in `varname`.
2. The procedure replaces previously existing global variables. It does not update or add data to existing Python structures.
3. See the I/O *Driver python* Section for more details about type conversions.

Related topics

`pyget`, `pyexec`, `pysetdf`, `pyusepandas`, *Driver python*

Module

python3

pysetdf

Purpose

Convert a list of Mosel arrays to a pandas DataFrame.

Synopsis

```
procedure pysetdf(varname:string,input:list of array)
procedure pysetdf(varname:string,input:list of array,labels:list of string)
```

Arguments

`varname`	Global Python variable name for the new DataFrame
`input`	Mosel list of arrays to be converted to the DataFrame
`labels`	Labels for the DataFrame columns

Example

In this example, two Mosel arrays with the same index sets are converted to a DataFrame. With the first call to `pysetdf`, a DataFrame is created with integer column labels and the second creates a DataFrame with string column labels.

```
declarations
    I, J: set of integer
    Numbers: dynamic array(I, J) of integer
    Labels: dynamic array(I, J) of string
end-declarations

pyinitpandas
Numbers(1,1) := 11;    Labels(1,1) := "eleven"
Numbers(2,3) := 23;    Labels(2,3) := "twenty-three"
Numbers(4,2) := 42;    Labels(4,2) := "forty-two"

writeln("Integer column labels:")
pysetdf("df", [Numbers, Labels])
pyexec("print(df)")

pysetdf("df", [Numbers, Labels], ["number", "label"])
writeln("\nString column labels:")
pyexec("print(df)")
```

Further information

1. The first version of the procedure creates a new DataFrame with numbers as column labels and the second version uses the provided string column labels.
2. The procedure creates or overwrites the global variable by writing the new value to the attributes of the Python `__main__` module. If the variable name is not a valid Python variable identifier the procedure will succeed anyway and write the value to the module attributes using the name specified in `varname`.
3. The procedure replaces previously existing global variables. It does not update or add data to existing Python structures.
4. DataFrame conversion is supported in all module functions that accept lists of arrays. In particular, it is supported by `pycall` and the I/O *Driver python* .

Related topics

`pygetdf`, `pyset`, `pyinitpandas`

Module

python3

pyunload

Purpose

Release the Python interpreter and its resources.

Synopsis

```
procedure pyunload
```

Example

The following example releases the Python interpreter:

```
pyunload
```

Further information

1. The use of this procedure is optional: the Python interpreter is automatically released at the end of a model execution. However, you may prefer to release it sooner to free resources allocated by Python.
2. After unloading the interpreter it cannot be reinitialized in the same Mosel instance. This is due to a bug in Python's finalization function and its extension modules. For example, NumPy and pandas do not work after reinitializing the interpreter in the same process, *i.e.*, in the same Mosel instance. See https://docs.python.org/3/c-api/init.html#c.Py_FinalizeEx and https://github.com/numpy/numpy/issues/8097 for more details.

Related topics

`pyinit`

Module

python3

22.6 I/O drivers

The *python3* module provides a driver that is designed to be used in `initializations` blocks for both reading data from and writing data to Python.

22.6.1 Driver `python`

```
python:optional_module_name
```

The driver can only be used in 'initializations' blocks. The optional string after the colon is the Python module name to read the data from or write the data to. If a module name is provided, then the optional item labels are understood as attribute names of the specified module. Initializing data to, for example, `"python:client_data"` will create a new module called `client_data`. To access that module in Python, you need to import it like a normal Python module (`"import client_data"`). After importing the module, the converted Mosel variables will be the attributes of the module, for example, `client_data.demand`.

If no module name is provided, i.e. if the file name is `"python:"`, then the driver behaves like `pyset` and `pyget`: When *writing* data to Python, the optional labels are understood as global variable names. The driver creates or overwrites the global variables by writing the new values to the attributes of the Python `__main__` module. If a variable name is not a valid Python variable identifier the driver will succeed anyway and write the value to the module attributes using the name specified in the label. When *reading* data from Python, the optional labels are understood as Python expressions. At first, the driver checks whether an expression is a global variable and tries to access it by getting it from the attributes of the Python `__main__` module. If this fails, the expression is evaluated by Python and the result is written to the Mosel variable.

The driver throws an I/O error if the expression evaluation or the type conversion fails. Use the parameters `ioctrl` (see `setparam`) and `iostatus` (see `getparam`) to catch I/O errors.

When initializing data from Mosel to Python, a possibly existing Python object with the same name will be replaced by a new Python object with a Python object type that matches the type of the Mosel source variable.

When initializing arrays, sets, or lists from Python to Mosel, the initialization behavior is *additive*: The elements of the Python structures are added to the Mosel structures and existing elements in the Mosel structures will not be deleted automatically. If, for example, the target Mosel array is dense and the source Python dictionary or Series is sparse, then the Mosel array may contain old and new values after initialization from Python. If the Mosel array is meant to contain only the values retrieved from the Python dictionary, it is recommended to clear the array with `reset` before initializing it from Python.

22.6.1.1 Type mapping to Python

- Mosel boolean →
  - Python bool
  - NumPy bool_ if element of pandas Series
- Mosel integer →
  - Python int
  - NumPy int64 if element of pandas Series
- Mosel real →
  - Python float

  - NumPy float64 if element of pandas Series
- Mosel string/text → Python str
- Mosel set → Python set
- Mosel list → Python list
- Mosel array(I) →
  - If `pyusepandas`: pandas Series with one-dimensional index
  - If `not pyusepandas`: Python dictionary with scalar keys
- Mosel array(I, J, ...) →
  - If `pyusepandas`: pandas Series with multi-dimensional index
  - If `not pyusepandas`: Python dictionary with tuples of scalars as keys
- Mosel list of array →
  - If `pyusepandas`: pandas DataFrame with one- or multi-dimensional index
  - If `not pyusepandas`: not supported
- Mosel nested types → Python nested type
- Mosel records: not supported
- Other Mosel external types: not supported

22.6.1.2 Type mapping from Python

The NumPy and pandas types are only supported if the pandas interface is initialized.

- Mosel boolean ← Python bool; NumPy bool_
- Mosel int ← Python int, bool; NumPy integer, bool_
- Mosel real ← Python float, int, bool; Numpy floating, integer, bool_
- Mosel string/text ← String representation of Python object as returned by `repr()`
- Mosel list ← Python list
- Mosel set ← iterable types (*e.g.*, set, generator expression, classes that implement `__iter__()`)
- Mosel array ←
  - pandas Series with one- or multi-dimensional index
  - NumPy ndarray with one or multiple dimensions
  - Python dictionary with scalar or tuple keys
- Mosel list of array ←
  - pandas DataFrame with one- or multi-dimensional index
- Mosel nested types ← Python nested type of supported subtypes
- Mosel records: not supported
- Other Mosel external types: not supported

In the following example, a sparse array is transferred to Python and then the same array is reused for retrieving data from a sparse Python dictionary.

```
model "Python I/O example"
  uses "python3"

  declarations
    I = 1..4
    A: dynamic array(I) of integer
  end-declarations

  A(1) := 1*2; A(3) := 3*2

  initializations to "python:"
    I as "MyRange"
    A
  end-initializations

  pyrun("io-example.py")
  reset(A) ! Delete existing elements from array A.

  initializations from "python:"
    A
  end-initializations

  writeln("Values initialized from Python:")
  writeln("  A   = ", A)
end-model
```

The content of `io-example.py`:

```
print("Values initialized to Python:")
print("  MyRange =", MyRange)
print("  A =", A)
print("Modifying data in Python...")
A = {i: 2 * i for i in MyRange if i % 2 == 0}
```

Executing this model generates the following output:

```
Values initialized to Python:
  MyRange = range(1, 5)
  A = {1: 2, 3: 6}
Modifying data in Python...
Values initialized from Python:
  A   = [(2,4),(4,8)]
```

22.7 Troubleshooting

This section describes some known issues and possible solutions.

- `Mosel: E-353: Module 'python3' disabled by restrictions.`

  This module does not handle Mosel *restrictions*, it will therefore fail to load if Mosel is run in *restricted mode*. Section 22.3 provides information about configuring the security restrictions.

- If the initialization of a Python extension module fails when it is imported from within Mosel, then first check which Python environment is used from within Mosel (set `pyinitverbose` to true) and check whether the extension module is installed in that environment. If it is installed and can be imported from within the interactive shell of that environment, but fails when it is imported from within Mosel, then check whether your environment is set up correctly: *Windows Anaconda Setup*, *Linux Anaconda Setup*.

CHAPTER 23

R

The module *r* makes it possible to easily exchange data with R and execute R scripts or evaluate expressions in the R language.
R is a free software environment for statistical computing and graphics. R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License.
To use this module, the following line must be included in the header of the Mosel model file:

```
uses 'r';
```

23.1 Introduction

This module implements functionality for exchanging data between a Mosel model and R and for calling R functions from a Mosel model.

The *r* module also defines an I/O driver for exchanging data using the `initializations from` and `initializations to` Mosel constructs.

It is the Mosel run-time library that loads and runs R, not vice versa.

The purpose of the module is to make the extensive data processing capabilities of R available within Mosel. The interactive and graphing features of R are beyond the scope of this module as it does not implement a full interactive R GUI. However, it is possible to use some of these to a limited extent.

23.1.1 Prerequisites

This module does not include R binaries. In order to use R you need a working installation of R, version 3.0 or newer and targeting the same platform as Mosel (you won't be able to use, *e.g.*, the Windows 32-bit version of R from the Windows 64-bit version of Mosel). The most recent supported R version is 4.1.x. To download R, please visit the R Project web site at www.r-project.org.

This module will try to load R from the directory specified by the *R_HOME* environment variable, if set, or from the default R installation locations otherwise.

More specifically Mosel looks for a file named `R.dll` in Windows, `libR.so` in Linux, and `libR.dylib` in Mac OS X.

For Windows platforms, the default location is retrieved from the registry (from registry key `HKEY_LOCAL_MACHINE\Software\R-core\R\InstallationPath`); it is `/Library/Frameworks/R.framework/Resources` for Mac OS X, `/usr/lib/R` for 32bit Linux, and either `/usr/lib64/R` or `/usr/lib/R` for 64bit Linux.

If *R_HOME* and *R_ARCH* environment variables are defined, they are used to construct a path like *R_HOME*`/lib` in Linux and like *R_HOME*`\bin\`*R_ARCH* in Windows (the default for *R_ARCH* is `x64` or `i386` respectively for Windows 64-bit and Windows 32-bit).

If you have multiple installations of R, or if R is installed in a different location or not automatically found, you will need to set the environment variable *R_HOME* to point to your R installation directory.

Note that the loading of R is not influenced by eventual Mosel statements like `setparam('workdir',...)` or `setenv('R_HOME',...)` as these don't affect the process's environment used for R loading. The environment variables or current path must eventually be set before launching Mosel in order for this to influence R loading.

As an example, if R 3.2.3 is installed in `"C:\Program Files\R\R-3.2.3\bin\..."` in Windows 64-bit, then the correct value for the *R_HOME* environment variable (or registry key) is `C:\Program Files\R\R-3.2.3` (thus, without the `bin` subdirectory) and Mosel would try and load `R.dll` from `C:\Program Files\R\R-3.2.3\bin\x64\R.dll`.

23.1.2 R initialization

The R environment is automatically initialized at the point where a Mosel model uses for the first time any function that requires it. So we can have the following small example that just prints the R version (it prints the same output as if you typed `R.version.string` on an R console):

```
model "r version example"
  uses 'r';
  Rprint('R.version.string')
end-model
```

Alternatively it is possible to explicitly initialize R using the `Rinit` function. This can be useful in order to retrieve a status code or to specify non-default initialization options.

By default, R is initialized with the options "–slave –vanilla", so no site or user environment, profile, history and workspace files are processed. Please refer to the R documentation for more details on these and other options (http://cran.r-project.org/doc/manuals/r-release/R-intro.html#Invoking-R).

Upon startup, only the "utils", "stats", and "methods" R packages are loaded by default. Other packages can be loaded via R statements (using for example the `library` or `require` R functions) or a different initial package list can be specified by setting the `R_DEFAULT_PACKAGES` environment variable (prior to running Mosel).

As R is single-threaded, it is not possible to create more than one R session per model, nor to execute two models in parallel if both use R.

23.1.3 Memory limit on Windows

On Windows platforms, R has an internal mechanism that can limit the maximum amount of memory it can use. The limit can be read or changed using the R `memory.limit` function; for example, the current limit can be printed from Mosel with

```
writeln('R memory limit is ',Rgetreal("memory.limit()"),' MB')
```

and the limit can be set, *e.g.* to 16 GB, with

```
Reval("memory.limit(16*1024)")
```

Note that in versions of R prior to 3.6 the default value for this limit is different when R is executed as a standalone application rather than embedded in another application (including Mosel): in the first case the limit is set to the amount of physical memory available whereas it is fixed to 2 GB for embedded mode. Therefore, in order to allow R to use more than 2 GB of memory from Mosel on Windows it is necessary to explicitly raise this limit as shown above. Starting with R version 3.6, by default there is no memory limit anymore when R is executed in embedded mode.

23.1.4 Data types

The types of data that can be exchanged with R are the four Mosel elementary types `boolean`, `integer`, `real` and `string`, plus arrays, lists and sets of these (nested compositions are not supported). Both static and dynamic Mosel arrays are supported and mapped into R atomic vectors of the corresponding type. Mosel lists and sets can also be exported into R vectors.

In general, there is no direct mapping of more complex R types such as factors or data.frames, with the exception of the `Rsetdf` function, however these can be exchanged after conversion to basic types. For example, a factor can be loaded into a Mosel array as an array of integers with:

```
Rgetarr("unclass(f)", intarray)
```

or as an array of strings with:

```
Rgetarr("levels(f)[f]", strarray)
```

Note that the first is also equivalent to this simpler form:

```
Rgetarr("f", intarray)
```

since this module ignores the factor's "class" and "levels" attributes; similarly the second is equivalent to the simpler:

```
Rgetarr("f", strarray)
```

since the casting to string, performed within R, automatically takes into account the "levels" attribute.

To load a data.frame into Mosel, it should be converted to a matrix (for instance using `as.matrix` if the column types allow that) or split into individual column vectors.

For the opposite operation, that is, exporting a Mosel array to R, note that, except for the `Rsetdf` function, Mosel arrays are always exported as R (dense) atomic vectors. Any index that is not a 1-based integer range is created in R as a named index. Index names, in R, are always strings, so for example, when the Mosel array in the following example is converted to R, the index set `J` is kept as an unnamed integer index, while `I` (which does not start with 1) and `K` (which has holes) are created as named indices.

```
model "array to r"
  uses "r"

  declarations
    I= 2..3
    J= {1,2}
    K= {1,3}
    a: array(I,J,K) of integer
  end-declarations

  a(2,1,1):=4                       ! Define some test data entry
  Rset('aR',a)                      ! Copy data to R
  writeln("Array in R:")
  Rprint("aR")                      ! Display data held in R
  writeln("dimnames(aR):")
  Rprint("dimnames(aR)")            ! Display R indices
end-model
```

Executing this model generates the following output:

```
Array in R:
, , 1
```

```
  [,1] [,2]
2    4    0
3    0    0

, , 3

  [,1] [,2]
2    0    0
3    0    0

dimnames(aR):
[[1]]
[1] "2" "3"

[[2]]
NULL

[[3]]
[1] "1" "3"
```

Note how the first and last entry of `dimnames`, which correspond to indices `I` and `K` respectively, are set to the list of index elements converted to strings; while the second entry is left to NULL since the index set `J` is a 1-based integer index with contiguous elements.

Conversion to R data frames can be done using function `Rsetdf`. If this does not provide the required data frame format or other complex R data structures are needed, then the conversion should be done in the R realm and is outside of the scope of this guide. A few examples are shown below, but please refer to the R documentation for further information.

Some common and useful R functions to convert vectors into data frames are *e.g.* `data.frame()`, `as.data.frame()`, and the functions from the *reshape* or *reshape2* packages, just to name a few. Also functions `names()` (for 1-dimensional vectors) or `dimnames()` (for any vectors) can be used to retrieve the index names of a vector.
In the following example, a Mosel single-indexed `demand` array is converted to a 2-column R data frame: the first column for the index and the second column for the value:

```
 model "dataframe"
  uses "r"

  declarations
    Locations = {12,34,56}
    demand: dynamic array(Locations) of real
  end-declarations

  forall(l in Locations) demand(l):=l*100      ! Fill array with some data
  Rset("demand", demand)
  Rprint("table <- data.frame(Loc=names(demand),Dem=demand,row.names=NULL)")
end-model
```

This is the resulting output:

```
  Loc  Dem
1  12 1200
2  34 3400
3  56 5600
```

Note that this is the same result that you would get, more simply, with `Rsetdf("table", demand, ["Loc","Dem"])`.

Alternatively, calling data.frame just as `data.frame(demand)` without any other parameters would create a data frame with a single column (for `demand`) and named rows, thus yielding:

```
  demand
```

```
12    1200
34    3400
56    5600
```

A *bidimensional* `demand` array such as:

```
declarations
  Locations = {12,34,56}
  C={"A","B"}
  demand: dynamic array(Locations,C) of real
end-declarations
demand(12,"A"):=1234
demand(56,"B"):=6789
Rset("demand", demand)
```

using `Rsetdf("df", demand, ["Loc","C", "Value"])` would yield:

```
  Loc C Value
1  12 A  1234
2  56 B  6789
```

or it could be converted to a data frame via `data.frame(Loc=dimnames(demand)[[1]],demand, row.names=NULL)` which results in the following form:

```
  Loc    A    B
1  12 1234   NA
2  34   NA   NA
3  56   NA 6789
```

Finally, for instance by calling function `melt` form the *reshape2* package such as `melt(demand, varnames = c('Loc','Prod'), value.name = 'Demand')`, it is possible to obtain a data frame with a column for each index plus a column with the array values like the following:

```
  Loc Prod Demand
1  12    A   1234
2  34    A     NA
3  56    A     NA
4  12    B     NA
5  34    B     NA
6  56    B   6789
```

23.2 Example

The following example shows how to execute R statements and exchange data with the R workspace.

```
model "r example"
  uses "r"

  declarations
    CITIES = {"LONDON", "PARIS", "ROME"}
    ZONES = 1..4
    mosarray, backarr, backarrio: array(ZONES, CITIES) of integer
    backnum: real
  end-declarations

  setparam("Rverbose",true)  ! Enable showing R error messages

! Reval evaluates arbitrary R statements
  Reval("t<-Sys.time();now<-format(t, '%H:%M')")
! Rprint also prints the result (via the R print function)
  Rprint("paste('Hello from R at',now)")
```

```
! Assign some Mosel scalars to R vars and show results
  Rset("a_num", 1.2)
  Reval("str(a_num)")
  Rset("a_chr", "word")
  Reval("str(a_chr)")

! The lvalue can be any R valid lvalue, e.g. the dim attribute
  Rset("a_vec", 1..6)        ! a_vec is an R vector
  Rset("dim(a_vec)", [2,3])  ! change its dimensions
  writeln("a_vec")
  Rprint("a_vec")            ! now it is a 2x3 matrix

! Assign a Mosel array to an R variable
  forall(i in ZONES, c in CITIES) mosarray(i,c):=i*10+getsize(c)
  Rset("arr", mosarray)
! The R vector keeps index names
  writeln("arr")
  Rprint("arr")

! Retrieve R variables
  writeln("a_num is ", Rgetreal("a_num"))
  writeln("a_chr is ", Rgetstr("a_chr"))
  Rgetarr("arr", backarr)
  writeln("arr is ", backarr)

! Data can also be exchanged via the I/O driver
  newnumber:=1.3
  mosarray(1,"LONDON"):=1
! Send data to R
  initializations to "r.rws:"
    newnumber as "a_num"
    mosarray as "arr"
  end-initializations
! Get data back from R
  initializations from "r.rws:"
    backnum as "a_num"
    backarrio as "arr"
  end-initializations
  writeln("backnum is ", backnum)
  writeln("backarrio is ", backarrio)

end-model
```

23.3 Control parameters

The following parameters are defined by the module *r*:

Rcleanscript	R cleanup script to be run at the end of a session.	p. 854
Rinteractive	Control the R interactive flag.	p. 854
Rsessionmode	R session handling mode.	p. 855
Runloadscript	R unload script to be run at the end of a session.	p. 854
Rusemosstreams	Enable/disable R output redirection.	p. 854
Rverbose	Enable/disable R error messages.	p. 853

Rverbose

Description Enables or disables the printing of error messages when errors occur during the evaluation of R statements. When this parameter is set, two corresponding R options are set accordingly,

namely `show.error.messages`, which is set to the same value as this parameter, and `warn` which is set to `1` or `-1` when this parameter is set to `true` or `false` respectively.

Type Boolean, read/write

Default value false

Module r

Rinteractive

Description This has effects on eventual user prompts and confirmation requests from R, please refer to R documentation (*e.g.* on "interactive()") for more details.

Type Boolean, read/write

Default value false

Module r

Rusemosstreams

Description By default R sends output to stdout and stderr. Using this parameter it is possible to redirect R console output to Mosel streams instead. Note that the R notion of `stdin` connection is not affected by this parameter.

Type Boolean, read/write

Default value true

Module r

Rcleanscript

Description This parameter can be used to specify the R statement(s) to be executed at the end of an R session; its purpose should be to clear the R workspace. Note that this script is run only for session modes 2 and 3.

Type String, write only

Default value *remove all objects currently defined in the R workspace*

Affects routines `Rfree`.

Module r

Runloadscript

Description This parameter can be used to specify the R statement(s) to be executed at the end of an R session; its purpose should be to free and unload all resources used by R. Note that this script is run only for session mode 3 and after the `Rcleanscript` statement(s).

Type String, write only

Default value *unload all packages and dynamic libraries*

Affects routines `Rfree`.

Module r

Rsessionmode

Description Specifies what actions are taken at the end of an R session.

Type Integer, read/write

Values

0	END: the R session is ended.
1	KEEP: the R session is kept alive and the current R workspace is preserved.
2	CLEAR: the R session is kept alive and the Rcleanscript is executed.
3	UNLOAD: both the Rcleanscript and Runloadscript are executed, then R is unloaded.

Default value 2

Notes This parameter is useful mainly when multiple Mosel models that use R are executed within the same process.
When an R session is ended, R does not allow the creation of further sessions, therefore R will not be usable again within the same process.
Session mode 3, by unloading R, should enable the possibility to create new R sessions within the same process, however it may not completely free all resources allocated by R.

Affects routines `Rfree`.

Module r

23.4 Procedures and functions

All R statements are evaluated in the R Global Environment, more often known as the user's *workspace*.

In general, the procedures and functions of *r* do not fail in case of R parsing or evaluation errors but set an internal status variable that can be read with `Rerrcode`. To make sure that an operation has been performed correctly, it is recommended to check the value of this variable after each call.

`Rclearerr`	Clear the last error code and message.	p. 870
`Rerrcode`	Get the last error code.	p. 868
`Rerrmsg`	Get the last error message.	p. 869
`Reval`	Evaluate R statements.	p. 856
`Rfree`	Terminate an R session.	p. 857
`Rgetarr`	Get the resulting array of an R expression.	p. 858
`Rgetbool`	Get the boolean value of an R expression.	p. 859
`Rgetint`	Get the integer value of an R expression.	p. 860
`Rgetreal`	Get the real value of an R expression.	p. 861
`Rgetstr`	Get the string value of an R expression.	p. 862
`Rinit`	Initialize an R session.	p. 863
`Rprint`	Evaluate R statements and print the result.	p. 864
`Rset`	Assign a Mosel value to an R object.	p. 865
`Rsetdf`	Assign a Mosel array to an R data.frame object.	p. 866
`Rsource`	Evaluate an R script file.	p. 867

Reval

Purpose

Evaluate R statements.

Synopsis

```
procedure Reval(cmd:string)
```

Argument

`cmd` Statements to evaluate

Example

The following example loads the `datasets` package, calculates summary statistics of the `attenu` dataset and prints results:

```
Reval('library(datasets); s<-summary(attenu)')
Rprint('s')
```

Further information

It is possible to evaluate multiple statements separating them with semicolons.

Related topics

`Rprint`.

Rfree

Purpose

Terminate an R session.

Synopsis

```
procedure Rfree
```

Example

The following example terminates the R session:

```
Rfree
```

Further information

The use of this procedure is optional: R is automatically terminated at the end of a model execution. However you may prefer to terminate it sooner to free resources allocated by R.

Related topics

`Rinit`.

Rgetarr

Purpose

Get the resulting array of an R expression.

Synopsis

```
procedure Rgetarr(cmd:string, arr:array)
```

Arguments

`cmd`	Statements to evaluate
`arr`	Destination Mosel array

Example

The following example loads the R `cars` example dataset into the Mosel array `cars`:

```
declarations
 cars:array(range, set of string) of integer
end-declarations
Rgetarr('as.matrix(datasets::cars)',cars)
```

Further information

1. If `cmd` contains more than one statement, the returned value is the result of the last one.
2. The Mosel array `arr` must have the same number of dimensions as the R array; NA entries in R are skipped and corresponding entries in `arr` are left unchanged (note that `arr` is not cleared before loading R data).
3. Supported index types for the `arr` array are string and integer. In the case of strings, the R array must have a valid `names` or `dimnames` attribute for the corresponding dimension; in the case of integers, the R integer indices (1 to n) are used. All entries of the R array are converted to the same type as the destination array within R.

Related topics

`Rgetarr`, `Rgetint`, `Rgetreal`, `Rgetstr`

Rgetbool

Purpose

Get the boolean value of an R expression.

Synopsis

```
function Rgetbool(cmd:string):boolean
```

Argument

`cmd` Statements to evaluate

Return value

The result of the evaluation as a boolean.

Example

The following example checks if the R entity `vec` is atomic and sets the boolean variable `boolvar` accordingly:

```
boolvar:=Rgetbool('is.atomic(vec)')
```

Further information

If `cmd` contains more than one statement, the returned value is the result of the last one. If the results is `NA`, then `false` is returned. The returned value is first converted to `logical` within R.

Related topics

`Rgetarr`, `Rgetint`, `Rgetreal`, `Rgetstr`

Rgetint

Purpose

Get the integer value of an R expression.

Synopsis

```
function Rgetint(cmd:string):integer
```

Argument

`cmd` Statements to evaluate

Return value

The result of the evaluation as an integer.

Example

The following example retrieves the length of the R entity `vec` into variable `intvar`:

```
intvar:=Rgetint('length(vec)')
```

Further information

If `cmd` contains more than one statement, the returned value is the result of the last one. If the results is `NA`, then the R `NA_Integer` value (-2^{31}) is returned. The returned value is first converted to `integer` within R.

Related topics

`Rgetarr`, `Rgetbool`, `Rgetint`, `Rgetstr`

Rgetreal

Purpose

Get the real value of an R expression.

Synopsis

```
function Rgetreal(cmd:string):real
```

Argument

`cmd` Statements to evaluate

Return value

The result of the evaluation as a real.

Example

The following example retrieves the mean of the speed/dist ratios for the `cars` dataset into the variable `realvar`:

```
realvar:=Rgetreal('mean(cars$speed/cars$dist)')
```

Further information

If `cmd` contains more than one statement, the returned value is the result of the last one. If the results is `NA`, then a `NaN` value is returned. The returned value is first converted to `numeric` within R.

Related topics

`Rgetarr`, `Rgetbool`, `Rgetint`, `Rgetstr`

Rgetstr

Purpose

Get the string value of an R expression.

Synopsis

```
function Rgetstr(cmd:string):string
```

Argument

`cmd` Statements to evaluate

Return value

The result of the evaluation as a string.

Example

The following example retrieves the version string of R into the variable `strvar`:

```
strvar:=Rgetstr('R.version.string')
```

Further information

If `cmd` contains more than one statement, the returned value is the result of the last one. If the results is `NA`, then the string "NA" is returned. The returned value is first converted to `string` within R.

Related topics

`Rgetarr`, `Rgetbool`, `Rgetreal`, `Rgetstr`

Rinit

Purpose

Initialize an R session.

Synopsis

```
function Rinit([args:string...]): integer
```

Argument

`args` List of R startup options (optional)

Return value

0 if the initialization was successful.

Example

The following example initializes R with default options:

```
initok:=Rinit
if initok<>0 then writeln('Failed to initialize R')
end-if
```

Further information

The use of this function is optional: R is automatically initialized upon first use. Default R startup options are "–slave", "–vanilla", so no site or user environment, profile, history and workspace files are processed. Please refer to the R documentation for the exact meaning of these and other options (`http://cran.r-project.org/doc/manuals/r-release/R-intro.html#Invoking-R`).

Related topics

`Rfree`.

Rprint

Purpose

Evaluate R statements and print the result.

Synopsis

```
procedure Rprint(cmd:string)
```

Argument

`cmd` Statements to evaluate and print

Example

The following example prints the R version number and summary statistics of the `cars` dataset:

```
Rprint("R.version.string")
Rprint('library(datasets); summary(cars)')
```

Further information

It is possible to evaluate multiple statements separating them with semicolons. The return value of the last statement is printed using R's own print function, thus with R style and formatting.

Related topics

`Reval`.

Rset

Purpose

Assign a Mosel value to an R object.

Synopsis

```
procedure Rset(dst:string, value:[set|array|list of]
       boolean|integer|real|string)
```

Arguments

`dst` An R variable name

`value` The Mosel value to be assigned to `dst`

Example

The following example assigns values 1.2, "hello" and an array with numbers 1 to 6 to the R objects `a_num`, `a_string` and `a_vec` respectively:

```
Rset('a_num', 1.2)
Rset('a_string', 'hello')
Rset("a_vec", 1..6)         ! An R vector with real values 1 to 6
Rset("dim(a_vec)", [2,3])   ! Change its dimensions into a 2x3 matrix
```

Further information

1. A new temporary R entity is created from `value` and then assigned to `dst`, unless `value` is a scalar and `dst` is an existing R entity of the corresponding type, in which case `dst` is just set to the new value
2. Argument `dst` can represent any assignable expression (including subsetting and attributes).
3. The type of argument `value` can be any elementary Mosel type, or an array, list or set of these (compositions are not supported).
4. When `value` is an array, for each of the array's dimensions, its index values are exported into the corresponding R array's `names` or `dimnames` attribute (after conversion to string) unless the indices are integer values from 1 to that dimension size.
5. If `value` is a dynamic array, only the existing values are copied to R and the remaining array entries are set to NA (Not Available).

Related topics

`Reval`, `Rsetdf`.

Rsetdf

Purpose

Assign a Mosel array to an R data.frame object.

Synopsis

```
procedure Rsetdf(dst:string, arr:array of boolean|integer|real|string)
```

Synopsis

```
procedure Rsetdf(dst:string, arr:array of boolean|integer|real|string,
       cname:list of string)
```

Arguments

`dst` An R variable name

`arr` The Mosel array to be assigned to `dst`

`cname` List of names to be assigned to the data.frame columns

Example

The following:

```
declarations
 CITIES = {"LONDON", "NEW YORK", "ROME"}
 ZONES = 1..4
 myarray: dynamic array(ZONES, CITIES) of integer
end-declarations
myarray(1,'LONDON') := 8
myarray(1,'ROME') := 3
myarray(2,'NEW YORK') := 9
Rsetdf("a_df", myarray, ['Zone','City','Value'])
Rprint("a_df")
```

produces this output:

```
  Zone     City Value
1    1   LONDON     8
2    1     ROME     3
3    2 NEW YORK     9
```

Further information

1. A new R data.frame is created from `arr` and assigned to `dst`
2. The argument `dst` can represent any assignable expression (including subsetting and attributes).
3. The R data.frame is constructed with `n+1` columns (where `n` is the number of dimensions of `arr`): one column for each of the array's indices, plus one column for the array's values; and one row for each existing value of the array.
4. Rows are numbered from 1 to the number of existing values of `arr` and column names are taken from the `cname` argument, when given.
5. Only the first `n+1` strings from `cname` are used; if `cname` is shorter, then the right-most columns are left unnamed.

Related topics

`Reval`, `Rset`.

Rsource

Purpose

Evaluate an R script file.

Synopsis

```
procedure Rsource(filename:string)
```

Argument

`filename` Filename of the R script to evaluate

Example

The following example executes the `myscript.R` file:

```
Rsource('myscript.R')
```

Related topics

`Reval`.

Rerrcode

Purpose

Get the last error code.

Synopsis

```
function Rerrcode:integer
```

Return value

0 if the last operations were executed successfully.

Example

The following example prints an error message in case of errors in R evaluations:

```
Reval('missingfunction()')
if Rerrcode<>0 then
 writeln('Something went wrong: ', Rerrmsg)
 Rclearerr
end-if
```

Further information

The `Rerrcode` is set to non-zero values in case of errors, but not cleared after successful operations, so it is possible to check it after several operations to verify that all executed without errors. To clear it, use function `Rclearerr`.

Related topics

`Rclearerr`, `Rerrmsg`.

Rerrmsg

Purpose

Get the last error message.

Synopsis

```
function Rerrmsg:string
```

Return value

The last error message in case of errors, or the empty string otherwise.

Example

The following example prints an error message in case of errors in R evaluations:

```
Reval('missingfunction()')
if Rerrcode<>0 then
 writeln('Something went wrong: ', Rerrmsg)
 Rclearerr
end-if
```

Further information

The message returned by this function is a top-level description of the error. It is possible to also retrieve R own error message for example with `Rgetstr("geterrmessage()")`.

Related topics

`Rclearerr`, `Rerrcode`.

Rclearerr

Purpose

Clear the last error code and message.

Synopsis

```
procedure Rclearerr
```

Example

The following example prints an error message in case of errors in R evaluations and subsequently clears the error information:

```
Reval('missingfunction()')
if Rerrcode<>0 then
 writeln('Something went wrong: ', Rerrmsg)
 Rclearerr
end-if
```

Related topics

Rerrcode, Rerrmsg.

23.5 I/O drivers

In order to simplify access to R this module provides a driver that is designed to be used in `initializations` blocks for both reading and writing data, providing the same functionalities as the Rget and Rset functions.

23.5.1 Driver *rws*

```
rws:
```

The driver can only be used in 'initializations' blocks. It does not take any argument and provides access to the R workspace.

In the block, each label entry is understood as one or more R statements. For 'from' blocks, if the label contains more than one statement, the value from the last one is returned. For 'to' blocks, the label must contain only one expression.

This driver requires an existing R session, therefore it is necessary to initialize R (either by calling function `Rinit` or any of the other module functions that create an R session) before using it.

Example:

```
initok:=Rinit                    ! Initialize R
initializations to "r.rws:"      ! Send data to R
  scalarvar as "val"
  arrayvar  as "arr"
end-initializations
initializations from "r.rws:"    ! Get data from R
  backscalar as "val"
  backarr as "arr"
end-initializations
```

23.6 Troubleshooting

This section describes some known issues and possible solutions.

- When running a model in Windows, a dialog is shown with title 'Unable to locate component' and content 'The application has failed to start because Rlapack.dll was not found...'.
  This may occur with Windows 2003. Please add your R binary directory (usually 'C:\Program Files\R\R-3.x.x\bin\i386' or 'C:\Program Files\R\R-3.x.x\bin\x64' to the system `PATH` environment variable.
- When an R session is initialized in Windows, R installs a console handler to detect `Ctrl-C` events which may prevent Mosel from properly detecting these same events itself.
- In Linux, R may fail to load if the dynamic libraries in `$R_HOME/lib` cannot be found by the dynamic linker. In this case, please add `$R_HOME/lib` to the `LD_LIBRARY_PATH` environment variable.
- This module is not compatible with Mosel security *restrictions*, therefore it would fail to load if Mosel is run in *restricted mode*.
- On Mac OS X, if the R release being used is linking the Apple CoreFoundation library, then this module can only be successfully initialized from the main thread of the process in which Mosel is running (because the CoreFoundation library can only be loaded from the main thread of a process). So, for example, the module would fail to load R from an *mmjobs* submodel. In this case, it is possible to overcome this issue by setting the environment variable *DYLD_INSERT_LIBRARIES* to `/System/Library/Frameworks/CoreFoundation.framework/Versions/A/CoreFoundation`

(use the correct path to the CoreFoundation library on your system) before launching the Mosel process, thus forcing an anticipated loading of the CoreFoundation library at process creation.

CHAPTER 24

zlib

The *zlib* Mosel module is an interface to the zlib compression library by Jean-Loup Gailly and Mark Adler (http://zlib.net). Thanks to two IO drivers it makes possible the creation and use of compressed files from Mosel models. As an additional feature this module also integrates the MiniZip library by Gilles Vollant (http://www.winimage.com/zLibDll/minizip.html) for supporting the ZIP archive format.

24.1 I/O drivers

The following two drivers behave the same: a stream open for reading is decompressed and a stream open for writing is created compressed. Both drivers are also based on the same compression algorithm (*deflate*) but use different container formats. The last published driver (`zip`) can only be open for reading: it will be used to access a file stored in a zip archive. For more advanced use of ZIP archives please refer to the dedicated routines proposed by the *mmsystem* module.

24.1.1 Driver `gzip`

```
gzip:filename
```

This driver handles files compressed using the *gzip* compression format: this corresponds to files created using the `gzip` compression tool.

For instance the following statement decompresses the file `"myfile.gz"`:

```
fcopy("zlib.gzip:myfile.gz","myfile")
```

24.1.2 Driver `deflate`

```
deflate:filename
```

This driver handles files compressed using the *zlib* compression format. This driver can read documents compressed by `gzip` but compressed files it generates are not compatible with this tool.

24.1.3 Driver `zip`

```
zip:zipfile,filename
```

This driver handles archives using the *ZIP* format. It can be used only for reading files: the filename of this driver consists in two parts separated by a coma. The first part is the name of the archive to open (that must be a physical file) and the second one is the archive member name.

For instance the following statement compiles the file `"main.mos"` stored in the archive `"myproject.zip"`:

```
compile("G","zlib.zip:myproject.zip,main.mos","tmp:main.bim")
```

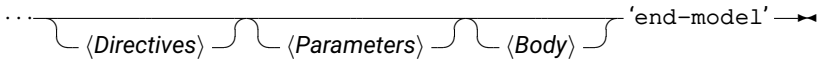
Appendix

APPENDIX A

Syntax diagrams for the Mosel language

A.1 Main structures and statements

⟨*Model*⟩ ::=



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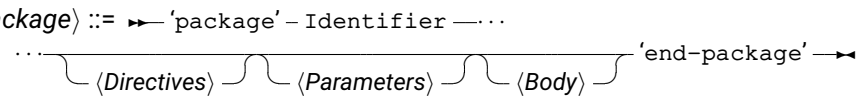

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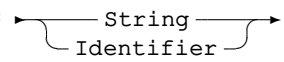

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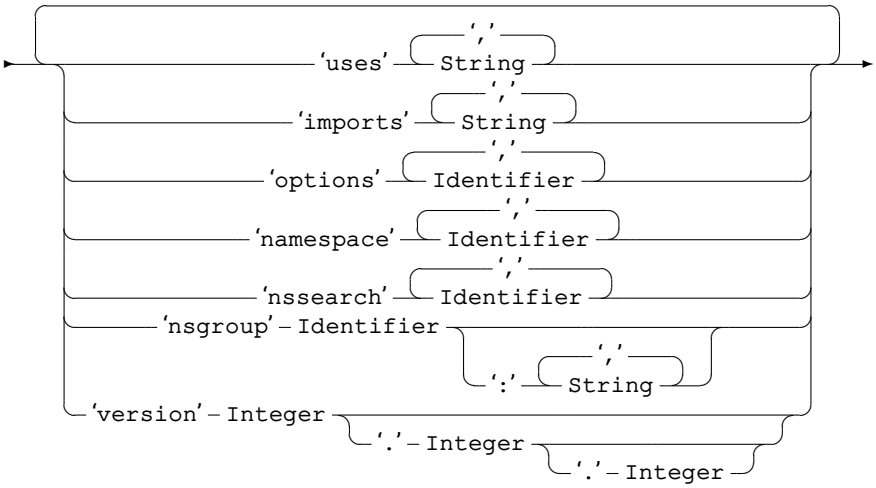

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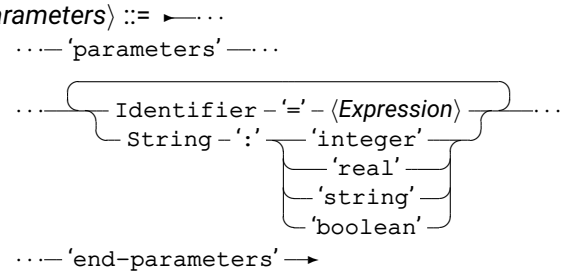

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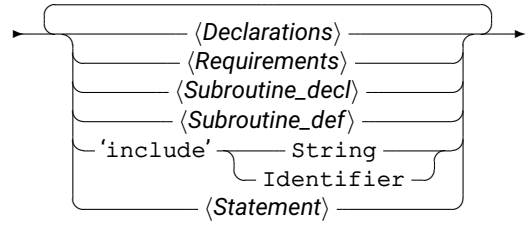

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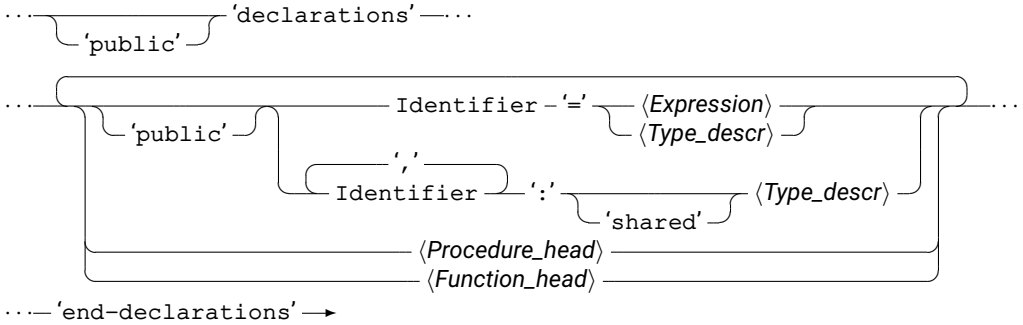

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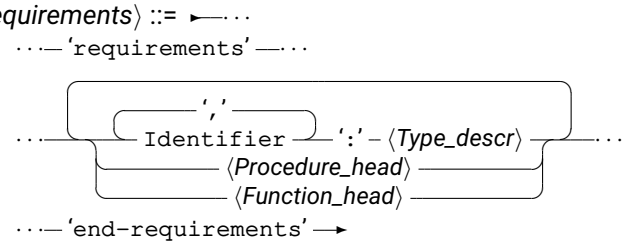

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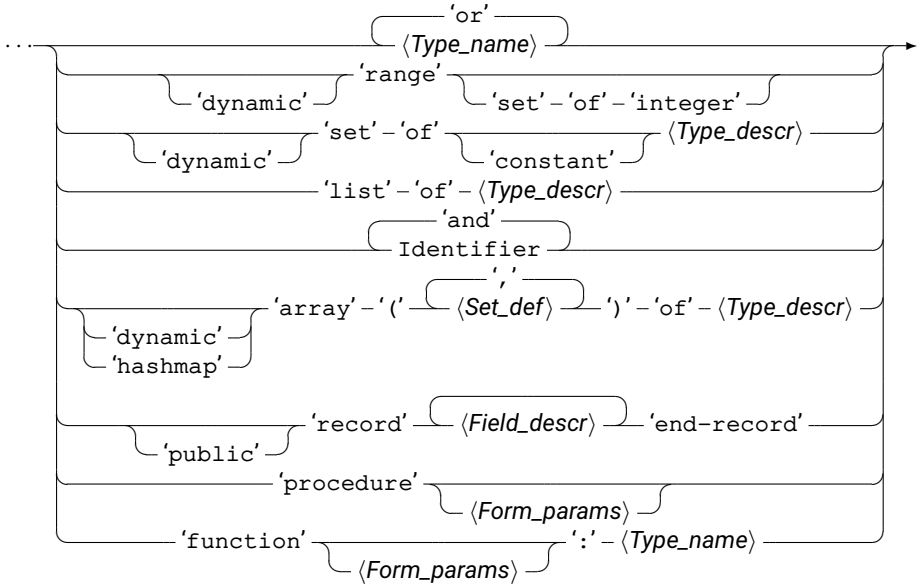

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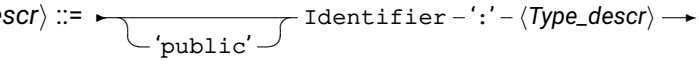

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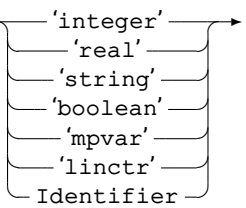

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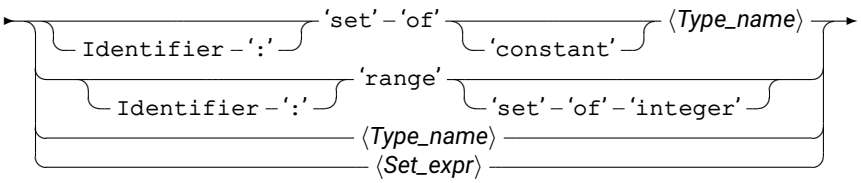

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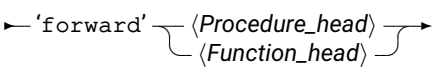

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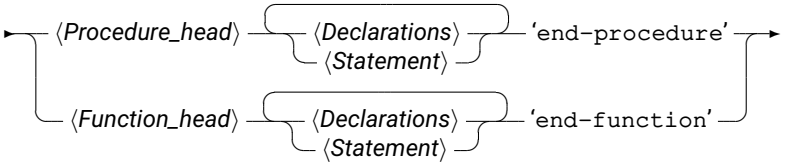

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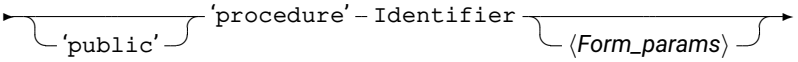

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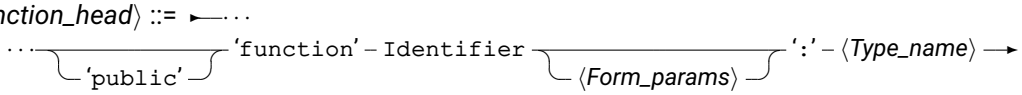

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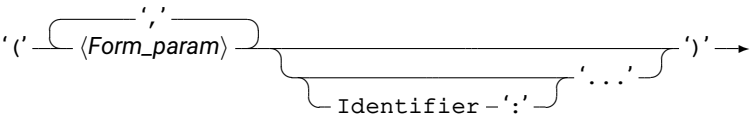

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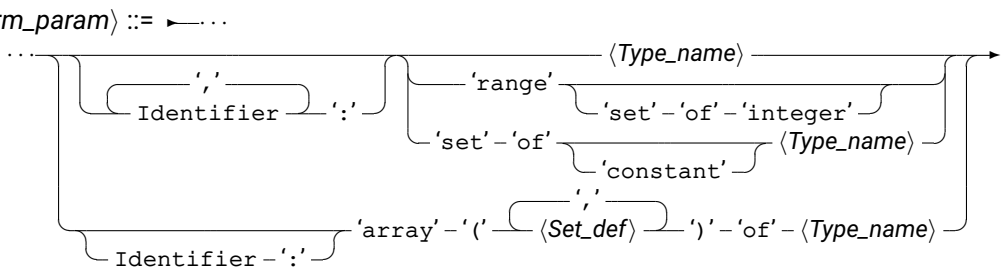

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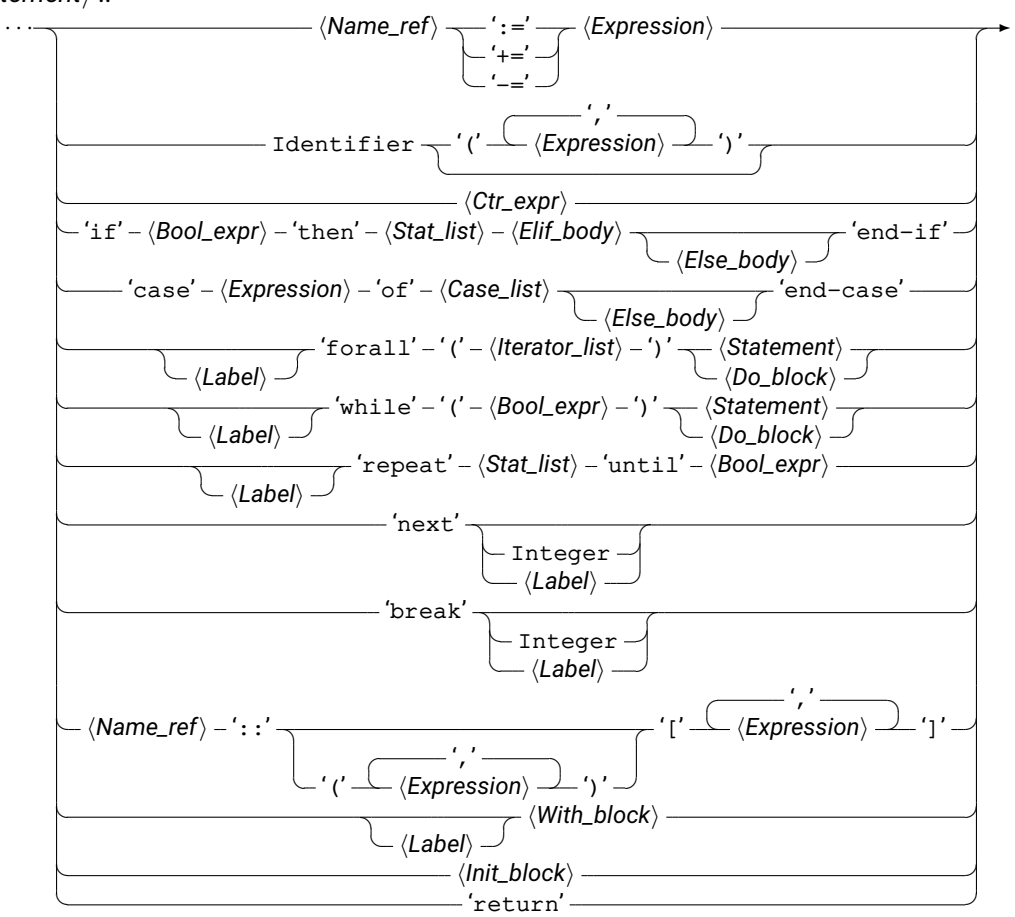

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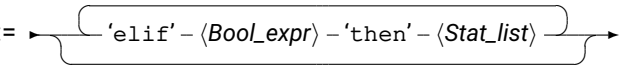

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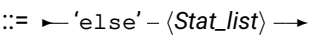

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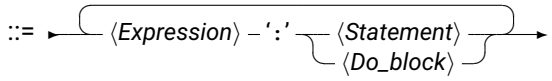

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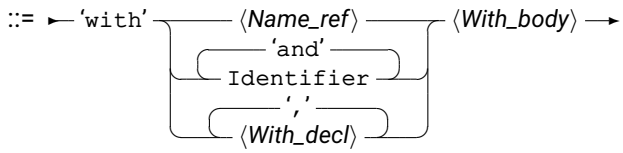

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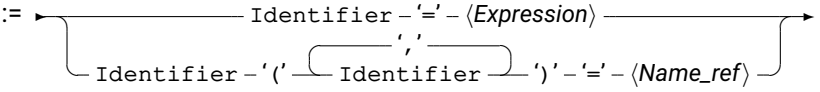

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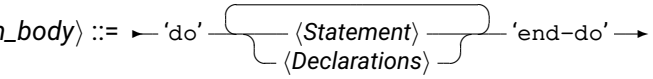

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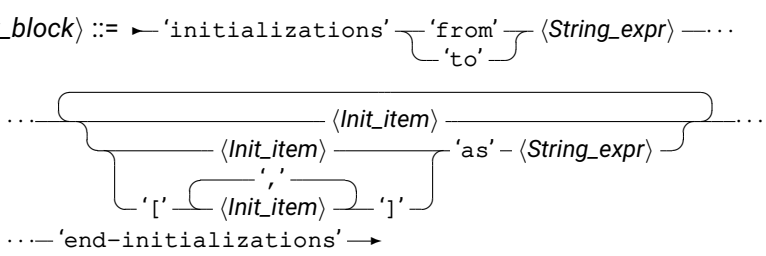

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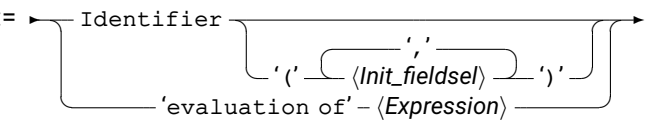
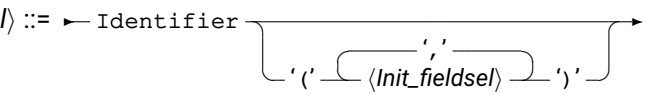


⟨*Init_fieldsel*⟩ ::=



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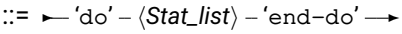

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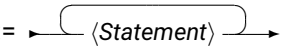

A.2 Expressions

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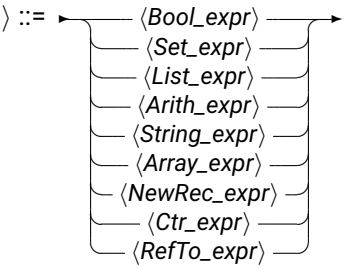

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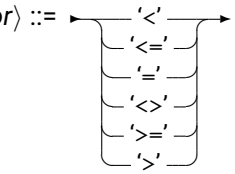

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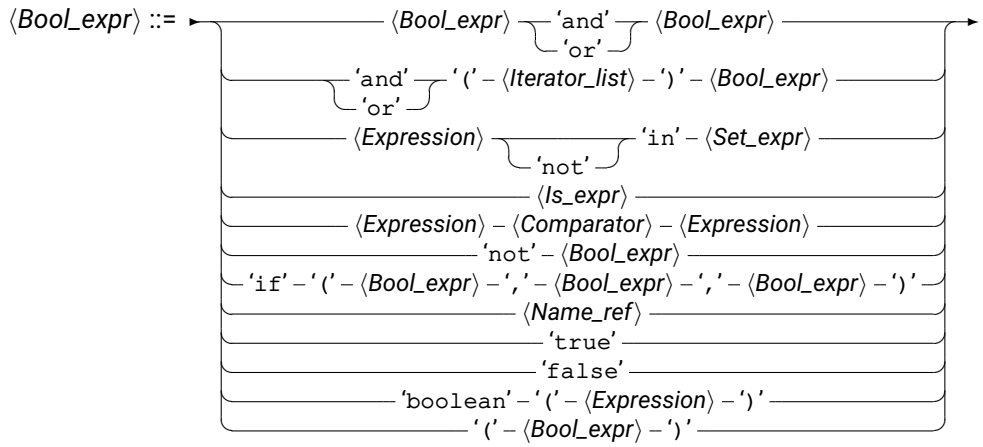

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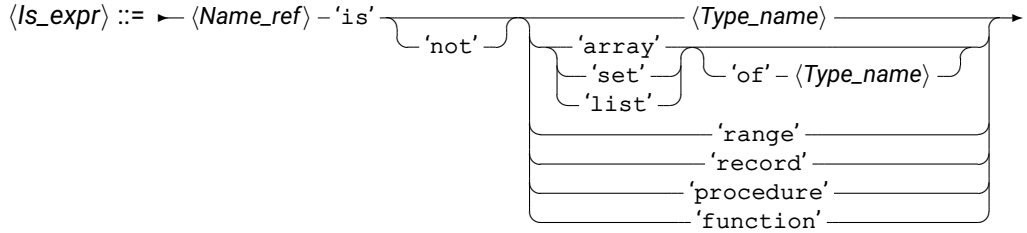

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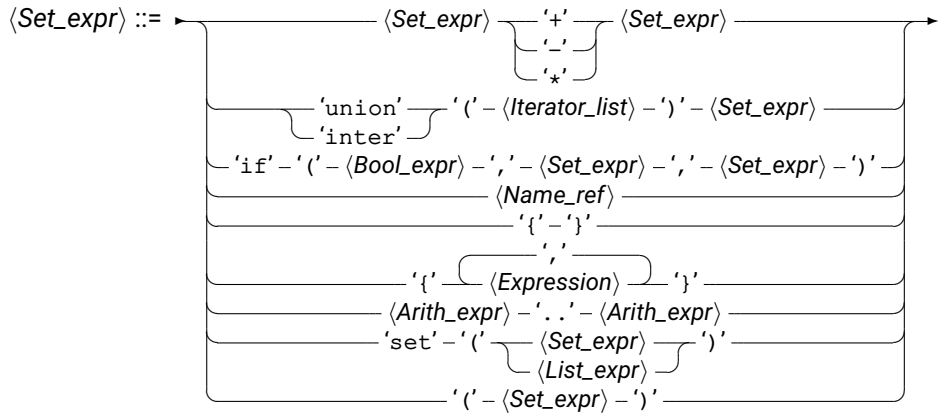
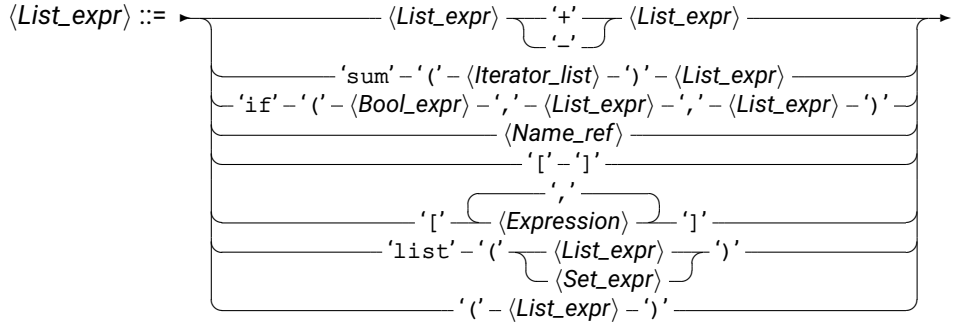
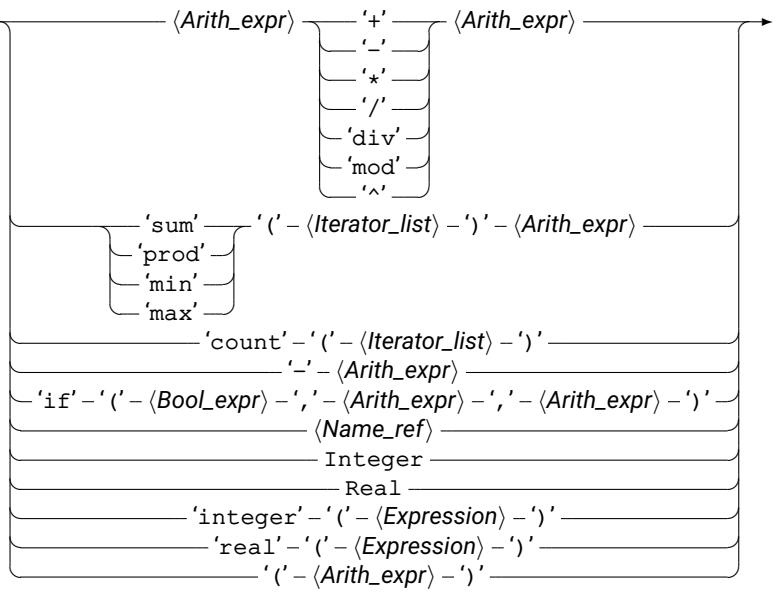


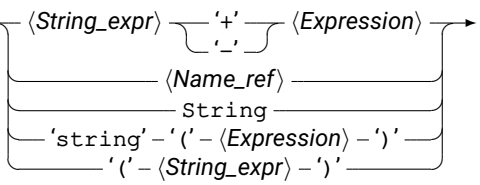
⟨*List_expr*⟩ ::=



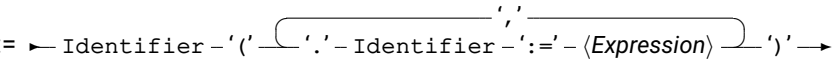
⟨*Arith_expr*⟩ ::=



⟨*String_expr*⟩ ::=

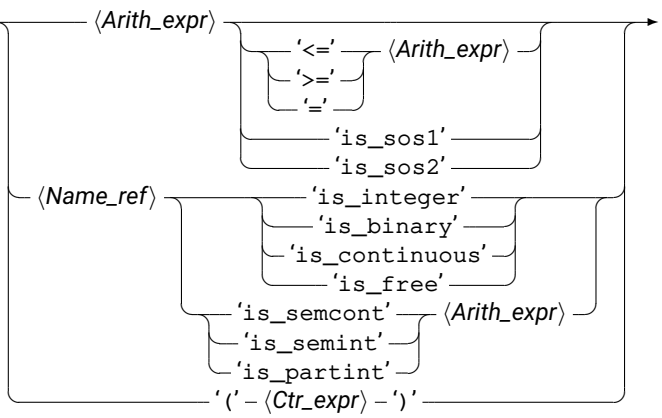


⟨*NewRec_expr*⟩ ::=

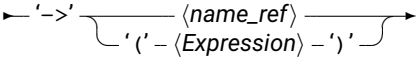


⟨*Array_expr*⟩ ::=

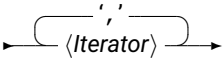
⟨*Ctr_expr*⟩ ::=

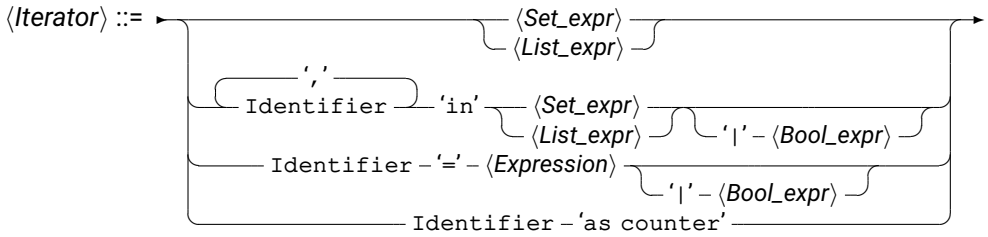


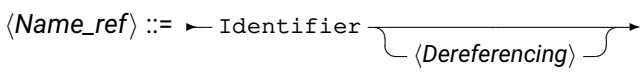
⟨*RefTo_expr*⟩ ::=

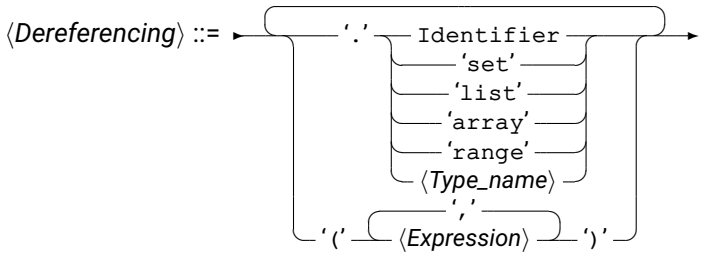


⟨*Iterator_list*⟩ ::=

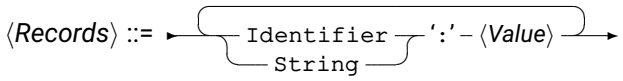


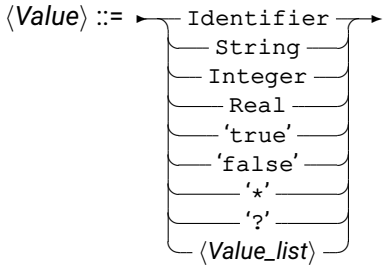


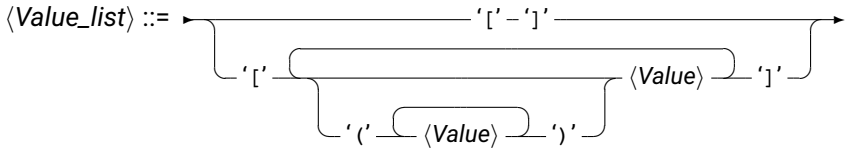




A.3 Initializations data file format







APPENDIX B

Remote Invocation Protocol

A Mosel instance may be started remotely using either the `connect` procedure of the module *mmjobs* or its equivalent routine of the XPRD library. From any of these environments one can compile, load and run models as well as access files on the remote system. The *remote invocation protocol* also makes it possible to control more precisely the execution of models (*e.g.* suspending execution or profiling) and query information of a model (such as the value of entities) or the entire instance (*e.g.* to retrieve the list of available modules).

This protocol relies on two mechanisms:

1. the procedure `setcontrol` (available in *mmjobs* and XPRD) to (re)define Mosel instance control parameters
2. the special remote file `'mcmd'` that only supports read access: the file name is interpreted as a query and the retrieved data is the answer to this request

B.1 Instance control parameters

Mosel instance control parameters are either defined at the instance level or they apply to a specific model (see `setcontrol`). Some of the parameters serve for changing the behaviour of other commands, others provide a means to execute some specific command.

The supported instance parameters are:

- `zerotol` (real,instance): set the zero tolerance used for comparison and displaying real numbers (*i.e.* a real number smaller than the tolerance is treated as 0)
- `realfmt` (string,instance): set the C-format used to display reals
- `flushdso` (none,instance): unloads unused modules (*i.e.* calls XPRMflushdso)
- `lang` (string,instance): set the language of the instance
- `defaultnode` (integer,instance): set the default node number used by the `"rmt:"` IO driver when it is used without node reference (see Section 8.5.6)
- `runmode` (int,model): set the execution mode of a model (cannot be changed during the execution of the model):
  - 0: default
  - 1: debug
  - 2: profile
  - 3: tracing

- `dbgctrl` (string,model): send a command to the debugger (model must be running in debug mode). See Section B.4
- `dbgbrksub` (int,model): toggle *breaksub* mode during a debugging session (default is 0)
- `sdmax` (int,instance): set the maximum depth of a call stack dump (default is 0)

B.2 mcmd pseudo file

The special remote file `'mcmd'` takes the form of an I/O driver where the file name is interpreted as a query and the retrieved data is the answer to this request. Except for the `dsostream` command that can also be open in write mode, `'mcmd'` only supports read access. A file name for this driver has the following form:

```
mcmd:cmd[-opts][@mod[.submod]] cmdargs
```

cmd: the operation to execute (*e.g.* `'eval'`,`'profres'`...).

opts: options to change the format of the result. By default all data are sent using the Mosel binary format `'bin:'`. Adding option `'t'` switches to text format (still compatible with initialisations blocks) and `'j'` will cause results to be sent as a JSON object (not compatible with initialisations blocks). If option `'z'` is used the resulting file is compressed with gzip. A given command may also support additional options (see `'lslib'`). Except for the `'eval'` command, the result set publishes always the same records that are either scalars of basic types or lists of basic types. When a collection of values is returned a specific label indicating the dimension of the list precedes the list.

mod: master model on which the operation will be performed.

submod: submodel. Only some operations can be applied to a submodel. Note that submodel `'0'` is the master model itself (the first submodel has ID `'1'`).

Supported commands:

covres *(model)*
Retrieve profiling results for test coverage. This command can only be called after the model has been run in profiling mode (see Section B.3).

```
tottime:real
Rlines: range
lines:  array(Rlines) of integer
iters:  array(Rlines) of integer
Rfiles: range
files:  array(Rfiles) of string
Rstarts:range
starts: array(Rstarts) of integer
```

dbgbrkp `[ lndx [ cond|* ] ]` *(model or submodel)*
Breakpoint management. The model must be suspended. Without any parameters this command returns the current list of breakpoints; the first parameter is interpreted as a line index and the second parameter is a logical expression (*i.e.* the breakpoint condition). With only one parameter, the breakpoint on the corresponding line index is removed (no operation is performed if there was no breakpoint). Use '*' to remove all breakpoints. With two parameters the corresponding breakpoint is created (or modified). To set an unconditional breakpoint use '*' as the condition. Note that breakpoints are attached to a model: even if several models running concurrently are resulting from the same source file, setting a breakpoint for one model (instance) will have no effect on the others.

```
Rlndx: range
lndx:  array(Rlndx) of integer
cond:  array(Rlndx) of string
```

dbgflndx [fctname|*] *(model or submodel)*

Line indices corresponding to a function name. This command returns the line indices corresponding to the beginning (`lndx`) and end (`elndx`) of the requested function (several values are returned when the routine is overloaded). The values of `elndx` are valid only if the model has been compiled with option `-G`. Without any arguments or with argument '*', the command returns all functions of the model. If option 'N' is used, the arrays are sorted according to the function names. With option 'L' arrays are sorted following the line indices order.

```
Rsign: range
sign:  array(Rsign) of string
lndx:  array(Rsign) of integer
name:  array(Rsign) of string
elndx: array(Rsign) of integer
```

dbglndx *(model or submodel)*

Retrieve the mapping of the *line indices* of a model/submodel. The model must be either suspended or not running. The debugger interface works on *line indices*: each line index corresponds to a file name and a line number in this file.

```
Rfiles: range
files:  array(Rlines:range) of integer
Rlines: range
lines:  array(Rfiles:range) of string
```

dbgstat *(model or submodel)*

Current execution status of a model. The model must be suspended. If no submodel is specified, statuses of all submodels are returned in addition to the master model (to get the status of the master model only use submodel '0').

```
Rid:  range
id:   array(Rid) of integer
stat: array(Rid) of integer
stlev:array(Rid) of integer
lndx: array(Rid) of integer
```

dbgstlev [stlev|* [maxlev]] *(model or submodel)*

Stack management. The model must be suspended. Without any arguments or with argument '*', the command returns a stack dump (*i.e.* a list of line indices). If the argument is ≥ 0, it becomes the current stack level. The optional argument 'maxlev' defines the maximum number of levels to return (default:10). The stack level defines the context in which expression evaluations are performed in the 'eval' command.

```
Rid: range
id:  array(Rid) of integer
stat:array(Rid) of integer
stlev:array(Rid) of integer
lndx:array(Rid) of integer
```

dsostream dsoname [specific parameters] *(model or submodel)*

This command opens a stream to the specified module (this command supports both read and write mode). The module must implement the SRV_DSOSTRE service. The behaviour of the stream and the expected parameters depend on the implementation.

eval label:expression [range] *(model or submodel)*

Evaluate an expression in the context of the provided model/submodel. Execution of the model must be completed or suspended. If option `'i'` is used, array indices are reported as order

numbers instead of values. With option `'n'` array values are replaced by empty strings. The label "`label`" is used to identify the expresion in the result file: if it is '.' no label is generated (the data result is directly sent to the result file), if it is omitted then the expression itself is used as the label, otherwise the provided string is the label. Several expressions may be evaluated in a single request (in this case they must all be labelled).
It is possible to grab only a part of a collection (array, set or list) by specifying range information. Ranges definitions take one of these two forms:

- `[ maxelt ]`: get at most 'maxelt' elements
- `[ skip maxelt ]`: get at most 'maxelt' entries after skipping 'skip' elements

Several range definitions may be specified (separated by blanks): they are used when exploring complex structures (*e.g.* a list of list). The structure and type of the result set depends on the expression.

info *(instance, model or submodel)*
This command reports all symbols defined by Mosel (if used without specifying any argument), a module (the argument is the module name) or a model (the argument is a model or submodel ID). In the case of a module, the command loads the module if it is not yet in memory. For a model (or package), it must have been loaded prior to this command since it is referenced by its ID and be either not running or suspended. Information returned by the 'info' command:

```
fmt:     integer
Rhdr:    range
hdr:     array(Rhdr) of string
Rdeps:   range
deps:    array(Rdeps) of integer
depsvers:array(Rdeps) of integer
depstyp: array(Rdeps) of integer
Rtyps:   range
typs:    array(Rtyps) of string
typscod: array(Rtyps) of integer
Rparms:  range
parms:   array(Rparms) of string
parmsval:array(Rparms) of integer
parmsdesc:array(Rparms) of string
Rconsts: range
consts:  array(Rconsts) of string
conststyp:array(Rconsts) of integer
Rcstint: range
cstint:  array(Rcstint) of integer
Rcststr: range
cststr:  array(Rcststr) of string
Rcstdbl: range
cstdbl:  array(Rcstdbl) of real
Rvars:   range
vars:    array(Rvars) of string
varstyp: array(Rvars) of integer
varsopt: array(Rvars) of integer
Rarrndx: range
arrndx:  array(Rarrndx) of string
Rfct:    range
fct:     array(Rfct) of string
fctsign: array(Rfct) of string
fcttyp:  array(Rfct) of integer
Rdtyp:   range
dtyp:    array(Rdtyp:range) of string
dtyptyp: array(Rdtyp) of integer
Rrecsstart:range
recsstart:array(Rrecsstart) of integer
Rrecfield:range
recfield:array(Rrecfield) of string
recftype:array(Rrecfield) of integer
Riodrv:  range
iodrv:   array(Riodrv) of string
```

```
iodrvinfo:array(Riodrv) of string
Rannsident:range
annsident:array(Rannsidente) of string
Rannsstart:range
annsstart:array(Rannsstart) of integer
Ranns:     range
anns:      array(Ranns) of string
```

lsattr *(model or submodel)*
Return the list of available types attributes. The array 'attrsntyp' gives the type supporting the attribute and 'attrsatyp' is the type of the attribute.

```
Rattrs:   range
attrs:    array(Rattrs) of string
attrsntyp: array(Rattrs) of integer
attrsatyp: array(Rattrs) of integer
```

lslib *(instance)*
Return the list of available packages and modules. If option 'p' is used, packages are reported with their full path.

```
Rpkgs: range
pkgs:  array(Rpkgs) of string
Rdsos: range
dsos:  array(Rdsos) of string
```

lsloc *(model or submodel)*
This command is similar to 'info' but it can only be applied to a suspended model: it reports all local variables.

```
Rtyps:   range
typs:    array(Rtyps) of string
typscod: array(Rtyps) of integer
Rvars:   range
vars:    array(Rvars) of string
varstyp: array(Rvars) of integer
varsopt: array(Rvars) of integer
Rarrndx: range
arrndx:  array(Rarrndx) of string
```

profrep `[ srcpath ]` *(model)*
Ask for generation of result files after a profiling or covering execution, the result of this operation is a list of strings corresponding to the messages displayed by the commands `profile` or `cover`. This command can only be called after the model has been run in profiling or covering mode (see Section B.3). The optional `srcpath` argument is a list of paths (conforming to the operating system conventions) where the source files can be found. The option `'C'` implies the generation of the coverage files (*e.g.* 'file.mos.cov'), with option `'c'` the same files are produced but without counting of lines (*i.e.* a line that is executed is marked with `'1'` instead of the actual number of executions). The option `'P'` (the default) will generate the profiling files (*e.g.* 'file.mos.prof'), with option `'p'` timings are reported in percentage of the total amount of time (instead of elapsed time).

```
msg:list of string
```

profres `[ path ]` *(model)*
Retrieve profiling results. This command can only be called after the model has been run in profiling mode (see Section B.3). The `path` argument indicates which execution is requested: several "executions" may be available when the model starts other models with 'mmjobs' (the returned data set includes the number of additional executions available via the `nbsub` field). For instance the path `1.3` corresponds to the third "execution" started by the first "execution".

```
tottime:real
nbsub:  integer
nbnoprf:integer
Rlines: range
lines:  array(Rlines) of integer
iters:  array(Rlines) of integer
times:  array(Rlines) of real
elaps:  array(Rlines) of real
Rfiles: range
files:  array(Rfiles) of string
Rstarts:range
starts: array(Rstarts) of integer
```

B.3 Profiler interface

Profiling a model requires a bim file compiled with option '-G'. The runmode has to be set to '2' before starting the execution. After the end of the profiler run, calls to the command 'mcmd:profres', 'mcmd:profrep' or 'mcmd:covres' can be used for retrieving the results.

B.4 Debugger interface

The debugger can be started even if the flag `'-G'` has not been used for compilation but in this case most commands will fail to return useful information. To run a debugging session the runmode of the model must be set to `'1'` before starting its execution. If the model was compiled with `'-G'`, the execution is immediately suspended before the first statement of the model and a notification event is sent.

During a debugging session changes of the model execution status are notified by specific events of class `'EVENT_DBG'` (32770). The value of these events is a 32bit integer (cast to a real): the first 16 bits are a parameter (meaning depending on the reason) and the following 16 bits indicate the reason for the notification:

- `DBG_NOTIF_START` (1«16): Submodel starting (the parameter is the submodel ID)
- `DBG_NOTIF_END` (2«16): Submodel ending (the parameter is the submodel ID)
- `DBG_NOTIF_STOP` (3«16): Execution suspended (the parameter is the VM status)

When an event `'DBG_NOTIF_STOP'` is received, the model (and its submodels) is in suspended state and can be sent commands (see Section B.2). To continue execution a control parameter `'dbgctrl'` has to be set. The possible values are (the operation applies to the master model unless a submodel number 'num' is given):

- `C`: continue
- `E`: end of execution, abort debugging session
- `N [num]`: continue to next statement
- `S [num]`: step into subroutine
- `F [num]`: continue up to end of subroutine
- `T num lndx`: continue up to the specified line number on submodel 'num' (0 for master model)

Additionally, during the execution of a model running in debugging mode (but that is not suspended), the following 'dbgctrl' commands can be used:

- `B`: suspend execution (*e.g.* consequence of `ctrl-C`)
- `E`: end of execution, abort debugging session

When the execution of the model is about to end (including after an error), it is suspended just before exiting such that the user can look at the current status.

APPENDIX C

Error messages

The Mosel error messages listed in the following are grouped according to the following categories:

- **General errors**: may occur either during compilation or when running a model.
- **Parser/compiler errors**: raised during the model compilation.
- **Runtime errors**: when running a model.

All messages are identified by their code number, preceded either by the letter `E` for *error* or `W` for *warning*. Errors cause the compilation or execution of a model to fail, warnings simply indicate that there may be something to look into without causing a failure or interruption.

This chapter documents the error mesages directly generated by Mosel, not the messages stemming from Mosel modules or from other libraries used by modules.

C.1 General errors

These errors may occur either during compilation or when running a model.

E-1 ***Internal error in*** **'location'** ***(errortype)***
An unrecoverable error has been detected, Mosel exits. Please contact Xpress Support.

E-2 ***General error in*** **'location'** ***(errortype)***
An internal error has been detected but Mosel can recover. Please contact Xpress Support.

E-4 ***Not enough memory***
Your system has not enough memory available to compile or execute a Mosel model.

E-21 ***I cannot open file*** **'file'** ***for writing (*****driver_error*****)***
Likely causes are an incorrect access path or write-protected files.

E-22 ***I cannot open file*** **'file'** ***for reading (*****driver_error*****)***
Likely causes are an incorrect access path or filename or not read-enabled files.

E-23 ***Error when writing to the file*** **'file'** ***(*****driver_error*****)***
The file could be opened for writing but an error occurred during writing (*e.g.* disk full).

E-24 ***Error when reading from the file*** **'file'** ***(*****driver_error*****)***
The file could be opened for reading but an error occurred while reading it.

E-25 ***Unfinished string***
A string is not terminated, or different types of quotes are used to indicate start and end of a string.

Examples:

```
writeln("mytext)
```

E-26 ***Identifier expected***

May occur when reading data files: a label is missing or a numerical value has been found where a string is expected.

Examples:

```
declarations
 D: range
end-declarations

initializations from "test.dat"
 D
end-initializations
```

Contents of `test.dat`:

```
[1 2 3]
```

The label `D:` is missing.

E-27 ***Number expected***

May occur when reading data files: another data type has been found where a numerical value is expected.

Examples:

```
declarations
 C: set of real
end-declarations

initializations from "test.dat"
 C
end-initializations
```

Contents of `test.dat`:

```
C: [1 2 c]
```

`c` is not a number.

E-28 ***Digit expected for constant exponent***

May occur when using scientific notation for real values.

Examples:

```
b:= 2E -10
```

`E` must be immediately followed by a signed integer (*i.e.* no spaces).

E-29 ***Wrong file descriptor number for selection (*num*)***

`fselect` is used with an incorrect parameter value.

E-34 ***I cannot find IO driver '*driver*'***

The system cannot locate the IO driver *driver* for opening a file. This may happen if the driver is provided by a module not already loaded in memory. To avoid this problem the module name should be given with the driver name. For instance use `"mmodbc.odbc"` instead of `"odbc"` alone.

E-35 ***Error when closing file '*file*' (*driver_error*)***

An error occurred while closing a file. Typically the last write operation for clearing buffers failed.

E-36 ***Read error (*file*)***

I/O error during file reading.

E-37 ***Invalid character***
Invalid character sequence found while reading a text file, non-conforming to the current encoding. Possibly an incorrect encoding (Mosel default is UTF-8) has been specified for accessing this file.

E-38 ***Unknown compiler flag(s) 'flag' ignored***
Some of the flag(s) used with `compile` have not been recognized, please refer to the list documented for `compile`.

E-39 ***Unknown BIM reader flag(s) 'flag' ignored***
Some of the flag(s) used with `load` have not been recognized, please refer to the list documented for `load`.

E-40 ***Unsupported encoding 'encoding' (ignored)***
The encoding name specified after the marker `!@encoding` is unknown.

C.2 Parser/compiler errors

Whenever possible Mosel displays the location where an error has been detected during compilation in the format *(line_number/character_position_in_line)*.

E-100 ***Syntax error before* token**
The parser cannot continue to analyze the source file because it has encountered an unexpected token. When the error is not an obvious syntax error, make sure you are not using an identifier that has not been defined before.

Examples:

***token*:)**

```
writeln(3 mod)
```

`mod` must be followed by an integer (or a numerical expression evaluating to an integer).
***token*: write**

```
if i > 0
 write("greater")
end-if
```

`then` has been omitted.
***token*: end**

```
if i > 0 then write("greater") end-if
```

A semicolon must be added to indicate termination of the statement preceeding the `end-if`.

E-101 ***Incompatible types (type_of_problem)***
We try to apply an operation to incompatible types. Check the types of the operands.

Examples:

***type_of_problem*: assignment**

```
i:=0
i:=1.5
```

The first assignment defines `i` as an integer, the second tries to re-assign it a real value: `i` needs to be explicitly declared as a real.
***type_of_problem*: cmp**

```
12=1=2
```

A truth value (the result of `12=1` is compared to a numerical value.

E-102 ***Incompatible types for parameters of* 'routine'**
A subroutine is called with the wrong parameter type. This message may also be displayed instead of E-104 if a subroutine is called with the wrong number of parameters. (This is due to the possibility to overload the definition of subroutines).

Examples:

```
procedure myprint(a:integer)
 writeln("a: ", a)
end-procedure

myprint(1.5)
```

The subroutine `myprint` is called with a real-valued argument instead of an integer.

E-103 ***Incorrect number of subscripts for* 'array'*(num1/num2)***
An array is used with *num2* subscripts instead of the number of subscripts *num1* indicated at its declaration.

Examples:

***'array'*(num1/num2): 'A'(2/1)**

```
declarations
 A: array(1..5,range) of integer
end-declarations

writeln(A(3))
```

E-104 ***Incorrect number of parameters for* 'routine'*(num1/num2)***
Typically displayed if `write` or `read` are used without argument(s).

E-106 ***Division by zero detected***
Explicit division by 0 (otherwise error only detected at runtime).

E-107 ***Math error detected on function* 'fct'**
For example, a negative number is used with a fractional exponent.

E-108 ***Logical expression expected here***
Something else than a logical condition is used in an `if` statement.

E-109 ***Trying to redefine* 'name'**
Objects can only be defined once, changing their type is not possible.

Examples:

```
i:=0

declarations
 i: real
end-declarations
```

`i` is already defined as an integer by the assignment.

E-111 ***Logical expression expected for operator* 'op'**
Examples:

***op*: and**

```
2+3 and true
```

E-112 ***Numeric expression expected for operator* 'op'**
Examples:

***op*: +**

```
12+{13}
```

***op*: ***

```
uses "mmxprs"

declarations
 x:mpvar
end-declarations

minimize(x*x)
```

Multiplication of decision variables of type `mpvar` is only possible if a suitable module (like *mmnl*) supporting non-linear expressions is loaded.

E-113 ***Wrong type for conversion***
Mosel performs automatic conversions when required (for instance from an integer to a real) or when explicitly requested by using the type name, *e.g.* `integer(12.5)`. This error is raised when an unsupported conversion is requested or when no implicit conversion can be applied.

E-114 ***Unknown type for constant* 'const'**
A constant is defined but there is not enough information to deduce its type or the type implied cannot be used for a constant (for instance a linear constraint).

E-115 ***Expression cannot be passed by reference***
We try to use a constant where an identifier is expected. For instance, only non-constants can be used in an `initializations` block.

E-118 ***Wrong logical operator***
A logical opeartor is used with a type for which it is not defined.

Examples:

```
if("abc" in "acd") then writeln("?"); end-if
```

The operator `in` is not defined for strings.

W-121 ***Statement with no effect***
A statement is used that has no effet, for example `r += 0`.

E-122 ***Control parameter* 'param' *unknown***
The control parameters of Mosel are documented in the Mosel Reference manual under function `getparam`. All control parameters provided by a module, *e.g. mmxprs*, can be display with the command `EXAM`, *e.g.* `exam -p mmxprs`. In IVE this information is displayed by the module browser.

E-123 **'identifier' *is not defined***
identifier is used without or before declaring it. Check the spelling of the name. If *identifier* is defined by a module, make sure that the corresponding module is loaded. If *identifier* is a subroutine that is defined later in the program, add a `forward` declaration at the beginning of the model.

E-124 ***An expression cannot be used as a statement***
An expression stands where a statement is expected. In this case, the expression is ignored — typically, a constraint has been stated and the constraint type is missing (*i.e.* >= or <= ...) or an equality constraint occurs without decision variables, *e.g.* `2=1`.
This error also appears when the return value of a function call is not retrieved.

E-125 ***Set expression expected***
For instance when trying to compute the union between an integer constant and a set of integers: `union(12+{13})`

E-126 ***String expression expected***
A string is expected here: for instance a file name for an initializations block.

E-127 ***A function cannot be of type '*type*'***
Some types cannot be the return value of a function. Typically no function can return a decision variable (type `mpvar`).

E-128 ***Type '*type*' has no field named '*field*'***
Trying to access an unknown field in a record type.

Examples:

```
declarations
 myrec=record
         i,j:integer
       end-record
 r:myrec
end-declarations
r.k:=0
```

`k` is not a field of `r`.

E-129 ***Type '*type*' is not a record***
Trying to use a record dereference on an object that is not a record. For instance using `i.j` with `i` defined as an integer.

E-130 ***A type definition cannot be local***
It is not possible to declare a type in a procedure or function.

W-131 ***Array '*identifier*' is not indexed by ranges: assignment may be incorrect***
When performing an inline initialization (operator `::`) on an array, it is recommended to list indices if the indexing sets are not ranges. Indeed, since order of set elements is not guaranteed the values provided may not be assigned to the expected cells in the array.

Examples:

```
declarations
  a:array({3,2,1}) of integer
 end-declarations
 ! a::[3,2,1]         !=> a(1)=3 a(2)=2 a(3)=1
 a::([3,2,1])[3,2,1] !=> a(1)=1 a(2)=2 a(3)=3
```

E-132 ***Set or list expression expected***
Aggregate operators (like `sum` or `forall`) require sets or lists to describe the domains for their loops.

Examples:

```
declarations
  i:integer
 end-declarations
 forall(i = 2) writeln(i)
```

Since `i` is declared as an integer before the loop, the expression `i=2` is a logical expression (it checks whether `i` is equal to 2) instead of an index definition.

W-144 ***Symbol '*identifier*' implicitly declared***
When a model is compiled with option `-wi` this message gets displayed for every symbol that is not explicitly declared by the model.

E-147 ***Trying to interrupt a non existing loop***
`break` or `next` is used outside of a loop.

E-148 ***Procedure/function '*identifier*' declared but not defined***
A procedure or functions is declared with `forward`, but no definition of the subroutine body has been found or the subroutine body does not contain any statement.

E-149 ***Some requirements are not met***
A package may declare *requirements*: these are symbols that must be declared by models using this package. This error occurs when a model uses a package without providing the definitions for all the requirements.

E-150 ***End of file inside a commentary***
A commentary (usually started with `(!`) is not terminated. This error may occur, for instance, with several nested commentaries.

E-151 ***Incompatible type for subscript*** **num** ***of '*****identifier****'***
The subscript counter *num* may be wrong if an incorrect number of subscripts is used.

Examples:

```
declarations
 A:array(1..2,3..4) of integer
end-declarations

writeln(A(1.3))
```

This prints the value `2` for *num*, although the second subscript is actually missing.

W-152 ***Empty set for a loop detected***
This warning will be printed in a few cases where it is possible to detect an empty set during compilation.

E-153 ***Trying to assign the index '*****idx****'***
Loop indices cannot be re-assigned.

Examples:

```
declarations
 C: set of string
 D: range
end-declarations

forall(d in D) d+=1
forall(c in C) if (c='a') then c:='A'; end-if
```

Both of these assignments will raise the error. To replace an element of the set `C`, the element needs to be removed and the new element added to the set.

E-154 ***Unexpected end of file***
May occur, for instance, if an expression at the end of the model file is incomplete and in addition `end-model` is missing.

E-155 ***Empty 'case'***
A `case` statement is used without defining any choices.

E-156 ***'*****identifier****' has no type***
The type of *identifier* cannot be deduced. Typically, an undeclared object is assigned an empty set.

E-157 ***Scalar expression expected***
Examples:

```
declarations
 B={'a','b','c'}
end-declarations

case B of
 1: writeln("stop")
end-case
```

The `case` statement can only be used with the basic types (integer, real, boolean, string).

```
D:: [1,2]
```

Declaration of arrays by assignment is only possible if the index set can be deduced (*e.g.* definition of an array of linear constraints in a loop).

E-159 ***Compiler option* 'option' *unknown***
Valid compiler options include `explterm` and `noimplicit`. See section 2.3.3 for more details.

E-160 ***Definition of functions and procedures cannot be nested***
May occur, for instance, if `end-procedure` or `end-function` is missing and the definition of a second subroutine follows.

E-161 ***Expressions not allowed as procedure/function parameter***
Occurs typically if the index set(s) of an array are defined directly in the procedure/function prototype.

Examples:

```
procedure myproc(F:array(1..5) of real)
 writeln("something")
end-procedure
```

Replace either by `array(range)` or `array(set of integer)` or define `A:=1..5` outside of the subroutine definition and use `array(A)`

E-162 ***Non empty string expected here***
This error is raised, for example, by `uses ""`

E-163 ***Array declarations in the form of a list are not allowed as procedure/function parameter***
Basic types may be given in the form of a list, but not arrays.

Examples:

```
procedure myproc(F,G,H:array(range) of real, a,b,c:real)
 writeln("something")
end-procedure
```

Separate declaration of every array is required:

```
procedure myproc(F:array(range) of real, G:array(range) of real,
                 H:array(range) of real, a,b,c:real)
```

W-164 ***A local symbol cannot be made public***
Examples:

```
procedure myproc
 declarations
  public i:integer
 end-declarations
 i:=1
end-procedure
```

Any symbol declared in a subroutine is local and cannot be made public.

E-165 ***Declaration of* 'identifier' *hides a parameter***
The name of a function/procedure parameter is re-used in a local declaration.

Examples:

```
procedure myproc(D:array(range) of real)
 declarations
  D: integer
 end-declarations
 writeln(D)
end-procedure
```

Rename either the subroutine argument or the name used in the declaration.

W-166 ***';' missing at end of statement***
If the option `explterm` is employed, then all statements must be terminated by a semicolon.

E-167 ***Operator 'op' not defined***
A constructor for a type is used in a form that is not defined.

Examples:

```
uses "complex"
c:=complex(1,2,3)
```

The module *complex* defines constructors for complex numbers from one or two reals, but not from three.

E-168 **'something'** ***expected here***
Special case of "syntax error" (E-100) where the parser is able to provide a guess of what is missing.

Examples:

***something*: :=**

```
a: 3
```

The assignment is indicated by `:=`.
***something*: of**

```
declarations
 S: set integer
end-declarations
```

`of` has been omitted.
***something*: ..**

```
declarations
 A: array(1:2) of integer
end-declarations
```

Ranges are specified by `...`

E-169 **'identifier'** ***cannot be used as an index name (the identifier is already in use or declared)***
Examples:

```
i:=0
sum(i in 1..10)
```

The identifier `i` has to be replaced by a different name in one of these lines.

E-170 ***'=' expects a scalar here (use 'in' for a set)***
Special case of syntax error (E-100).

Examples:

```
sum(i = 1..10)
```

Replace = by `in`.

E-171 ***The [upper/lower] bound of a range is not an integer expression***
Examples:

```
declarations
 A: array(1..2.5) of integer
end-declarations
```

Ranges are intervals of integers, so the upper bound of the index range must be changed to either `2` or `3`.

E-172 ***Only a reference to a public set is allowed here***
All index sets of a public array must also be public.

E-173 ***Statement allowed in packages only***
The block `requirements` can only be used in packages.

E-175 ***Index sets of array types must be named***
User types defined as arrays must be indexed by named sets (*i.e.* declared separately). For instance it is not allowed to use `range` or `set of string` as an index of such an array.

E-176 ***Only a public type is allowed here***
If a user type depending on another user type is declared declared public, the secondary type must also be public. For instance, assuming type `T1` is private, it is not possible to declare `T2` as a `public T2=set of T1`.

E-177 ***Incorrect number of initializers (*n1/n2*)***
In an inline initialization (operator `::`) the number of provided values to assign does not match the list of indices.

E-202 ***Integer constant expected***
Versions numbers (stated by means of the `version` compiler directive) must consist in 1 to 3 numbers separated by dots (*e.g.* `1.2.3`). This error is displayed if a version number does not conform to this syntax.

E-207 ***Problem reference/type expected here***
The operator `with` is used with something that is not a problem.

E-208 ***There can be only one counter***
The `as counter` declaration can appear only once in an iterator list.

E-209 ***Missing loop indices***
Typically an iterator list contains only a counter declaration: it is necessary to provide at least one index.

E-210 ***String starting at line* line *is unfinished***
A multiline string is not correctly terminated with the matching end marker.

E-211 ***Invalid annotation syntax (ignored)***
Malformed annotation that cannot be identified (*e.g.* containing `..` or invalid characters—only alphanumeric and underscore are allowed in annotation names).

E-212 ***Annotations: invalid path* 'name'**
Some portion of the path forming an annotation identifier, *e.g.* `cat1.cat2` is the path for the annotation `!@cat1.cat2.name`, cannot be accessed.

E-213 ***Annotations: name* 'name' *not found***
Some portion of the path forming an annotation identifier, *e.g.* `cat1.cat2` is the path for the annotation `!@cat1.cat2.name`, is not defined.

E-214 ***Annotations: trying to redefine* 'name' *(ignored)***
An annotation can only be defined once.

E-215 ***Annotations: invalid definition string for* 'name' *(value)***
Incorrect or incomplete annotation declaration in an `@mc.def` statement, such as duplicate or missing property or value, use of an unknown keyword. Please refer to the list of permissible declaration statements in Section 2.14.3.

E-217 ***Annotations: wrong value* 'value' *for* 'name' *(expecting:* value2*)***
An annotation is assigned a value that does not correpond to the value type or set of values that have been specified in its declaration (via `@mc.def`).

E-218 ***Annotations: missing chapter for* 'name'**
moseldoc is trying to add a documentation entry under a chapter or section that has not (yet) been defined.

C.2.1 Errors related to modules

E-302 ***The symbol*** **'identifier'** ***from*** **'module'** ***cannot be defined (redefinition)***
Two different modules used by a model define the same symbol (incompatible definitions).

E-303 ***Wrong type for symbol*** **'identifier'** ***from*** **'module'**
Internal error in the definition of a user module (an unknown type is used): refer to the list of type codes in the Native Interface reference manual.

W-306 ***Unknown operator*** **'op'** ***(code*** **num)** ***in module*** **'module'**
Internal error in the definition of a user module: refer to the list of operator codes in the Native Interface reference manual.

E-307 ***Operator*** **'op'** ***(code*** **num)** ***from module*** **'module'** ***rejected***
Internal error in the definition of a user module: an operator is not defined correctly.

E-308 ***Parameter string of a native routine corrupted***
Internal error in the definition of a user module: refer to the list of parameter type codes in the Native Interface reference manual.

W-309 ***Problem type*** **'typ'** ***unknown: extension*** **'ext'** ***ignored***
A module declares a native type as a problem extension but the compiler cannot find the base type. For instance the new type is named `"myprob.pb"` but `"myprob"` does not exist.

C.2.2 Errors related to packages

E-320 ***Package*** **'package'** ***not found***
A package has not been found in the module path (see section 2.3.1 for the search rules).

E-321 **'file'** ***is not a package***
Typically displayed if a model is used as a package (the source for the bim file starts with the `model` keyword instead of `package`).

E-322 ***Wrong version for package*** **'package'** ***(using:*** **num1.num2.num3** ***/required:*** **num4.num5.num6** ***)***
A model is compiled with package A depending on a package B. The bim file Mosel has loaded for B is not compatible with the one used for compiling A (found version *num1.num2.num3*, required version is *num4.num5.num6*).

E-323 ***Package*** **'package'** ***imported several times***
A package cannot be imported several times in a model. This error occurs usually when a model uses packages A and B, and package B already includes A.

C.3 Runtime errors

Runtime errors are usually displayed without any information about where they have occurred. To obtain the location of the error, use the flag *g* with the `COMPILE`, `CLOAD`, or `EXECUTE` command.

C.3.1 Initializations

E-30 ***Duplicate label*** **'label'** ***at line*** **num** ***of file*** **'file'** ***(ignored)***
The same label is used repeatedly in a data file.

Examples:

```
D: [1 2 3]
D: [1 2 4]
```

E-31 ***Error when reading label*** **'label'** ***at (*****num1,num2*****) of file*** **'file'**
The data entry labeled *label* has not been read correctly. Usually this message is preceded by a more detailed one, *e.g.* E-24, E-27 or E-28.

E-32 ***Error when writing label*** **'label'** ***at (*****num1,num2*****) of file*** **'file'**
The data entry labeled *label* has not been written correctly. Usually this message is preceded by a more detailed one, *e.g.* E-23.

E-33 ***Initialization with file*** **'file'** ***failed for:*** **list_of_identifier**
Summary report at the end of an `initializations` section. Usually this message is preceded by more detailed ones, *e.g.* E-27, E-28, E-30, E-31.

C.3.2 General runtime errors

E-51 ***Division by zero***
Division by 0 resulting from the evaluation of an expression.

E-52 ***Math error performing function*** **'identifier'**
For example `ln` used with inadmissible argument, such as 0 or negative values.

E-72 ***Not a runnable model (main procedure not found)***
Most likely, you are trying to execute a 'package' as if it were a 'model'.

E-1000 ***Inconsistent range***
Typically displayed if the lower bound specified for a range is greater than its upper bound.

Examples:

```
D:=3..-1
```

E-1001 ***Conflicting types in set operation (*****op*****)***
A set operation can only be carried out between sets of the same type.

Examples:

```
declarations
 C: set of integer
 D: range
end-declarations

C:={5,7}
D:=C
```

The inverse, `C:=D`, is correct because ranges are a special case of sets of integers.

E-1002 ***An index is out of range***
An attempt is being made to access an array entry that lies outside of the index sets of the array.

E-1003 ***Trying to modify a finalized or fixed set***
Occurs, for instance, when it is attempted to re-assign a constant set or to add elements to a fixed set.

E-1004 ***Trying to access an uninitialized object (*****type_of_object*****)***
Occurs typically in models that define subroutines.

Examples:

type_of_object**: array**

```
forward procedure myprint
myprint
declarations
 A:array(1..2,3..4) of integer
end-declarations
```

```
procedure myprint
 writeln(A(1,2))
end-procedure
```

Move the declaration of `A` before the call of the subroutine

E-1005 ***Wrong type for "*procedure*"***
Occurs when procedures `settype` or `getvars` are used with incorrect types.

E-1006 ***Null reference (*internal_function*)***
This error is a special case of *E-1004* when the problem is detected on an external type or scalar (*e.g.* accessing a record field on an object that has not been initialized).

E-1009 ***Too many initializers***
The number of data elements exceeds the maximum size of an array.

Examples:

```
declarations
 A:array(1..3) of integer
end-declarations

A::[1,2,3,4]
```

E-1010 ***Trying to extend a unary constraint***
Most types of unary constraints cannot be transformed into constraints on several variables.

Examples:

```
declarations
 x,y: mpvar
end-declarations

c:=x is_integer
c+=y
```

E-1011 ***Dense array too big***
The model is trying to create a dense array with more than 4 billion cells, typically such an array should have been declared as sparse (dynamic or hashmap). This error will be raised when the array is allocated (after its declaration or when it is first accessed).

E-1013 ***Infeasible constraint***
The simple cases of infeasible unnamed constraints that are detected at run time include:

Examples:

```
declarations
 x:mpvar
end-declarations
i:=-1
if(i>=0,x,0)>=1

! or:
 x-x>=1
```

E-1014 ***Conflicting types in array operation (*op*)***
An array operation (like assignment) can only be carried out between arrays of the same type and structure.

E-1015 ***Trying to modify a constant list***
Occurs, for instance, when it is attempted to apply a destructive operation (like `splittail`) to a constant list.

E-1016 ***Trying to get an element in an empty set***
The function `getfirst` or `getlast` is applied to an empty set.

E-1017 ***Trying to get an element in an empty list***
The function `getfirst` or `getlast` is applied to an empty list.

E-1018 ***Invalid identifier* 'identifier' *for publish***
The `publish` command has received an invalid identifier name (*e.g.* not a valid Mosel identifier or the name is already in use as Mosel idientifier).

E-1100 ***Empty problem***
We are trying to generate or load an empty problem into a solver (*i.e.* no constraints; bounds do not count as constraints).

E-1103 ***Too many matrix coefficients***
Matrix size exceeds machine capacity: for 32bit versions the limit are 2billion (2 · 10E9) elements.

C.3.3 BIM reader

E-80 **'file'** ***is not a BIM file***
Trying to load a file that does not have the structure of a BIM file.

E-82 ***Wrong BIM format version (current:*num1*/required:*num2*) for file* 'file'
A BIM file is loaded with an incompatible version of Mosel: preferably the same versions should be used for generating and running a BIM file.

E-83 ***BIM file* 'file' *corrupted***
A BIM file has been corrupted, *e.g.* by saving it with a text editor.

E-84 ***File* 'file'*: model cannot be renamed***
A model file that is being executed cannot be re-loaded at the same time.

W-85 ***Trailing data at end of file* 'file' *ignored***
At the end of a BIM file additional, unidentifiable data has been found (may be a sign of file corruption).

E-88 ***BIM file* 'file' *corrupted***
Incomplete or otherwise damaged BIM file.

E-90 ***Signature error (*description*)***
During the generation of a BIM file, a problem with the signature has occurred.

E-91 ***Signature verification error (*description*)***
While reading a BIM file, a problem with the signature has occurred (*e.g.* trying to check signature for a file that is not signed; or the keys that have been employed don't match).

E-92 ***Encryption error (*description*)***
Problem with encryption during the generation of a BIM file (*e.g.* invalid or missing key).

E-93 ***Decryption error (*description*)***
Problem with decryption while reading a BIM file (*e.g.* invalid or missing key).

C.3.4 Module manager errors

E-350 ***Module* 'module' *not found***
A module has not been found in the module path (see section 2.3.1 for the search rules). This message is also displayed, if a module depends on another library that has not been found (*e.g.* module *mmxprs* has been found but Xpress Optimizer has not been installed or cannot be located by the operating system).

E-351 ***File* 'file' *is not a Mosel DSO***
Typically displayed if Mosel cannot find the module initialization function.

E-352 ***Module* 'module' *requires a more recent version of Mosel (unsupported interface)***
A module is not compatible with the Mosel version used to load it.

E-353 ***Module* 'module' *disabled by restrictions***
Module *module* either does not implement restriction handling at all or it requires features that are not authorized. See section 1.3.4 (restricted mode) and section 8.6.2 (Remote Launcher configuration) to learn how to relax the restrictions.

Examples:

mmxprs will fail with the restriction setting `NoTmp`

E-354 ***Error when initializing module* 'module'**
Usually preceded by an error message generated by the module. Please refer to the documentation of the module for further detail.

E-355 ***Wrong version for module* 'module'*(using:*num1.num2.num3*/required:*num4.num5.num6*)***
A model is run with a version of a module that is different from the version that has been used to compile the model (trying to run with version *num1.num2.num3*, required version is *num4.num5.num6*).

E-358 ***Error when resetting module* 'module'**
A module cannot be executed (*e.g.* due to a lack of memory).

E-359 ***Driver* 'pkg.driver' *rejected (*reason*)***
A module publishes an IO driver which name is invalid or that is missing some mandatory function.

E-360 ***Control parameter* 'module.param' *unknown (setting ignored)***
It is possible to set module parameters when running a model (using the `RUN` command for instance): in the list of assignments, a control parameter cannot be found in the indicated module.

E-361 ***Version number truncated ('*vernum*')***
A version number (for module, model or package) consists in three positive numbers *a.b.c*. This error is raised if one of these numbers is larger than 999.

E-362 ***The operating system failed to load file* 'file' *('*description*')***
The module file has been found but cannot be loaded by the system—there will typically be some system error message indicating the exact cause, such as wrong architecture (*e.g.* using a library compiled for Windows under Linux or bitness mismatch) or missing additional files (*e.g.* tyring to use module *matlab* without having previously installed Matlab—see the manual *Xpress MATLAB Interface* for further detail, or attempting to use *mmoci* without having installed the Oracle Instant Client—see setup instructions in the whitepaper *Using ODBC and other database interfaces with Mosel*).

APPENDIX D

Contacting FICO

FICO provides clients with support and services for all our products. Refer to the following sections for more information.

Product support

FICO offers technical support and services ranging from self-help tools to direct assistance with a FICO technical support engineer. Support is available to all clients who have purchased a FICO product and have an active support or maintenance contract. You can find support contact information and a link to the Customer Self Service Portal (online support) on the Product Support home page (www.fico.com/en/product-support).

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Please include *'Xpress'* in the subject line of your support queries.

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Please include your contact information (name, company, email address, and optionally, your phone number) so we may reach you if we have questions.

Sales and maintenance

If you need information on other Xpress Optimization products, or you need to discuss maintenance contracts or other sales-related items, contact FICO by:

- Phone: +1 (408) 535-1500 or +44 207 940 8718
- Web: www.fico.com/optimization and use the available contact forms

Related services

Strategy Consulting: Included in your contract with FICO may be a specified amount of consulting time to assist you in using FICO Optimization Modeler to meet your business needs. Additional consulting time can be arranged by contract.

Conferences and Seminars: FICO offers conferences and seminars on our products and services. For announcements concerning these events, go to www.fico.com or contact your FICO account representative.

FICO Community

The FICO Community is a great resource to find the experts and information you need to collaborate, support your business, and solve common business challenges. You can get informal technical support, build relationships with local and remote professionals, and improve your business practices. For additional information, visit the FICO Community (community.fico.com/welcome).

About FICO

FICO (NYSE:FICO) powers decisions that help people and businesses around the world prosper. Founded in 1956 and based in Silicon Valley, the company is a pioneer in the use of predictive analytics and data science to improve operational decisions. FICO holds more than 165 US and foreign patents on technologies that increase profitability, customer satisfaction, and growth for businesses in financial services, telecommunications, health care, retail, and many other industries. Using FICO solutions, businesses in more than 100 countries do everything from protecting 2.6 billion payment cards from fraud, to helping people get credit, to ensuring that millions of airplanes and rental cars are in the right place at the right time. Learn more at www.fico.com.

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