GNU PROLOG

A Native Prolog Compiler with Constraint Solving over Finite Domains
Edition 1.50, for GNU Prolog version 1.5.0
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3 Introduction

GNU Prolog [5] is a free Prolog compiler with constraint solving over finite domains. For recent information about GNU Prolog please consult the GNU Prolog page.

GNU Prolog is a Prolog compiler based on the Warren Abstract Machine (WAM) [9][1]. It first compiles a Prolog program to a WAM file which is then translated to a low-level machine independent language called mini-assembly specifically designed for GNU Prolog. The resulting file is then translated to the assembly language of the target machine (from which an object is obtained). This allows GNU Prolog to produce a native stand alone executable from a Prolog source (similarly to what does a C compiler from a C program). The main advantage of this compilation scheme is to produce native code and to be fast. Another interesting feature is that executables are small. Indeed, the code of most unused built-in predicates is not included in the executables at link-time.

A lot of work has been devoted to the ISO compatibility. Indeed, GNU Prolog is very close to the ISO standard for Prolog [6].

GNU Prolog also offers various extensions very useful in practice (global variables, OS interface, sockets,...). In particular, GNU Prolog contains an efficient constraint solver over Finite Domains (FD). This opens constraint logic programming to the user combining the power of constraint programming to the declarativity of logic programming. The key feature of the GNU Prolog solver is the use of a single (low-level) primitive to define all (high-level) FD constraints. There are many advantages of this approach: constraints can be compiled, the user can define his own constraints (in terms of the primitive), the solver is open and extensible (as opposed to black-box solvers like CHIP),... Moreover, the GNU Prolog solver is rather efficient, often more than commercial solvers.

GNU Prolog is inspired from two systems:
• **wamcc**: a Prolog to C compiler \[3\]. the key point of wamcc was its ability to produce stand alone executables using an original compilation scheme: the translation of Prolog to C via the WAM. Its drawback was the time needed by gcc to compile the produced sources. GNU Prolog can also produce stand alone executables but using a faster compilation scheme.

• **clp(FD)**: a constraint programming language over FD \[4\]. Its key feature was the use of a single primitive to define FD constraints. GNU Prolog is based on the same idea but offers an extended constraint definition language. In comparison to clp(FD), GNU Prolog offers new predefined constraints, new predefined heuristics, reified constraints,…

Here are some features of GNU Prolog:

• **Prolog system:**
  – conforms to the ISO standard for Prolog (floating point numbers, streams, dynamic code,…).
  – a lot of extensions: global variables, definite clause grammars (DCG), sockets interface, operating system interface,…
  – more than 300 Prolog built-in predicates.
  – Prolog debugger and a low-level WAM debugger.
  – line editing facility under the interactive interpreter with completion on atoms.
  – powerful bidirectional interface between Prolog and C.

• **Compiler:**
  – native-code compiler producing stand alone executables.
  – simple command-line compiler accepting a wide variety of files: Prolog files, C files, WAM files,…
  – direct generation of assembly code 15 times faster than wamcc + gcc.
  – most of unused built-in predicates are not linked (to reduce the size of the executables).
  – compiled predicates (native-code) as fast as wamcc on average.
  – consulted predicates (byte-code) 5 times faster than wamcc.

• **Constraint solver:**
  – FD variables well integrated into the Prolog environment (full compatibility with Prolog variables and integers). No need for explicit FD declarations.
  – very efficient FD solver (comparable to commercial solvers).
  – high-level constraints can be described in terms of simple primitives.
  – a lot of predefined constraints: arithmetic constraints, boolean constraints, symbolic constraints, reified constraints,…
  – several predefined enumeration heuristics.
  – the user can define his own new constraints.
  – more than 50 FD built-in constraints/predicates.
4 Using GNU Prolog

4.1 Introduction

GNU Prolog offers two ways to execute a Prolog program:

- interpreting it using the GNU Prolog interactive interpreter.
- compiling it to a (machine-dependent) executable using the GNU Prolog native-code compiler.

Running a program under the interactive interpreter allows the user to list it and to make full use of the debugger on it (section 5, page 31). Compiling a program to native code makes it possible to obtain a stand-alone executable, with a reduced size and optimized for speed. Running a Prolog program compiled to native-code is around 3-5 times faster than running it under the interpreter. However, it is not possible to make full use of the debugger on a program compiled to native-code. Nor is it possible to list the program. In general, it is preferable to run a program under the interpreter for debugging and then use the native-code compiler to produce an autonomous executable. It is also possible to combine these two modes by producing an executable that contains some parts of the program (e.g. already debugged predicates whose execution-time speed is crucial) and interpreting the other parts under this executable. In that case, the executable has the same facilities as the GNU Prolog interpreter but also integrates the native-code predicates. This way to define a new enriched interpreter is detailed later (section 4.4.5, page 27).

4.2 The GNU Prolog interactive interpreter

4.2.1 Starting/exiting the interactive interpreter

GNU Prolog offers a classical Prolog interactive interpreter also called *top-level*. It allows the user to execute queries, to consult Prolog programs, to list them, to execute them and to debug them. The top-level can be invoked using the following command:

```
% gprolog [OPTION]...
```

(the `%` symbol is the operating system shell prompt)

**Options:**

- `--init-goal GOAL` execute `GOAL` before entering the top-level
- `--consult-file FILE` consult `FILE` inside the top-level
- `--entry-goal GOAL` execute `GOAL` inside the top-level
- `--query-goal GOAL` execute `GOAL` as a query for the top-level
- `--help` print a help and exit
- `--version` print version number and exit
- `--` do not parse the rest of the command-line

The main role of the `gprolog` command is to execute the top-level itself, i.e. to execute the built-in predicate `top_level/0` (section 8.18.1, page 120) which will produce something like:

```
GNU Prolog 1.5.0 (64 bits)
Compiled May 3 2021, 16:36:43 with gcc
Copyright (C) 1999-2021 Daniel Diaz

| ?- |
```

The top-level is ready to execute your queries as explained in the next section.
To quit the top-level type the end-of-file key sequence (Ctl-D) or its term representation: end_of_file. It is also possible to use the built-in predicate halt/0 (section 8.18.1 page 126).

However, before entering the top-level itself, the command-line is processed to treat all known options (those listed above). All unrecognized arguments are collected together to form the argument list which will be available using argument_value/2 (section 8.27.2 page 160) or argument_list/1 (section 8.27.3 page 161). The -- option stops the parsing of the command-line, all remaining options are collected into the argument list.

Several options are provided to execute a goal before entering the interaction with the user:

- The --init-goal option executes the GOAL as soon as it is encountered (while the command-line is processed). GOAL is thus executed before entering top_level/0.
- The --consult-file option consults the FILE at the entry of top_level/0 just after the banner is displayed. --consult-file options are handled before --consult-file options.
- The --entry-goal option executes the GOAL at the entry of top_level/0 just after the banner is displayed.
- The --query-goal option executes the GOAL as if the user has typed in (under the top-level).

The above order is thus the order in which each kind of goal (init, entry, query) is executed. If there are several goals of a same kind they are executed in the order of appearance. Thus, all init goals are executed (in the order of appearance) before all entry goals and all entry goals are executed before all query goals.

Each GOAL is passed as a shell argument (i.e. one shell string) and should not contain a terminal dot. Example: --init-goal 'write(hello), nl' under a sh-like. To be executed, a GOAL is transformed into a term using read_term_from_atom(Goal, Term, [end_of_term(eof)]). Respecting both the syntax of shell strings and of Prolog can be heavy. For instance, passing a backslash character \ can be difficult since it introduces an escape sequence both in sh and inside Prolog quoted atoms. The use of back quotes can then be useful since, by default, no escape sequence is processed inside back quotes (this behavior can be controlled using the back_quotes Prolog flag (section 8.22.1 page 148)).

Since the Prolog argument list is created when the whole command-line is parsed, if a --init-goal option uses argument_value/2 or argument_list/1 it will obtained the original command-line arguments (i.e. including all recognized arguments).

Here is an example of using execution goal options:

```bash
% gprolog --init-goal 'write(before), nl' --entry-goal 'write(inside), nl'  
  --query-goal 'append([a,b],[c,d],X)'
```

will produce the following:

```
before
GNU Prolog 1.5.0 (64 bits)
Compiled May 3 2021, 16:36:43 with gcc
Copyright (C) 1999-2021 Daniel Diaz

inside
| ?- append([a,b],[c,d],X).
X = [a,b,c,d]
yes
| ?-
```
NB: depending on the used shell it may be necessary to use other string delimiters (e.g. use " under Windows cmd.exe).

### 4.2.2 The interactive interpreter read-execute-write loop

The GNU Prolog top-level is built on a classical read-execute-write loop that also allows for re-executions (when the query is not deterministic) as follows:

- display the prompt, i.e. 'l ?-'.
- read a query (i.e. a goal).
- execute the query.
- in case of success display the values of the variables of the query.
- if there are remaining alternatives (i.e. the query is not deterministic), display a ? and ask the user who can use one of the following commands: RETURN to stop the execution, ; to compute the next solution or a to compute all remaining solution.

Here is an example of execution of a query ("find the lists X and Y such that the concatenation of X and Y is [a,b]"): |

| ?- append(X,Y,[a,b,c]). |

X = []
Y = [a,b,c] ? ; (here the user presses ; to compute another solution)

X = [a]
Y = [b,c] ? a (here the user presses a to compute all remaining solutions)

X = [a,b]
Y = [c] (here the user is not asked and the next solution is computed)

X = [a,b,c]
Y = [] (here the user is not asked and the next solution is computed)

no (no more solution)

In some cases the top-level can detect that the current solution is the last one (no more alternatives remaining). In such a case it does not display the ? symbol (and does not ask the user). Example:

| ?- (X=1 ; X=2). |

X = 1 ? ; (here the user presses ; to compute another solution)

X = 2 (here the user is not prompted since there are no more alternatives)

yes

The user can stop the execution even if there are more alternatives by typing RETURN.

| ?- (X=1 ; X=2). |

X = 1 ? (here the user presses RETURN to stop the execution)

yes
The top-level tries to display the values of the variables of the query in a readable manner. For instance, when a variable is bound to a query variable, the name of this variable appears. When a variable is a singleton an underscore symbol \_ is displayed (\_ is a generic name for a singleton variable, it is also called an anonymous variable). Other variables are bound to new brand variable names. When a query variable name \texttt{X} appears as the value of another query variable \texttt{Y} it is because \texttt{X} is itself not instantiated otherwise the value of \texttt{X} is displayed. In such a case, nothing is output for \texttt{X} itself (since it is a variable). Example:

\begin{verbatim}
| ?- \texttt{X=f(A,B,\_,A), A=k}.  \\
A = k \quad \text{(the value of A is displayed also in f/3 for X)}  \\
X = f(k,B,\_,k) \quad \text{(since B is a variable which is also a part of X, B is not displayed)}

| ?- functor(T,f,3), arg(1,T,X), arg(3,T,X).
T = f(X,\_,X) \quad \text{(the 1\textsuperscript{st} and 3\textsuperscript{rd} args are equal to X, the 2\textsuperscript{nd} is an anonymous variable)}

| ?- read_from_atom('k(X,Y,X).',T).
T = k(A,\_,A) \quad \text{(the 1\textsuperscript{st} and 3\textsuperscript{rd} args are unified, a new variable name A is introduced)}
\end{verbatim}

The top-level uses variable binding predicates (section 8.5, page 63). To display the value of a variable, the top-level calls \texttt{write_term/3} with the following option list: [\texttt{quoted(true)},\texttt{numbervars(false)}, \texttt{namevars(true)}] (section 8.14.6, page 108). A term of the form \$\texttt{VARNAME}'(Name) where \texttt{Name} is an atom is displayed as a variable name while a term of the form \$\texttt{VAR}'(N) where \texttt{N} is an integer is displayed as a normal compound term (such a term could be output as a variable name by \texttt{write_term/3}). Example:

\begin{verbatim}
| ?- \texttt{X='$VARNAME'(Y)}, Y='$VAR'(1).
X = Y \quad \text{(the term '$VARNAME'(Y) is displayed as Y)}
Y = '$VAR'(1) \quad \text{(the term '$VAR'(1) is displayed as is)}

| ?- X=Y, Y='$VAR'(1).
X = '$VAR'(1)
Y = '$VAR'(1)
\end{verbatim}

In the first example, \texttt{X} is explicitly bound to \$\texttt{VARNAME}'(Y) by the query so the top-level displays \texttt{Y} as the value of \texttt{X}. \texttt{Y} is unified with \$\texttt{VAR}'(1) so the top-level displays it as a normal compound term. It should be clear that \texttt{X} is not bound to \texttt{Y} (whereas it is in the second query). This behavior should be kept in mind when doing variable binding operations.

Finally, the top-level computes the user-time (section 8.24.2, page 155) taken by a query and displays it when it is significant. Example:

\begin{verbatim}
| ?- retractall(p(\_)), assertz(p(0)), repeat,  \\
\quad retract(p(X)),  \\
\quad Y is X + 1,  \\
\quad assertz(p(Y)),  \\
\quad X = 1000, !.
\end{verbatim}

\begin{verbatim}
X = 1000
Y = 1001
(180 ms) yes \quad \text{(the query took 180ms of user time)}
\end{verbatim}
4.2.3 Consulting a Prolog program

The top-level allows the user to consult Prolog source files. Consulted predicates can be listed, executed and debugged (while predicates compiled to native-code cannot). For more information about the difference between a native-code predicate and a consulted predicate refer to the introduction of this section (section 4.1, page 13) and to the part devoted to the compiler (section 4.4.1, page 21).

To consult a program use the built-in predicate consult/1 (section 8.23.1, page 153). The argument of this predicate is a Prolog file name or user to specify the terminal. This allows the user to directly input the predicates from the terminal. In that case the input shall be terminated by the end-of-file key sequence (Ctl-D) or its term representation: end_of_file. A shorthand for consult(FILE) is [FILE]. Example:

```prolog
| ?- [user].  
{compiling user for byte code...}  
even(0).  
even(s(s(X))):-  
   even(X).  
          (here the user presses Ctl-D to end the input)  
{user compiled, 3 lines read - 350 bytes written, 1180 ms}  
| ?- even(X).  
X = 0 ? ;  
X = s(s(0)) ? ;  
X = s(s(s(s(0)))) ?  
          (here the user presses RETURN to stop the execution)  
yes  
| ?- listing.  
even(0).  
even(s(s(A))):-  
   even(A).  
```

When consult/1 (section 8.23.1, page 153) is invoked on a Prolog file it first runs the GNU Prolog compiler (section 4.4, page 21) as a child process to generate a temporary WAM file for byte-code. If the compilation fails a message is displayed and nothing is loaded. If the compilation succeeds, the produced file is loaded into memory using load/1 (section 8.23.2, page 153). Namely, the byte-code of each predicate is loaded. When a predicate $P$ is loaded if there is a previous definition for $P$ it is removed (i.e. all clauses defining $P$ are erased). We say that $P$ is redefined. Note that only consulted predicates can be redefined. If $P$ is a native-code predicate, trying to redefine it will produce an error at load-time: the predicate redefinition will be ignored and the following message displayed:

```
native code procedure P cannot be redefined
```

Finally, an existing predicate will not be removed if it is not re-loaded. This means that if a predicate $P$ is loaded when consulting the file $F$, and if later the definition of $P$ is removed from the file $F$, consulting $F$ again will not remove the previously loaded definition of $P$ from the memory.

Consulted predicates can be debugged using the Prolog debugger. Use the debugger predicate trace/0 or debug/0 (section 5.3.1, page 31) to activate the debugger.
4.2.4 Scripting Prolog

Since version 1.4.0 it is possible to use a Prolog source file as a Unix script-file (shebang support). A PrologScript file should begin as follows:

```bash
#!/usr/bin/gprolog --consult-file
```

GNU Prolog will be invoked as

```bash
/usr/bin/gprolog --consult-file FILE
```

Then `FILE` will be consulted. In order to correctly deal with the `#!` first line, `consult/1` treats as a comment a first line of a file which begins with `#` (if you want to use a predicate name starting with a `#`, simply skip a line before its definition).

Remark: it is almost never possible to pass additional parameters (e.g. `query-goal`) this way since in most systems the shebang implementation delivers all arguments (following `#!/usr/bin/gprolog`) as a single string (which cannot then correctly be recognized by `gprolog`).

4.2.5 Interrupting a query

Under the top-level it is possible to interrupt the execution of a query by typing the interruption key (Ctl-C). This can be used to abort a query, to stop an infinite loop, to activate the debugger,... When an interruption occurs the top-level displays the following message: `Prolog interruption (h for help) ?`
The user can then type one of the following commands:

<table>
<thead>
<tr>
<th>Command</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>abort</td>
<td>abort the current execution. Same as <code>abort/0</code> (section 8.18.1 page 126)</td>
</tr>
<tr>
<td>e</td>
<td>exit</td>
<td>quit the current Prolog process. Same as <code>halt/0</code> (section 8.18.1 page 126)</td>
</tr>
<tr>
<td>b</td>
<td>break</td>
<td>invoke a recursive top-level. Same as <code>break/0</code> (section 8.18.1 page 126)</td>
</tr>
<tr>
<td>c</td>
<td>continue</td>
<td>resume the execution</td>
</tr>
<tr>
<td>t</td>
<td>trace</td>
<td>start the debugger using <code>trace/0</code> (section 5.3.1 page 31)</td>
</tr>
<tr>
<td>d</td>
<td>debug</td>
<td>start the debugger using <code>debug/0</code> (section 5.3.1 page 31)</td>
</tr>
<tr>
<td>h or ?</td>
<td>help</td>
<td>display a summary of available commands</td>
</tr>
</tbody>
</table>

4.2.6 The line editor

The line editor (`linedit`) allows the user to build/update the current input line using a variety of commands. This facility is available if the `linedit` part of GNU Prolog has been installed. `linedit` is implicitly called by any built-in predicate reading from a terminal (e.g. `get_char/1`, `read/1`,...). This is the case when the top-level reads a query.

**Bindings**: each command of `linedit` is activated using a key. For some commands another key is also available to invoke the command (on some terminals this other key may not work properly while the primary key always works). Here is the list of available commands:
### 4.2 The GNU Prolog interactive interpreter

<table>
<thead>
<tr>
<th>Key</th>
<th>Alternate key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl-B</td>
<td>←</td>
<td>go to the previous character</td>
</tr>
<tr>
<td>Ctrl-F</td>
<td>→</td>
<td>go to the next character</td>
</tr>
<tr>
<td>Esc-B</td>
<td>Ctrl←</td>
<td>go to the previous word</td>
</tr>
<tr>
<td>Esc-F</td>
<td>Ctrl→</td>
<td>go to the next word</td>
</tr>
<tr>
<td>Ctrl-A</td>
<td>Home</td>
<td>go to the beginning of the line</td>
</tr>
<tr>
<td>Ctrl-E</td>
<td>End</td>
<td>go to the end of the line</td>
</tr>
<tr>
<td>Ctrl-H</td>
<td>Backspace</td>
<td>delete the previous character</td>
</tr>
<tr>
<td>Ctrl-D</td>
<td>Delete</td>
<td>delete the current character</td>
</tr>
<tr>
<td>Ctrl-U</td>
<td>Ctrl-Home</td>
<td>delete from beginning of the line to the current character</td>
</tr>
<tr>
<td>Ctrl-K</td>
<td>Ctrl-End</td>
<td>delete from the current character to the end of the line</td>
</tr>
<tr>
<td>Esc-L</td>
<td></td>
<td>lower case the next word</td>
</tr>
<tr>
<td>Esc-U</td>
<td></td>
<td>upper case the next word</td>
</tr>
<tr>
<td>Esc-C</td>
<td></td>
<td>capitalize the next word</td>
</tr>
<tr>
<td>Ctrl-T</td>
<td></td>
<td>exchange last two characters</td>
</tr>
<tr>
<td>Ctrl-V</td>
<td>Insert</td>
<td>switch on/off the insert/replace mode</td>
</tr>
<tr>
<td>Ctrl-I</td>
<td>Tab</td>
<td>complete word (twice displays all possible completions)</td>
</tr>
<tr>
<td>Esc-Ctrl-I</td>
<td>Esc-Tab</td>
<td>insert spaces to emulate a tabulation</td>
</tr>
<tr>
<td>Ctrl-space</td>
<td></td>
<td>mark beginning of the selection</td>
</tr>
<tr>
<td>Esc-W</td>
<td></td>
<td>copy (from the begin selection mark to the current character)</td>
</tr>
<tr>
<td>Ctrl-W</td>
<td></td>
<td>cut (from the begin selection mark to the current character)</td>
</tr>
<tr>
<td>Ctrl-Y</td>
<td></td>
<td>paste</td>
</tr>
<tr>
<td>Ctrl-P</td>
<td>↑</td>
<td>recall previous history line</td>
</tr>
<tr>
<td>Ctrl-N</td>
<td>↓</td>
<td>recall next history line</td>
</tr>
<tr>
<td>Esc-P</td>
<td></td>
<td>recall previous history line beginning with the current prefix</td>
</tr>
<tr>
<td>Esc-N</td>
<td></td>
<td>recall next history line beginning with the current prefix</td>
</tr>
<tr>
<td>Esc-&lt;</td>
<td>Page Up</td>
<td>recall first history line</td>
</tr>
<tr>
<td>Esc-&gt;</td>
<td>Page Down</td>
<td>recall last history line</td>
</tr>
<tr>
<td>Ctrl-C</td>
<td></td>
<td>generate an interrupt signal (section 4.2.5, page 18)</td>
</tr>
<tr>
<td>Ctrl-D</td>
<td></td>
<td>generate an end-of-file character (at the begin of the line)</td>
</tr>
<tr>
<td>RETURN</td>
<td></td>
<td>validate a line</td>
</tr>
<tr>
<td>Esc-?</td>
<td></td>
<td>display a summary of available commands</td>
</tr>
</tbody>
</table>

**History**: when a line is entered (i.e. terminated by RETURN), linedit records it in an internal list called history. It is later possible to recall history lines using appropriate commands (e.g. Ctrl-P recall the last entered line) and to modify them as needed. It is also possible to recall a history line beginning with a given prefix. For instance to recall the previous line beginning with `write` simply type `write` followed by Esc-P. Another Esc-P will recall an earlier line beginning with `write`,...

**Completion**: another important feature of linedit is its completion facility. Indeed, linedit maintains a list of known words and uses it to complete the prefix of a word. Initially this list contains all predefined atoms and the atoms corresponding to available predicates. This list is dynamically updated when a new atom appears in the system (whether read at the top-level, created with a built-in predicate, associated with a new consulted predicate,...). When the completion key (Tab) is pressed linedit acts as follows:

- use the current word as a prefix.
- collect all words of the list that begin with this prefix.
- complete the current word with the longest common part of all matching words.
- if more than one word matches emit a beep (a second Tab will display all possibilities).

**Example:**
Balancing: linedit allows the user to check that (square/curly) brackets are well balanced. For this, when a close bracket symbol, i.e. ), ] or }, is typed, linedit determines the associated open bracket, i.e. (, [ or {, and temporarily repositions the cursor on it to show the match.

Customization: the behavior of linedit can be controlled via an environment variable called LINEDIT. This variable can contain the following substrings:

no do not activated linedit (should the only value of the variable)
ansi=no do not use ANSI escape sequence (unix only)
out=N use the file descriptor N for the output (unix only)
gui=no even if compiled with the GUI console run in text mode (windows)
gui=silent if the GUI console is not found, silently run in text mode (windows)
cp=N use code page N (windows text console)
oem_put=no do not use Char→Oem conversion when emitting a char (windows text console)
oem_get=no do not use Oem→Char conversion when reading a char (windows text console)

4.3 Adjusting the size of Prolog data

GNU Prolog uses several stacks to execute a Prolog program. Each stack has a static size and cannot be dynamically increased during the execution. For each stack there is a default size but the user can define a new size by setting an environment variable. When a GNU Prolog program is run it first consults these variables and if they are not defined uses the default sizes. The following table presents each stack of GNU Prolog with its default size and the name of its associated environment variable:

Since version 1.4.2, the size of the atom table (the table recording all atoms) is managed similarly to stacks. It is then included in the following table (even if actually it is not a stack but an hash table). In this table, the associated name is atoms which is the key used in statistics (section 8.24.1 page 155). The environment variable name is derived from the corresponding Prolog flag max_atom, see (section 8.22.1 page 148).

<table>
<thead>
<tr>
<th>Stack name</th>
<th>Default size (Kb)</th>
<th>Environment variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>16384</td>
<td>LOCALSZ</td>
<td>control stack (environments and choice-points)</td>
</tr>
<tr>
<td>global</td>
<td>32768</td>
<td>GLOBALSZ</td>
<td>heap (compound terms)</td>
</tr>
<tr>
<td>trail</td>
<td>16384</td>
<td>TRAILSZ</td>
<td>conditional bindings (bindings to undo at backtracking)</td>
</tr>
<tr>
<td>cstr</td>
<td>16384</td>
<td>CSTRSZ</td>
<td>finite domain constraint stack (FD variables and constraints)</td>
</tr>
<tr>
<td>atoms</td>
<td>32768</td>
<td>MAX_ATOM</td>
<td>atom table</td>
</tr>
</tbody>
</table>

In addition, under Windows (since version 1.4.0), registry keys are consulted (key names are the same as environment names). The keys are stored in HKEY_CURRENT_USER\Software\GnuProlog\.

If the size of a stack is too small an overflow will occur during the execution. In that case GNU Prolog
emits the following error message before stopping:

\[
S \text{ stack overflow (size: } N \text{ Kb, environment variable used: } E)\]

where \( S \) is the name of the stack, \( N \) is the current stack size in Kb and \( E \) the name of the associated environment variable. When such a message occurs it is possible to (re)define the variable \( E \) with the new size. For instance to allocate Kb to the local stack under a Unix shell use:

```bash
LOCALSZ=32768; export LOCALSZ  # (under sh or bash)
setenv LOCALSZ 32768           # (under csh or tcsh)
```

This method allows the user to adjust the size of Prolog stacks. However, in some cases it is preferable not to allow the user to modify these sizes. For instance, when providing a stand alone executable whose behavior should be independent of the environment in which it is run. In that case the program should not consult environment variables and the programmer should be able to define new default stack sizes.

The GNU Prolog compiler offers this facilities via several command-line options such as `--local-size` or `--fixed-sizes` (section 4.4.3, page 23).

Finally note that GNU Prolog stacks are virtually allocated (i.e. use virtual memory). This means that a physical memory page is allocated only when needed (i.e. when an attempt to read/write it occurs). Thus it is possible to define very large stacks. At the execution, only the needed amount of space will be physically allocated.

### 4.4 The GNU Prolog compiler

#### 4.4.1 Different kinds of codes

One of the main advantages of GNU Prolog is its ability to produce stand alone executables. A Prolog program can be compiled to native code to give rise to a machine-dependent executable using the GNU Prolog compiler. However native-code predicates cannot be listed nor fully debugged. So there is an alternative to native-code compilation: byte-code compilation. By default the GNU Prolog compiler produces native-code but via a command-line option it can produce a file ready for byte-code loading. This is exactly what `consult/1` does as was explained above (section 4.2.3, page 17). GNU Prolog also manages interpreted code using a Prolog interpreter written in Prolog. Obviously interpreted code is slower than byte-code but does not require the invocation of the GNU Prolog compiler. This interpreter is used each time a meta-call is needed as by `call/1` (section 7.2.3, page 52). This also the case of dynamically asserted clauses. The following table summarizes these three kinds of codes:

<table>
<thead>
<tr>
<th>Type</th>
<th>Speed</th>
<th>Debug ?</th>
<th>For what</th>
</tr>
</thead>
<tbody>
<tr>
<td>interpreted-code</td>
<td>slow</td>
<td>yes</td>
<td>meta-call and dynamically asserted clauses</td>
</tr>
<tr>
<td>byte-code</td>
<td>medium</td>
<td>yes</td>
<td>consulted predicates</td>
</tr>
<tr>
<td>native-code</td>
<td>fast</td>
<td>no</td>
<td>compiled predicates</td>
</tr>
</tbody>
</table>

#### 4.4.2 Compilation scheme

**Native-code compilation**: a Prolog source is compiled in several stages to produce an object file that is linked to the GNU Prolog libraries to produce an executable. The Prolog source is first compiled to obtain a WAM \([1]\) file. For a detailed study of the WAM the interested reader can refer to "Warren’s Abstract Machine: A Tutorial Reconstruction"\([1]\). The WAM file is translated to a machine-independent language specifically designed for GNU Prolog. This language is close to a (universal) assembly language and is based on a very reduced instruction set. For this reason this language is called mini-assembly (MA). The mini-assembly file is then mapped to the assembly language of the target machine. This
assembly file is assembled to give rise to an object file which is then linked with the GNU Prolog libraries to provide an executable. The compiler also takes into account Finite Domain constraint definition files. It translates them to C and invoke the C compiler to obtain object files. The following figure presents this compilation scheme:

![Compilation Scheme Diagram]

Obviously all intermediate stages are hidden to the user who simply invokes the compiler on his Prolog file(s) (plus other files: C, . . . ) and obtains an executable. However, it is also possible to stop the compiler at any given stage. This can be useful, for instance, to see the WAM code produced (perhaps when learning the WAM). Finally it is possible to give any kind of file to the compiler which will insert it in the compilation chain at the stage corresponding to its type. The type of a file is determined using the suffix of its file name. The following table presents all recognized types/suffixes:
### 4.4 The GNU Prolog compiler

<table>
<thead>
<tr>
<th>Suffix of the file</th>
<th>Type of the file</th>
<th>Handled by</th>
</tr>
</thead>
<tbody>
<tr>
<td>.pl, .pro, .prolog</td>
<td>Prolog source file</td>
<td>pl2wam</td>
</tr>
<tr>
<td>.wam</td>
<td>WAM source file</td>
<td>wam2ma</td>
</tr>
<tr>
<td>.ma</td>
<td>Mini-assembly source file</td>
<td>ma2asm</td>
</tr>
<tr>
<td>.s</td>
<td>Assembly source file</td>
<td>the assembler</td>
</tr>
<tr>
<td>.c, .C, .CC, .cc, .cxx, .c++, .cpp</td>
<td>C or C++ source file</td>
<td>the C compiler</td>
</tr>
<tr>
<td>.fd</td>
<td>Finite Domain constraint source file</td>
<td>fd2c</td>
</tr>
<tr>
<td>any other suffix (., .a,...)</td>
<td>any other type (object, library,...)</td>
<td>the linker (C linker)</td>
</tr>
</tbody>
</table>

**Byte-code compilation:** the same compiler can be used to compile a source Prolog file for byte-code. In that case the Prolog to WAM compiler is invoked using a specific option and produces a WAM for byte-code source file (suffixed .wbc) that can be later loaded using `load/1` (section 8.23.2, page 153). Note that this is exactly what `consult/1` (section 8.23.1, page 153) does as explained above (section 4.2.3, page 17).

#### 4.4.3 Using the compiler

The GNU Prolog compiler is a command-line compiler similar in spirit to a Unix C compiler like `gcc`. To invoke the compiler use the `gplc` command as follows:

```
% gplc [OPTION]... FILE...
```

The arguments of `gplc` are file names that are dispatched in the compilation scheme depending on the type determined from their suffix as was explained previously (section 4.4.2, page 21). All object files are then linked to produce an executable. Note however that GNU Prolog has no module facility (since there is not yet an ISO reference for Prolog modules) thus a predicate defined in a Prolog file is visible from any other predicate defined in any other file. GNU Prolog allows the user to split a big Prolog source into several files but does not offer any way to hide a predicate from others.

The simplest way to obtain an executable from a Prolog source file `prog.pl` is to use:

```
% gplc prog.pl
```

This will produce an native executable called `prog` which can be executed as follows:

```
% prog
```

However, there are several options that can be used to control the compilation:

**General options:**

- `-o FILE`, `--output FILE`: use `FILE` as the name of the output file
- `-W`, `--wam-for-native`: stop after producing WAM file(s)
- `-w`, `--wam-for-byte-code`: stop after producing WAM for byte-code file(s) (force `--no-call-c`)
- `-M`, `--mini-assembly`: stop after producing mini-assembly file(s)
- `-S`, `--assembly`: stop after producing assembly file(s)
- `-F`, `--fd-to-c`: stop after producing C file(s) from FD constraint definition file(s)
- `-c`, `--object`: stop after producing object file(s)
- `--temp-dir PATH`: use `PATH` as directory for temporary files
- `--no-del-temp`: do not delete temporary files
- `--no-demangling`: do not decode predicate names (name demangling)
- `-v`, `--verbose`: print executed commands
- `-h`, `--help`: print a help and exit
- `--version`: print version number and exit
Prolog to WAM compiler options:

- **--pl-state** *FILE*  
  read *FILE* to set the initial Prolog state
- **--wam-comment** *COMMENT*  
  emit *COMMENT* as a comment in the WAM file
- **--no-susp-warn**  
  do not show warnings for suspicious predicates
- **--no-singl-warn**  
  do not show warnings for named singleton variables
- **--no-redef-error**  
  do not show errors for built-in predicate redefinitions
- **--foreign-only**  
  only compile foreign/1-2 directives
- **--no-call-c**  
  do not allow the use of *fd_tell, ’$call_c’,...*
- **--no-inline**  
  do not inline predicates
- **--no-reorder**  
  do not reorder predicate arguments
- **--no-reg-opt**  
  do not optimize registers
- **--min-reg-opt**  
  minimally optimize registers
- **--no-opt-last-subterm**  
  do not optimize last subterm compilation
- **--fast-math**  
  use fast mathematical mode (assume integer arithmetics)
- **--keep-void-inst**  
  keep void WAM instructions in the output file
- **--compile-msg**  
  print a compile message
- **--statistics**  
  print statistics information

WAM to mini-assembly translator options:

- **--comment**  
  include comments in the output file

Mini-assembly to assembly translator options:

- **--comment**  
  include comments in the output file
- **--pic**  
  produce position independent code (PIC)

C compiler options:

- **--c-compiler** *FILE*  
  use *FILE* as C compiler/linker
- **-C** *OPTION*  
  pass *OPTION* to the C compiler

Assembler options:

- **-A** *OPTION*  
  pass *OPTION* to the assembler

Linker options:
4.4 The GNU Prolog compiler

|--linker FILE     use FILE as linker
|--local-size N   set default local stack size to N Kb
|--global-size N  set default global stack size to N Kb
|--trail-size N   set default trail stack size to N Kb
|--cstr-size N    set default constraint stack size to N Kb
|--max-atom N     set default atom table size to N atoms
|--fixed-sizes    do not consult environment variables at run-time (use default sizes)
|--gui-console    link with the GUI console (windows only)
|--new-top-level  link the top-level main (to recognize top-level command-line options)
|--no-top-level   do not link the top-level (force --no-debugger)
|--no-debugger    do not link the Prolog/WAM debugger
|--min-pl-bips    link only used Prolog built-in predicates
|--min-fd-bips    link only used FD solver built-in predicates
|--min-bips       shorthand for: --no-top-level --min-pl-bips --min-fd-bips
|--min-size       shorthand for: --min-bips --strip
|--no-fd-lib      do not look for the FD library (maintenance only)
|s, --strip       strip the executable
-L OPTION        Pass OPTION to the linker

It is possible to only give the prefix of an option if there is no ambiguity.

The name of the output file is controlled via the -o FILE option. If present the output file produced will be named FILE. If not specified, the output file name depends on the last stage reached by the compiler. If the link is not done the output file name(s) is the input file name(s) with the suffix associated with the last stage. If the link is done, the name of the executable is the name (without suffix) of the first file name encountered in the command-line. Note that if the link is not done -o has no sense in the presence of multiple input file names. For this reason, several meta characters are available for substitution in FILE:

- %f is substituted by the whole input file name.
- %F is similar to %f but the directory part is omitted.
- %p is substituted by the whole prefix file name (omitting the suffix).
- %P is similar to %p but the directory part is omitted.
- %s is substituted by the file suffix (including the dot).
- %d is substituted by the directory part (empty if no directory is specified).
- %c is substituted by the value of an internal counter starting from 1 and auto-incremented.

By default the compiler runs in the native-code compilation scheme. To generate a WAM file for byte-code use the --wam-for-byte-code option. The resulting file can then be loaded using load/1 (section 8.23.2 page 153).

To execute the Prolog to WAM compiler in a given read environment (operator definitions, character conversion table,...) use --pl-state FILE. The state file should be produced by write_pl_state_file/1 (section 8.22.5 page 152).

By default the Prolog to WAM compiler inlines calls to some deterministic built-in predicates (e.g. arg/3 and functor/3). Namely a call to such a predicate will not yield a classical predicate call but a simple C function call (which is obviously faster). It is possible to avoid this using --no-inline.

Another optimization performed by the Prolog to WAM compiler is unification reordering. The arguments of a predicate are reordered to optimize unification. This can be deactivated using --no-reorder. The
compiler also optimizes the unification/loading of nested compound terms. More precisely, the compiler
emits optimized instructions when the last subterm of a compound term is itself a compound term (e.g.
lists). This can be deactivated using --no-opt-last-subterm.

By default the Prolog to WAM compiler fully optimizes the allocation of registers to decrease both the
number of instruction produced and the number of used registers. A good allocation will generate many
void instructions that are removed from the produced file except if --keep-void-inst is specified. To
prevent any optimization use --no-reg-opt while --min-reg-opt forces the compiler to only perform
simple register optimizations.

The Prolog to WAM compiler emits an error when a control construct or a built-in predicate is redefined.
This can be avoided using --no-redef-error. The compiler also emits warnings for suspicious predicate
definitions like ~/2 since this often corresponds to an earlier syntax error (e.g. _ instead of _). This can
be deactivated by specifying --no-susp-warn. Finally, the compiler warns when a singleton variable has a
name (i.e. not the generic anonymous name _). This can be deactivated specifying --no-singl-warn.

Internally, predicate names are encoded to fit the syntax of (assembly) identifiers. For this GNU Prolog
uses its own name mangling scheme. This is explained in more detail later (section 4.4.6, page 28). By
default the error messages from the linker (e.g. multiple definitions for a given predicate, reference to
an undefined predicate,...) are filtered to replace an internal name representation by the real predicate
name (demangling). Specifying the --no-demangling prevents gplc from filtering linker output messages
(internal identifiers are then shown).

When producing an executable it is possible to specify default stack sizes (using --STACK_NAME-size)
and to prevent it from consulting environment variables (using --fixed-sizes) as was explained above
(section 4.3, page 20). By default the produced executable will include the top-level, the Prolog/WAM
debugger and all Prolog and FD built-in predicates. It is possible to avoid linking the top-level (section
1.2, page 13) by specifying --no-top-level. In this case, at least one initialization/1 directive
(section 7.1.14, page 50) should be defined. The option --no-debugger does not link the debugger. To
include only used built-in predicates that are actually used the options --no-pl-bips and/or --no-fd-bips
can be specified. For the smallest executable all these options should be specified. This can be abbre-
viated by using the shorthand option --min-bips. By default, executables are not stripped, i.e. their
symbol table is not removed. This table is only useful for the C debugger (e.g. when interfacing Prolog
and C). To remove the symbol table (and then to reduce the size of the final executable) use --strip.
Finally --min-size is a shortcut for --min-bips and --strip, i.e. the produced executable is as small
as possible.

Example: compile and link two Prolog sources prog1.pl and prog2.pl. The resulting executable will
be named prog1 (since -o is not specified):

  % gplc prog1.pl prog2.pl

Example: compile the Prolog file prog.pl to study basic WAM code. The resulting file will be named
prog.wam:

  % gplc -W --no-inline --no-reorder --keep-void-inst prog.pl

Example: compile the Prolog file prog.pl and its C interface file utils.c to provide an autonomous
executable called mycommand. The executable is not stripped to allow the use of the C debugger:

  % gplc -o mycommand prog.pl utils.c

Example: detail all steps to compile the Prolog file prog.pl (the resulting executable is stripped). All
intermediate files are produced (prog.wam, prog.ma, prog.s, prog.o and the executable prog):

  % gplc -W prog.pl
  % gplc -M --comment prog.wam
4.4 The GNU Prolog compiler

4.4.4 Running an executable

In this section we explain what happens when running an executable produced by the GNU Prolog native-code compiler. The default main function first starts the Prolog engine. This function collects all linked objects (issued from the compilation of Prolog files) and initializes them. The initialization of a Prolog object file consists in adding to appropriate tables new atoms, new predicates and executing its system directives. A system directive is generated by the Prolog to WAM compiler to reflect a (user) directive executed at compile-time such as op/3 (section 7.1.11, page 49). Indeed, when the compiler encounters such a directive it immediately executes it and also generates a system directive to execute it at the start of the executable. When all system directives have been executed the Prolog engine executes all initialization directives defined with initialization/1 (section 7.1.14, page 50). If several initialization directives appear in the same file they are executed in the order of appearance. If several initialization directives appear in different files the order in which they are executed is machine-dependant. However, on most machines the order will be the reverse order in which the associated files have been linked (this is not true under native win32). When all initialization directives have been executed the default main function looks for the GNU Prolog top-level. If present (i.e. it has been linked) it is called otherwise the program simply ends. Note that if the top-level is not linked and if there is no initialization directive the program is useless since it simply ends without doing any work. The default main function detects such a behavior and emits a warning message.

Example: compile an empty file prog.pl without linking the top-level and execute it:

```
% gplc --no-top-level prog.pl
% prog
Warning: no initial goal executed
use a directive :- initialization(Goal)
or remove the link option --no-top-level (or --min-bips or --min-size)
```

4.4.5 Generating a new interactive interpreter

In this section we show how to define a new top-level extending the GNU Prolog interactive interpreter with new predicate definitions. The obtained top-level can then be considered as an enriched version of the basic GNU Prolog top-level (section 4.2, page 13). Indeed, each added predicate can be viewed as a predefined predicate just like any other built-in predicate. This can be achieved by compiling these predicates and including the top-level at link-time.

The real question is: why would we include some predicates in a new top-level instead of simply consulting them under the GNU Prolog top-level? There are two reasons for this:

- the predicate cannot be consulted. This is the case of a predicate calling foreign code, like a predicate interfacing with C (section 10, page 201) or a predicate defining a new FD constraint.
- the performance of the predicate is crucial. Since it is compiled to native-code such a predicate will be executed very quickly. Consulting will load it as byte-code. The gain is much more noticeable if the program is run under the debugger. The included version will not be affected by the debugger while the consulted version will be several times slower. Obviously, a predicate should be included in a new top-level only when it is itself debugged since it is difficult to debug native-code.

```
% gplc -S --comment prog.ma
% gplc -c prog.s
% gplc -o prog -s prog.o
```
To define a new top-level simply compile the set of desired predicates and linking them with the GNU Prolog top-level (this is the default) using gplc (section 4.4.3, page 23).

Example: let us define a new top-level called my_top_level including all predicates defined in prog.pl:
\[
\% \text{gplc} -o \text{my\_top\_level} \ \text{prog.pl}
\]

By the way, note that if prog.pl is an empty Prolog file the previous command will simply create a new interactive interpreter similar to the GNU Prolog top-level.

Example: as before where some predicates of prog.pl call C functions defined in utils.c:
\[
\% \text{gplc} -o \text{my\_top\_level} \ \text{prog.pl} \ \text{utils.c}
\]

To obtain a fully extended executable, it is desirable to accept the same set of options as the original top-level, see (section 4.2, page 13), e.g. --init-goal. For this it is necessary to link main function used by the original top-level. This can be achieved passing the --new-top-level to gplc:
\[
\% \text{gplc} --\text{new-top-level} -o \text{my\_top\_level} \ \text{prog.pl} \ \text{utils.c}
\]

In conclusion, defining a particular top-level is nothing else but a particular case of the native-code compilation. It is simple to do and very useful in practice.

### 4.4.6 The name mangling scheme

When the GNU Prolog compiler compiles a Prolog source to an object file it has to associate a symbol to each predicate name. However, the syntax of symbols is restricted to identifiers: string containing only letters, digits or underscore characters. On the other hand, predicate names (i.e. atoms) can contain any character with quotes if necessary (e.g. 'x+y=z' is a valid predicate name). The compiler may thus have to encode predicate names respecting the syntax of identifiers. In addition, Prolog allows the user to define several predicates with the same name and different arities, for this GNU Prolog encodes predicate indicators (predicate name followed by the arity). Finally, to support modules in the future, the module name is also encoded.

Since version 1.4.0, GNU Prolog adopts the following name mangling scheme. A predicate indicator of the form [MODULE:]PRED/N (where the MODULE can be omitted) will give rise to an identifier of the following form: XK_{E(Module)}_{E(Pred)}_{aN} where:

- K is a digit in 0..5 storing coding information about MODULE and PRED. Possible values are:
  - 0: no module present, PRED is not encoded
  - 1: no module present, PRED is encoded
  - 2: MODULE is not encoded, PRED is not encoded
  - 3: MODULE is not encoded, PRED is encoded
  - 4: MODULE is encoded, PRED is not encoded
  - 5: MODULE is encoded, PRED is encoded

- E(STR) is a function to encode a string STR which returns:
  - STR itself (not encoded) if STR only contains letters, digits or _ but does not contain the sub-string _ and does not begin nor end with _ (i.e. regexp: [a-zA-Z0-9]([-]?[a-zA-Z0-9]*)).
  - an hexadecimal representation of each character of the string otherwise. For example: E(x+y=z) returns 782B793D7A since 78 is the hexadecimal representation of the ASCII code of x, 2B of the code of +, etc.

Examples:
So, from the mini-assembly stage, each predicate indicator is handled via its name mangling identifier.
The knowledge of this scheme is normally not of interest for the user, i.e. the Prolog programmer. For this reason the GNU Prolog compiler hides this mangling. When an error occurs on a predicate (undefined predicate, predicate with multiple definitions,...) the compiler has to decode the symbol associated with the predicate indicator (name demangling). For this `gplc` filters each message emitted by the linker to locate and decode eventual predicate indicators. This filtering can be deactivated specifying `--no-demangling` when invoking `gplc` (section 4.4.3, page 23).

This filter is provided as an utility that can be invoked using the `hexgplc` command as follows:

```
% hexgplc [OPTION]... FILE... (the % symbol is the operating system shell prompt)
```

**Options:**

- `--decode` or `--demangling`: decoding mode (this is the default mode)
- `--encode` or `--mangling`: encoding mode
- `--relax`: decode also predicate names (not only predicate indicators)
- `--printf FORMAT`: pass encoded/decoded string to C `printf(3)` with `FORMAT`
- `--aux-father`: decode an auxiliary predicate as its father
- `--aux-father2`: decode an auxiliary predicate as its father + auxiliary number
- `--cmd-line`: encode/decode each argument of the command-line
- `-E` or `-M`: same as: `--cmd-line --encode --relax`
- `-P` or `-D`: same as: `--cmd-line --decode --relax --quote`
- `--help`: print a help and exit
- `--version`: print version number and exit

It is possible to give a prefix of an option if there is no ambiguity.

Without arguments `hexgplc` runs in decoding mode reading its standard input and decoding (demangling) each symbol corresponding to a predicate indicator. To use `hexgplc` in the encoding (mangling) mode the `--encode` option must be specified. By default `hexgplc` only decodes predicate indicators, this can be relaxed using `--relax` to also take into account simple predicate names (the arity can be omitted). It is possible to format the output of an encoded/decoded string using `--printf FORMAT` in that case each string `S` is passed to the C `printf(3)` function as `printf(FORMAT, S)`.

Auxiliary predicates are generated by the Prolog to WAM compiler when simplifying some control constructs like `';'/'2` present in the body of a clause. They are of the form `'$NAME/ARITY$auxN'` where `NAME/ARITY` is the predicate indicator of the simplified (i.e. father) predicate and `N` is a sequential number (a predicate can give rise to several auxiliary predicates). It is possible to force `hexgplc` to decode an auxiliary predicate as its father predicate indicator using `--aux-father` or as its father predicate indicator followed by the sequential number using `--aux-father2`.

If no file is specified, `hexgplc` processes its standard input otherwise each file is treated sequentially. Specifying the `--cmd-line` option informs `hexgplc` that each argument is not a file name but a string that must be encoded (or decoded). This is useful to encode/decode a particular string. For this reason the option `-E` (encode) and `-D` (decode) are provided as shorthand. Then, to obtain the mangling representation of a predicate `PRED` use:

```
% hexgplc -E PRED
```
NB: if \textit{PRED} is a complex atom it is necessary to quote it (the quotes must be passed to \texttt{hexgplc}). Here is an example under bash:

\begin{verbatim}
% hexgplc -E \'x+y=z\'/3
X1_782B793D7A__a3
\end{verbatim}

Or even more safely (using bash quotes to prevent bash from interpreting special characters):

\begin{verbatim}
% hexgplc -E \''x+y=z\''/3
X1_782B793D7A__a3
\end{verbatim}
5 Debugging

5.1 Introduction

The GNU Prolog debugger provides information concerning the control flow of the program. The debugger can be fully used on consulted predicates (i.e. byte-code). For native compiled code only the calls/exits are traced, no internal behavior is shown. Under the debugger it is possible to exhaustively trace the execution or to set spy-points to only debug a specific part of the program. Spy-points allow the user to indicate on which predicates the debugger has to stop to allow the user to interact with it. The debugger uses the “procedure box control flow model”, also called the Byrd Box model since it is due to Lawrence Byrd.

5.2 The procedure box model

The procedure box model of Prolog execution provides a simple way to show the control flow. This model is very popular and has been adopted in many Prolog systems (e.g. SICStus Prolog, Quintus Prolog, ...). A good introduction is the chapter 8 of “Programming in Prolog” of Clocksin & Mellish [2]. The debugger executes a program step by step tracing an invocation to a predicate (call) and the return from this predicate due to either a success (exit) or a failure (fail). When a failure occurs the execution backtracks to the last predicate with an alternative clause. The predicate is then re-invoked (redo). Another source of change of the control flow is due to exceptions. When an exception is raised from a predicate (exception) by throw/1 (section 7.2.4 page 53) the control is given back to the most recent predicate that has defined a handler to recover this exception using catch/3 (section 7.2.4 page 53). The procedure box model shows these different changes in the control flow, as illustrated here:

![Procedure Box Model Diagram]

Each arrow corresponds to a port. An arrow to the box indicates that the control is given to this predicate while an arrow from the box indicates that the control is given back from the procedure. This model visualizes the control flow through these five ports and the connections between the boxes associated with subgoals. Finally, it should be clear that a box is associated with one invocation of a given predicate. In particular, a recursive predicate will give raise to a box for each invocation of the predicate with different entries/exits in the control flow. Since this might get confusing for the user, the debugger associates with each box a unique identifier (i.e. the invocation number).

5.3 Debugging predicates

5.3.1 Running and stopping the debugger

trace/0 activates the debugger. The next invocation of a predicate will be traced.

debg/0 activates the debugger. The next invocation of a predicate on which a spy-point has been set will be traced.
It is important to understand that the information associated with the control flow is only available when
the debugger is on. For efficiency reasons, when the debugger is off the information concerning the control
flow (i.e. the boxes) is not retained. So, if the debugger is activated in the middle of a computation (by
a call to debug/0 or trace/0 in the program or after the interrupt key sequence (Ctl-C) by choosing
trace or debug), information prior to this point is not available.

debugging/0: prints onto the terminal information about the current debugging state (whether the
debugger is switched on, what are the leashed ports, spy-points defined,...).

notrace/0 or nodebug/0 switches the debugger off.

wam_debug/0 invokes the sub-debugger devoted to the WAM data structures (section 5.6, page 35). It
can be also invoked using the W debugger command (section 5.5, page 33).

5.3.2 Leashing ports

leash(Ports) requests the debugger to prompt the user, as he creeps through the program, for every
port defined in the Ports list. Each element of Ports is an atom in call, exit, redo, fail, exception.
Ports can also be an atom defining a shorthand:

- full: equivalent to [call, exit, redo, fail, exception]
- half: equivalent to [call, redo]
- loose: equivalent to [call]
- none: equivalent to []
- tight: equivalent to [call, redo, fail, exception]

When an unleashed port is encountered the debugger continues to show the associated goal but does not
stop the execution to prompt the user.

5.3.3 Spy-points

When dealing with big sources it is not very practical to creep through the entire program. It is preferable
to define a set of spy-points on interesting predicates to be prompted when the debugger reaches one of
these predicates. Spy-points can be added either using spy/1 (or spypoint_condition/3) or dynamically
when prompted by the debugger using the + (or *) debugger command (section 5.5, page 33). The current
mode of leashing does not affect spy-points in the sense that user interaction is requested on every port.

spy(PredSpec) sets a spy-point on all the predicates given by PredSpec. PredSpec defines one or several
predicates and has one of the following forms:

- [PredSpec1, PredSpec2,...]: set a spy-point for each element of the list.
- Name: set a spy-point for any predicate whose name is Name (whatever the arity).
- Name/Arity: set a spy-point for the predicate whose name is Name and arity is Arity.
- Name/A1-A2: set a spy-point for the each predicate whose name is Name and arity is between A1
and A2.
5.4 Debugging messages

It is not possible to set a spy-point on an undefined predicate.

The following predicate is used to remove one or several spy-points:

\texttt{nospy(PredSpec)} removes the spy-points from the specified predicates.

\texttt{nospyall/0} removes all spy-points:

It is also possible to define conditional spy-points.

\texttt{spypoint\_condition(Goal, Port, Test)} sets a conditional spy-point on the predicate for \texttt{Goal}. When the debugger reaches a conditional spy-point it only shows the associated goal if the following conditions are verified:

- the actual goal unifies with \texttt{Goal}.
- the actual port unifies with \texttt{Port}.
- the Prolog goal \texttt{Test} succeeds.

5.4 Debugging messages

We here described which information is displayed by the debugger when it shows a goal. The basic format is as follows:

\[ S \ N \ M \ Port: \ Goal \ ? \]

\textit{S} is a spy-point indicator: if there is a spy-point on the current goal the + symbol is displayed else a space is displayed. \textit{N} is the invocation number. This unique number can be used to correlate the trace messages for the various ports, since it is unique for every invocation. \textit{M} is an index number which represents the number of direct ancestors of the goal (i.e. the current depth of the goal). \textit{Port} specifies the particular port (call, exit, fail, redo, exception). \textit{Goal} is the current goal (it is then possible to inspect its current instantiation) which is displayed using \texttt{write\_term/3} with \texttt{quoted(true)} and \texttt{max\_depth(D)} options (section 8.14.6 page 108). Initially \textit{D} (the print depth) is set to 10 but can be redefined using the \texttt{\< debugger} command (section 5.5 page 33). The ? symbol is displayed when the debugger is waiting a command from the user. (i.e. \textit{Port} is a leashed port). If the port is unleashed, this symbol is not displayed and the debugger continues the execution displaying the next goal.

5.5 Debugger commands

When the debugger reaches a leashed port it shows the current goal followed by the ? symbol. At this point there are many commands available. Typing \texttt{RETURN} will creep into the program. Continuing to creep will show all the control flow. The debugger shows every port for every predicate encountered during the execution. It is possible to select the ports at which the debugger will prompt the user using the built-in predicate \texttt{leash/1} (section 5.3.2 page 32). Each command is only one character long:
<table>
<thead>
<tr>
<th>Command</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RET or c</td>
<td>creep</td>
<td>single-step to the next port</td>
</tr>
<tr>
<td>l</td>
<td>leap</td>
<td>continue the execution only stopping when a goal with a spy-point is reached</td>
</tr>
<tr>
<td>s</td>
<td>skip</td>
<td>skip over the entire execution of the current goal. No message will be shown until control returns</td>
</tr>
<tr>
<td>G</td>
<td>go to</td>
<td>ask for an invocation number and continue the execution until a port is reached for that invocation number</td>
</tr>
<tr>
<td>r</td>
<td>retry</td>
<td>try to restart the invocation of the current goal by failing until reaching the invocation of the goal. The state of execution is the same as when the goal was initially invoked (except when using side-effect predicates)</td>
</tr>
<tr>
<td>f</td>
<td>fail</td>
<td>force the current goal to fail immediately</td>
</tr>
<tr>
<td>w</td>
<td>write</td>
<td>show the current goal using write/2 (section 8.14.6, page 108)</td>
</tr>
<tr>
<td>d</td>
<td>display</td>
<td>show the current goal using display/2 (section 8.14.6, page 108)</td>
</tr>
<tr>
<td>p</td>
<td>print</td>
<td>show the current goal using print/2 (section 8.14.6, page 108)</td>
</tr>
<tr>
<td>e</td>
<td>exception</td>
<td>show the pending exception. Only applicable to an exception port</td>
</tr>
<tr>
<td>g</td>
<td>ancestors</td>
<td>show the list of ancestors of the current goal</td>
</tr>
<tr>
<td>A</td>
<td>alternatives</td>
<td>show the list of ancestors of the current goal combined with choice-points</td>
</tr>
<tr>
<td>u</td>
<td>unify</td>
<td>ask for a term and unify the current goal with this term. This is convenient for getting a specific solution. Only available at a call port</td>
</tr>
<tr>
<td>.</td>
<td>father file</td>
<td>show the Prolog file name and the line number where the current predicate is defined</td>
</tr>
<tr>
<td>n</td>
<td>no debug</td>
<td>switch the debugger off. Same as nodebug/0 (section 5.3.1, page 31)</td>
</tr>
<tr>
<td>=</td>
<td>debugging</td>
<td>show debugger information. Same as debugging/0 (section 5.3.1, page 31)</td>
</tr>
<tr>
<td>+</td>
<td>spy this</td>
<td>set a spy-point on the current goal. Uses spy/1 (section 5.3.3, page 132)</td>
</tr>
<tr>
<td>-</td>
<td>nospy this</td>
<td>remove a spy-point on the current goal. Uses nospy/1 (section 5.3.3, page 132)</td>
</tr>
<tr>
<td>*</td>
<td>spy conditionally</td>
<td>ask for a term Goal, Port, Test (terminated by a dot) and set a conditional spy-point on the current predicate. Goal and the current goal must have the same predicate indicator. Uses spypoint_condition/3 (section 5.3.3, page 132)</td>
</tr>
<tr>
<td>L</td>
<td>listing</td>
<td>list all the clauses associated with the current predicate. Uses listing/1 (section 8.23.3, page 154)</td>
</tr>
<tr>
<td>a</td>
<td>abort</td>
<td>abort the current execution. Same as abort/0 (section 8.18.1, page 126)</td>
</tr>
<tr>
<td>b</td>
<td>break</td>
<td>invoke a recursive top-level. Same as break/0 (section 8.18.1, page 126)</td>
</tr>
<tr>
<td>@</td>
<td>execute goal</td>
<td>ask for a goal and execute it</td>
</tr>
<tr>
<td>&lt;</td>
<td>set print depth</td>
<td>ask for an integer and set the print depth to this value (~1 for no depth limit)</td>
</tr>
<tr>
<td>h or ?</td>
<td>help</td>
<td>display a summary of available commands</td>
</tr>
<tr>
<td>W</td>
<td>WAM debugger</td>
<td>invoke the low-level WAM debugger (section 5.6, page 35)</td>
</tr>
</tbody>
</table>
5.6 The WAM debugger

In some cases it is interesting to have access to the WAM data structures. This sub-debugger allows the user to inspect/modify the contents of any stack or register of the WAM. The WAM debugger is invoked using the built-in predicate \texttt{wam\_debug/0} (section 5.3.1, page \pageref{wamdebug}) or the \texttt{\textasciicircum} debugger command (section 5.5, page \pageref{wamdebug}). The following table presents the specific commands of the WAM debugger:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{write} \texttt{A [N]}</td>
<td>write \texttt{N} terms starting at the address \texttt{A} using \texttt{write/1} (section 8.14.6, page \pageref{write})</td>
</tr>
<tr>
<td>\texttt{data} \texttt{A [N]}</td>
<td>display \texttt{N} words starting at the address \texttt{A}</td>
</tr>
<tr>
<td>\texttt{modify} \texttt{A [N]}</td>
<td>display and modify \texttt{N} words starting at the address \texttt{A}</td>
</tr>
<tr>
<td>\texttt{where} \texttt{A}</td>
<td>display the real address corresponding to \texttt{A}</td>
</tr>
<tr>
<td>\texttt{what} \texttt{RA}</td>
<td>display what corresponds to the real address \texttt{RA}</td>
</tr>
<tr>
<td>\texttt{deref} \texttt{A}</td>
<td>display the dereferenced word starting at the address \texttt{A}</td>
</tr>
<tr>
<td>\texttt{envir} \texttt{[SA]}</td>
<td>display the contents of the environment located at \texttt{SA} (or the current one)</td>
</tr>
<tr>
<td>\texttt{backtrack} \texttt{[SA]}</td>
<td>display the contents of the choice-point located at \texttt{SA} (or the current one)</td>
</tr>
<tr>
<td>\texttt{backtrack all}</td>
<td>display all choice-points</td>
</tr>
<tr>
<td>\texttt{quit}</td>
<td>quit the WAM debugger</td>
</tr>
<tr>
<td>\texttt{help}</td>
<td>display a summary of available commands</td>
</tr>
</tbody>
</table>

In the above table the following conventions apply:

- elements between [ and ] are optional.
- \texttt{N} is an optional integer (defaults to 1).
- \texttt{A} is a WAM address, its syntax is: \texttt{BANK\_NAME [ [ N ] ]}, i.e. a bank name possibly followed by an index (defaults to 0). \texttt{BANK\_NAME} is either:
  - \texttt{reg}: WAM general register (stack pointers, continuation, ...).
  - \texttt{x}: WAM X register (temporary variables, i.e. arguments).
  - \texttt{y}: WAM Y register (permanent variables).
  - \texttt{ab}: WAM X register saved in the current choice-point.
  - \texttt{STACK\_NAME}: WAM stack (\texttt{STACK\_NAME} in \texttt{local}, \texttt{global}, \texttt{trail}, \texttt{cstr}).
- \texttt{SA} is a WAM stack address, i.e. \texttt{STACK\_NAME [ [ N ] ]} (special case of WAM addresses).
- \texttt{RA} is a real address, its syntax is the syntax of C integers (in particular the notation \texttt{0x...} is recognized).

It is possible to only use the first letters of a commands and bank names when there is no ambiguity. Also the square brackets [ ] enclosing the index of a bank name can be omitted. For instance the following command (showing the contents of 25 consecutive words of the global stack from the index 3): \texttt{data global[3] 25} can be abbreviated as: \texttt{d g 3 25}.
6 Format of definitions

6.1 General format

The definition of control constructs, directives and built-in predicates is presented as follows:

Templates

Specifies the types of the arguments and which of them shall be instantiated (mode). Types and modes are described later (section 6.2, page 37).

Description

Describes the behavior (in the absence of any error conditions). It is explicitly mentioned when a built-in predicate is re-executable on backtracking. Predefined operators involved in the definition are also mentioned.

Errors

Details the error conditions. Possible errors are detailed later (section 6.3, page 39). For directives, this part is omitted.

Portability

 Specifies whether the definition conforms to the ISO standard or is a GNU Prolog extension.

6.2 Types and modes

The templates part defines, for each argument of the concerned built-in predicate, its mode and type. The mode specifies whether or not the argument must be instantiated when the built-in predicate is called. The mode is encoded with a symbol just before the type. Possible modes are:

- +: the argument must be instantiated.
- -: the argument must be a variable (will be instantiated if the built-in predicate succeeds).
- ?: the argument can be instantiated or a variable.

The type of an argument is defined by the following table:
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE_list</strong></td>
<td>a list whose the type of each element is TYPE</td>
</tr>
<tr>
<td><strong>TYPE1_or_TYPE2</strong></td>
<td>a term whose type is either TYPE1 or TYPE2</td>
</tr>
<tr>
<td>atom</td>
<td>an atom</td>
</tr>
<tr>
<td>atom_property</td>
<td>an atom property (section 8.19.11, page 134)</td>
</tr>
<tr>
<td>boolean</td>
<td>the atom true or false</td>
</tr>
<tr>
<td>byte</td>
<td>an integer ≥ 0 and ≤ 255</td>
</tr>
<tr>
<td>callable_term</td>
<td>an atom or a compound term</td>
</tr>
<tr>
<td>character</td>
<td>a single character atom</td>
</tr>
<tr>
<td>character_code</td>
<td>an integer ≥ 1 and ≤ 255</td>
</tr>
<tr>
<td>clause</td>
<td>a clause (fact or rule)</td>
</tr>
<tr>
<td>close_option</td>
<td>a close option (section 8.10.7, page 82)</td>
</tr>
<tr>
<td>compound_term</td>
<td>a compound term</td>
</tr>
<tr>
<td>evaluable</td>
<td>an arithmetic expression (section 8.6.1, page 66)</td>
</tr>
<tr>
<td>fd_bool_evaluable</td>
<td>a boolean FD expression (section 9.7.1, page 191)</td>
</tr>
<tr>
<td>fd_labeling_option</td>
<td>an FD labeling option (section 9.9.1, page 198)</td>
</tr>
<tr>
<td>fd_evaluable</td>
<td>an arithmetic FD expression (section 9.6.1, page 188)</td>
</tr>
<tr>
<td>fd_variable</td>
<td>an FD variable</td>
</tr>
<tr>
<td>flag</td>
<td>a Prolog flag (section 8.22.1, page 148)</td>
</tr>
<tr>
<td>float</td>
<td>a floating point number</td>
</tr>
<tr>
<td>head</td>
<td>a head of a clause (atom or compound term)</td>
</tr>
<tr>
<td>integer</td>
<td>an integer</td>
</tr>
<tr>
<td>in_byte</td>
<td>an integer ≥ 0 and ≤ 255 or -1 (for the end-of-file)</td>
</tr>
<tr>
<td>in_character</td>
<td>a single character atom</td>
</tr>
<tr>
<td>in_character_code</td>
<td>an integer ≥ 1 and ≤ 255 or -1 (for the end-of-file)</td>
</tr>
<tr>
<td>io_mode</td>
<td>an atom in: read, write or append</td>
</tr>
<tr>
<td>list</td>
<td>the empty list [] or a non-empty list [],</td>
</tr>
<tr>
<td>nonvar</td>
<td>any term that is not a variable</td>
</tr>
<tr>
<td>number</td>
<td>an integer or a floating point number</td>
</tr>
<tr>
<td>operatorSpecifier</td>
<td>an operator specifier (section 8.14.10, page 113)</td>
</tr>
<tr>
<td>os_file_property</td>
<td>an operating system file property (section 8.27.11, page 165)</td>
</tr>
<tr>
<td>predicate_indicator</td>
<td>a term Name/Arity where Name is an atom and Arity an integer ≥ 0. A callable term can be given if the strict_iso Prolog flag is switched off (section 8.22.1, page 148)</td>
</tr>
<tr>
<td>predicate_property</td>
<td>a predicate property (section 8.8.2, page 75)</td>
</tr>
<tr>
<td>read_option</td>
<td>a read option (section 8.14.11, page 104)</td>
</tr>
<tr>
<td>socket_address</td>
<td>a term of the form 'AF_UNIX'(A) or 'AF_INET'(A,N) where A is an atom and N an integer</td>
</tr>
<tr>
<td>socket_domain</td>
<td>an atom in: 'AF_UNIX' or 'AF_INET'</td>
</tr>
<tr>
<td>source_sink</td>
<td>an atom identifying a source or a sink</td>
</tr>
<tr>
<td>stream</td>
<td>a stream-term: a term of the form '$stream'(N) where N is an integer ≥ 0</td>
</tr>
<tr>
<td>stream_option</td>
<td>a stream option (section 8.10.6, page 81)</td>
</tr>
<tr>
<td>stream_or_alias</td>
<td>a stream-term or an alias (atom)</td>
</tr>
<tr>
<td>stream_position</td>
<td>a stream position: a term '$stream_position'(I1, I2, I3, I4) where I1, I2, I3 and I4 are integers</td>
</tr>
<tr>
<td>stream_property</td>
<td>a stream property (section 8.10.10, page 84)</td>
</tr>
<tr>
<td>stream_seek_method</td>
<td>an atom in: bof, current or eof</td>
</tr>
<tr>
<td>term</td>
<td>any term</td>
</tr>
<tr>
<td>var_binding_option</td>
<td>a variable binding option (section 8.5.3, page 64)</td>
</tr>
<tr>
<td>write_option</td>
<td>a write option (section 8.14.6, page 108)</td>
</tr>
</tbody>
</table>
6.3 Errors

6.3.1 General format and error context

When an error occurs an exception of the form: \texttt{error(ErrorTerm, Caller)} is raised. \texttt{ErrorTerm} is a term specifying the error (detailed in next sections) and \texttt{Caller} is a term specifying the context of the error. The context is either the predicate indicator of the last invoked built-in predicate or an atom giving general context information.

Using exceptions allows the user both to recover an error using \texttt{catch/3} (section 7.2.4, page 53) and to raise an error using \texttt{throw/1} (section 7.2.4, page 53).

To illustrate how to write error cases, let us write a predicate \texttt{my_pred(X)} where \texttt{X} must be an integer:

\begin{verbatim}
my_pred(X) :-
  (  nonvar(X) ->
      true
    ;    throw(error(instantiation_error, my_pred/1)),
  ),
  (  integer(X) ->
      true
    ;    throw(error(type_error(integer, X), my_pred/1))
  ),
... 
\end{verbatim}

To help the user to write these error cases, a set of system predicates is provided to raise errors. These predicates are of the form `'pl_err...'` and they all refer to the implicit error context. The predicates \texttt{set_bip_name/2} (section 8.22.3, page 151) and \texttt{current_bip_name/2} (section 8.22.4, page 151) are provided to set and recover the name and the arity associated with this context (an arity < 0 means that only the atom corresponding to the functor is significant). Using these system predicates the user could define the above predicate as follow:

\begin{verbatim}
my_pred(X) :-
  set_bip_name(my_pred,1),
  (  nonvar(X) ->
      true
    ;    '$pl_err_instantiation'
  ),
  (  integer(X) ->
      true
    ;    '$pl_err_type'(integer, X)
  ),
... 
\end{verbatim}

The following sections detail each kind of errors (and associated system predicates).

6.3.2 Instantiation error

An instantiation error occurs when an argument or one of its components is variable while an instantiated argument was expected. \texttt{ErrorTerm} has the following form: \texttt{instantiation_error}.

The system predicate `'pl_err_instantiation' raises this error in the current error context (section 6.3.1, page 39).
6.3.3 Uninstantiation error

An uninstantiation Error when an argument or one of its components is not a variable, and a variable or a component as variable is required. ErrorTerm has the following form: uninstantiation_error(Culprit) where Culprit is the argument or one of its components which caused the error.

The system predicate '$pl_err_uninstantiation'(Culprit) raises this error in the current error context (section 6.3.1 page 39).

6.3.4 Type error

A type error occurs when the type of an argument or one of its components is not the expected type (but not a variable). ErrorTerm has the following form: type_error(Type, Culprit) where Type is the expected type and Culprit the argument which caused the error. Type is one of:

- atom
- atomic
- boolean
- byte
- callable
- character
- compound
- evaluable
- fd_bool_evaluable
- fd_evaluable
- fd_variable
- float
- in_byte
- in_character
- integer
- list
- number
- pair
- predicate_indicator

The system predicate '$pl_err_type'(Type, Culprit) raises this error in the current error context (section 6.3.1 page 39).

6.3.5 Domain error

A domain error occurs when the type of an argument is correct but its value is outside the expected domain. ErrorTerm has the following form: domain_error(Domain, Culprit) where Domain is the expected domain and Culprit the argument which caused the error. Domain is one of:

- atom_property
- buffering_mode
- character_code_list
- close_option
- date_time
- eof.action
- fd_labeling_option
- flag_value
- format_control_sequence
- g_array_index
- io_mode
- non_empty_list
- not_less_than_zero
- operator_priority
- operatorSpecifier
- order
- os_file_permission
- os_file_property
- os_path
- predicate_property
- prolog_flag
- read_option
- selectable_item
- socket_address
- socket_domain
- source_sink
- statistics_key
6.3 Errors

- statistics_value
- stream
- stream_option
- stream_or_alias
- stream_position
- stream_property
- stream_seek_method
- stream_type
- term_stream_or_alias
- var_binding_option
- write_option

The system predicate ‘$pl_err_domain’(Domain, Culprit) raises this error in the current error context (section 6.3.1 page 39).

6.3.6 Existence error

an existence error occurs when an object on which an operation is to be performed does not exist. ErrorTerm has the following form: existence_error(Object, Culprit) where Object is the type of the object and Culprit the argument which caused the error. Object is one of:

- procedure
- source_sink
- stream

The system predicate ‘$pl_err_existence’(Object, Culprit) raises this error in the current error context (section 6.3.1 page 39).

6.3.7 Permission error

A permission error occurs when an attempt to perform a prohibited operation is made. ErrorTerm has the following form: permission_error(Operation, Permission, Culprit) where Operation is the operation which caused the error, Permission the type of the tried permission and Culprit the argument which caused the error. Operation is one of:

- access
- add_alias
- close
- create
- input
- modify
- open
- output
- reposition

and Permission is one of:

- binary_stream
- flag
- operator
- past_end_of_stream
- private_procedure
- source_sink
- static_procedure
- stream
- text_stream

The system predicate ‘$pl_err_permission’(Operation, Permission, Culprit) raises this error in the current error context (section 6.3.1 page 39).

6.3.8 Representation error

A representation error occurs when an implementation limit has been breached. ErrorTerm has the following form: representation_error(Limit) where Limit is the name of the reached limit. Limit is one of:
• character
• character_code
• in_character_code
• max arity
• max integer
• min integer
• integer_32bits
• too_many_variables

The errors max integer and min integer are not currently implemented.

The system predicate ‘$pl_err_representation’(Limit) raises this error in the current error context (section 6.3.1 page 39).

6.3.9 Evaluation error

An evaluation error occurs when an arithmetic expression gives rise to an exceptional value. ErrorTerm has the following form: evaluation_error(Error) where Error is the name of the error. Error is one of:

• float_overflow
• int_overflow
• undefined
• underflow

The errors float overflow, int overflow, undefined and underflow are not currently implemented.

The system predicate ‘$pl_err_evaluation’(Error) raises this error in the current error context (section 6.3.1 page 39).

6.3.10 Resource error

A resource error occurs when GNU Prolog does not have enough resources. ErrorTerm has the following form: resource_error(Resource) where Resource is the name of the resource. Resource is one of:

• print_object_not_linked
• too_big_fd_constraint

The system predicate ‘$pl_err_resource’(Resource) raises this error in the current error context (section 6.3.1 page 39).

6.3.11 Syntax error

A syntax error occurs when a sequence of character does not conform to the syntax of terms. ErrorTerm has the following form: syntax_error(Error) where Error is an atom explaining the error.

The system predicate ‘$pl_err_syntax’(Error) raises this error in the current error context (section 6.3.1 page 39).

6.3.12 System error

A system error can occur at any stage. A system error is generally associated with an external component (e.g. operating system). ErrorTerm has the following form: system_error(Error) where Error is
an atom explaining the error. This is an extension to ISO which only defines system_error without arguments.

The system predicate '\texttt{\$pl\_err\_system}(Error)' raises this error in the current error context (section 6.3.1 page 39).
7 Prolog directives and control constructs

7.1 Prolog directives

7.1.1 Introduction

Prolog directives are annotations inserted in Prolog source files for the compiler. A Prolog directive is used to specify:

- the properties of some procedures defined in the source file.
- the format and the syntax for read-terms in the source file (using changeable Prolog flags).
- included source files.
- a goal to be executed at run-time.

7.1.2 dynamic/1

Templates

dynamic(+predicate_indicator)
dynamic(+predicate_indicator_list)
dynamic(+predicate_indicator_sequence)

Description

dynamic(Pred) specifies that the procedure whose predicate indicator is Pred is a dynamic procedure. This directive makes it possible to alter the definition of Pred by adding or removing clauses. For more information refer to the section about dynamic clause management (section 8.7.1 page 70).

This directive shall precede the definition of Pred in the source file.

If there is no clause for Pred in the source file, Pred exists however as an empty predicate (this means that current_predicate(Pred) succeeds).

In order to allow multiple definitions, Pred can also be a list of predicate indicators or a sequence of predicate indicators using ',/2 as separator.

Portability

ISO directive.

7.1.3 public/1

Templates

public(+predicate_indicator)
public(+predicate_indicator_list)
public(+predicate_indicator_sequence)
Description

`public(Pred)` specifies that the procedure whose predicate indicator is `Pred` is a public procedure. This directive makes it possible to inspect the clauses of `Pred`. For more information refer to the section about dynamic clause management (section 8.7.1, page 70).

This directive shall precede the definition of `Pred` in the source file. Since a dynamic procedure is also public, it is useless (but correct) to define a public directive for a predicate already declared as dynamic.

In order to allow multiple definitions, `Pred` can also be a list of predicate indicators or a sequence of predicate indicators using ``, `/2 as separator.

Portability

GNU Prolog directive. The ISO reference does not define any directive to declare a predicate public but it does distinguish public predicates. It is worth noting that in most Prolog systems the `public/1` directive is as a visibility declaration. Indeed, declaring a predicate as public makes it visible from any predicate defined in any other file (otherwise the predicate is only visible from predicates defined in the same source file as itself). When a module system is incorporated in GNU Prolog a more general visibility declaration shall be provided conforming to the ISO reference.

7.1.4 multile/1

Templates

```prolog
multile(+predicate_indicator)
multile(+predicate_indicator_list)
multile(+predicate_indicator_sequence)
```

Description

`multile(Pred)` specifies that the procedure whose predicate indicator is `Pred` is a multile procedure (the clauses of `Pred` can reside in several source files). This directive is only supported by GNU Prolog since version 1.4.0.

The native compilation scheme of GNU Prolog requires that each Prolog source file referring to a multile predicate `Pred` must include a `multile(Pred)` directive even if no clause are defined in this file for `Pred` (i.e. `Pred` is only called by other predicates in this source file).

Portability

ISO directive.

7.1.5 discontiguous/1

Templates

```prolog
discontiguous(+predicate_indicator)
discontiguous(+predicate_indicator_list)
discontiguous(+predicate_indicator_sequence)
```

Description
discontiguous(Pred) specifies that the procedure whose predicate indicator is Pred is a discontiguous procedure. Namely, the clauses defining Pred are not restricted to be consecutive but can appear anywhere in the source file.

This directive shall precede the definition of Pred in the source file.

In order to allow multiple definitions, Pred can also be a list of predicate indicators or a sequence of predicate indicators using ',' as separator.

A multifile predicate (declared with a multifile/1 directive) cannot be directly called from a file where it is not declared as multifile (the native compiler must know the called predicate is multifile). Workarounds: either call it via a meta-call (e.g. using call/1) or declare it as multifile in the calling source file). A good habit is to encapsulate a multifile predicate in a monofile predicate which invokes it (external call only invoke the monofile wrapper predicate).

Portability

ISO directive.

7.1.6 ensure_linked/1

Templates

ensure_linked(+predicate_indicator)
ensure_linked(+predicate_indicator_list)
ensure_linked(+predicate_indicator_sequence)

Description

ensure_linked(Pred) specifies that the procedure whose predicate indicator is Pred must be included by the linker. This directive is useful when compiling to native code to force the linker to include the code of a given predicate. Indeed, if the gplc is invoked with an option to reduce the size of the executable (section 4.4.3 page 23), the linker only includes the code of predicates that are statically referenced. However, the linker cannot detect dynamically referenced predicates (used as data passed to a meta-call predicate). The use of this directive prevents it to exclude the code of such predicates.

In order to allow multiple definitions, Pred can also be a list of predicate indicators or a sequence of predicate indicators using ',','/2 as separator.

Portability

GNU Prolog directive.

7.1.7 built_in/0, built_in/1, built_in_fd/0, built_in_fd/1

Templates

built_in
built_in(+predicate_indicator)
built_in(+predicate_indicator_list)
built_in(+predicate_indicator_sequence)
built_in_fd
built_in_fd(+predicate_indicator)
built_in_fd(+predicate_indicator_list)
built_in_fd(+predicate_indicator_sequence)

**Description**

`built_in` specifies that the procedures defined from now have the `built_in` property (section 8.8.2 page 75).

`built_in(Pred)` is similar to `built_in/0` but only affects the procedure whose predicate indicator is `Pred`.

This directive shall precede the definition of `Pred` in the source file.

In order to allow multiple definitions, `Pred` can also be a list of predicate indicators or a sequence of predicate indicators using `',',/2` as separator.

`built_in_fd` (resp. `built_in_fd(Pred)`) is similar to `built_in` (resp. `built_in(Pred)`) but sets the `built_in_fd` predicate property (section 8.8.2 page 75).

**Portability**

GNU Prolog directives.

7.1.8 include/1

**Templates**

`include(+atom)`

**Description**

`include(File)` specifies that the content of the Prolog source `File` shall be inserted. The resulting Prolog text is identical to the Prolog text obtained by replacing the directive by the content of the Prolog source `File`.

In case of `File` is a relative file name, it is searched in the current directory. If it is not found it is then searched in each directory of parent includers.

See `absolute_file_name/2` for information about the syntax of `File` (section 8.26.1 page 158).

**Portability**

ISO directive.

7.1.9 if/1, else/0, endif/0, elif/1

**Templates**

```
if(+callable_term)
else
endif
elif(+callable_term)
```
Description

These directives are for conditional compilation.

\texttt{if(Goal)} compile subsequent code only if \texttt{Goal} succeeds. \texttt{Goal} is first processed by \texttt{expand_term/2} (section 8.17.2 page 124). If \texttt{Goal} raises an exception it is printed and \texttt{Goal} fails.

\texttt{else} introduces the \texttt{else} part.

\texttt{endif} terminates a conditional compilation part.

\texttt{elif(Goal)} is a shorthand for \texttt{:- else. :- if(Goal). ... :- endif}.

Portability

GNU Prolog directive. Also in SWI and YAP.

\texttt{7.1.10 ensure_loaded/1}

Templates

\begin{verbatim}
ensure_loaded(+atom)
\end{verbatim}

Description

\texttt{ensure_loaded(File)} is not supported by GNU Prolog. When such a directive is encountered it is simply ignored.

Portability

ISO directive. Not supported.

\texttt{7.1.11 op/3}

Templates

\begin{verbatim}
op(+integer, +operator_specifier, +atom_or_atom_list)
\end{verbatim}

Description

\texttt{op(Priority, OpSpecifier, Operator)} alters the operator table. This directive is executed as soon as it is encountered by calling the built-in predicate \texttt{op/3} (section 8.14.10 page 113). A system directive is also generated to reflect the effect of this directive at run-time (section 4.4.4 page 27).

Portability

ISO directive.

\texttt{7.1.12 char_conversion/2}

Templates
7.1.13 set_prolog_flag/2

Templates

    set_prolog_flag(+flag, +term)

Description

set_prolog_flag(Flag, Value) sets the value of the Prolog flag Flag to Value. This directive is executed as soon as it is encountered by a call to the built-in predicate set_prolog_flag/2 (section 8.22.1 page 148). A system directive is also generated to reflect the effect of this directive at run-time (section 4.4.4 page 27).

Portability

ISO directive.

7.1.14 initialization/1

Templates

    initialization(+callable_term)

Description

initialization(Goal) adds Goal to the set of goal which shall be executed at run-time. A user directive is generated to execute Goal at run-time. If several initialization directives appear in the same file they are executed in the order of appearance (section 4.4.4 page 27).

Portability

ISO directive.

7.1.15 foreign/2, foreign/1

Templates

    foreign(+callable_term, +foreign_option_list)
    foreign(+callable_term)
7.2 Prolog control constructs

Description

`foreign(Template, Options)` defines an interface predicate whose prototype is `Template` according to the options given by `Options`. Refer to the foreign code interface for more information (section 10.3, page 202).

`foreign(Template)` is equivalent to `foreign(Template, [])`.

Portability

GNU Prolog directive.

7.2 Prolog control constructs

GNU Prolog follows the ISO notion of control constructs.

7.2.1 true/0, fail/0, !/0

Templates

```prolog
true
fail
!
```

Description

`true` always succeeds.

`fail` always fails (enforces backtracking).

`!` always succeeds and the for side-effect of removing all choice-points created since the invocation of the predicate activating it.

Errors

None.

Portability

ISO control constructs.

7.2.2 (',')/2 - conjunction, (;/2 - disjunction, (->)/2 - if-then, (*->)/2 - soft-cut (soft if-then)

Templates

```
', '(+callable_term, +callable_term)
;/2(+callable_term, +callable_term)
->/(+callable_term, +callable_term)
*->/(+callable_term, +callable_term)
```
### Description

Goal1 ; Goal2 first creates a choice-point and executes Goal1. On backtracking Goal2 is executed.

Goal1 -> Goal2 first executes Goal1 and, in case of success, removes all choice-points created by Goal1 and executes Goal2. This control construct acts like an if-then (Goal1 is the test part and Goal2 the then part). Note that if Goal1 fails ->/2 fails also. ->/2 is often combined with ;/2 to define an if-then-else as follows: Goal1 -> Goal2 ; Goal3. Note that Goal1 -> Goal2 is the first argument of the (;)/2 and Goal3 (the else part) is the second argument. Such an if-then-else control construct first creates a choice-point for the else-part (intuitively associated with ;/2) and then executes Goal1. In case of success, all choice-points created by Goal1 together with the choice-point for the else-part are removed and Goal2 is executed. If Goal1 fails then Goal3 is executed.

Goal1 *-> Goal2 ; Goal3 implements the so-called soft-cut. It acts as the above if-then-else except that if Goal1 succeeds only Goal3 is cut (the alternative solutions of Goal1 are preserved and can be found by backtracking). Note that Goal1 *-> Goal2 alone (i.e. without an else branch Goal3) is equivalent to (Goal1 , Goal2).

',', ;, -> and *-> are predefined infix operators (section 8.14.10 page 113).

### Errors

<table>
<thead>
<tr>
<th>Goal1 or Goal2 is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal1 is neither a variable nor a callable term</td>
<td>type_error(callable, Goal1)</td>
</tr>
<tr>
<td>Goal2 is neither a variable nor a callable term</td>
<td>type_error(callable, Goal2)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Goal1 or Goal2 does not correspond to an existing procedure and the value of the unknown Prolog flag is error (section 8.22.1 page 148)</td>
<td>existence_error(procedure, Pred)</td>
</tr>
</tbody>
</table>

### Portability

ISO control constructs except (*->)/2 which is GNU Prolog specific.

### call/1

#### Templates

`call(+callable_term)`

#### Description

call(Goal) executes Goal. call/1 succeeds if Goal represents a goal which is true. When Goal contains a cut symbol ! (section 7.2.1 page 51) as a subgoal, the effect of ! does not extend outside Goal.

#### Errors
7.2 Prolog control constructs

<table>
<thead>
<tr>
<th>Goal is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is neither a variable nor a callable term</td>
<td>type_error(callable, Goal)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Goal does not correspond to an existing procedure and the value of the unknown Prolog flag is error (section 8.22.1 page 148)</td>
<td>existence_error(procedure, Pred)</td>
</tr>
</tbody>
</table>

Portability

ISO control construct.

7.2.4 catch/3, throw/1

Templates

```
catch(?callable_term, ?term, ?term)
throw(+nonvar)
```

Description

catch(Goal, Catcher, Recovery) is similar to call(Goal) (section 7.2.3 page 52). If this succeeds or fails, so does the call to catch/3. If however, during the execution of Goal, there is a call to throw(Ball), the current flow of control is interrupted, and control returns to a call of catch/3 that is being executed. This can happen in one of two ways:

- implicitly, when an error condition for a built-in predicate is satisfied.
- explicitly, when the program executes a call of throw/1 because the program wishes to abandon the current processing, and instead to take an alternative action.

throw(Ball) causes the normal flow of control to be transferred back to an existing call of catch/3. When a call to throw(Ball) happens, Ball is copied and the stack is unwound back to the call to catch/3, whereupon the copy of Ball is unified with Catcher. If this unification succeeds, then catch/3 executes the goal Recovery using call/1 (section 7.2.3 page 52) in order to determine the success or failure of catch/3. Otherwise, in case the unification fails, the stack keeps unwinding, looking for an earlier invocation of catch/3. Ball may be any non-variable term.

Errors

| Ball is a variable | instantiation_error |

If Ball does not unify with the Catcher argument of any call of catch/3, a system error message is displayed and throw/1 fails.

When catch/3 calls Goal or Recovery it uses call/1 (section 7.2.3 page 52), an instantiation_error, a type_error or an existence_error can then occur depending on Goal or Recovery.

Portability

ISO control construct.
8 Prolog built-in predicates

8.1 Type testing

8.1.1 var/1, nonvar/1, atom/1, integer/1, float/1, number/1, atomic/1, compound/1, callable/1, ground/1, is_list/1, list/1, partial_list/1, list_or_partial_list/1

Templates

\[
\begin{align*}
\text{var}(?\text{term}) & \quad \text{compound}(?\text{term}) \\
\text{nonvar}(?\text{term}) & \quad \text{callable}(?\text{term}) \\
\text{atom}(?\text{term}) & \quad \text{ground}(?\text{term}) \\
\text{integer}(?\text{term}) & \quad \text{is_list}(?\text{term}) \\
\text{float}(?\text{term}) & \quad \text{list}(?\text{term}) \\
\text{number}(?\text{term}) & \quad \text{partial_list}(?\text{term}) \\
\text{atomic}(?\text{term}) & \quad \text{list_or_partial_list}(?\text{term})
\end{align*}
\]

Description

\text{var}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently uninstantiated (which therefore has not been bound to anything, except possibly another uninstantiated variable).}

\text{nonvar}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated (opposite of } \text{var}/1).\text{ }

\text{atom}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to an atom.}

\text{integer}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to an integer.}

\text{float}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a floating point number.}

\text{number}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to an integer or a floating point number.}

\text{atomic}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to an atom, an integer or a floating point number.}

\text{compound}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a compound term, i.e. a term of arity } > 0 \text{ (a list or a structure).}

\text{callable}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a callable term, i.e. an atom or a compound term.}

\text{ground}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is a ground term.}

\text{list}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a list, i.e. the atom } [\text{empty list}] \text{ or a term with principal functor } '.^*/2\text{ and with second argument (the tail) a list.}

\text{is_list}(\text{T}erm) \text{ behaves like } \text{list}(\text{T}erm) \text{ (for compatibility purpose).}

\text{partial_list}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a partial list, i.e. a variable or a term whose the main functor is } '.^*/2\text{ and the second argument (the tail) is a partial list.}

\text{list_or_partial_list}(\text{T}erm) \text{ succeeds if } \text{T}erm \text{ is currently instantiated to a list or a partial list.}
Errors

None.

Portability

`var/1`, `nonvar/1`, `atom/1`, `integer/1`, `float/1`, `number/1`, `atomic/1`, `compound/1`, `callable/1` and `ground/1` are ISO predicates.

`list/1`, `partial_list/1` and `list_or_partial_list/1` are GNU Prolog predicates.

8.2 Term unification

8.2.1 (`=`)/2 - Prolog unification

Templates

`=(?term, ?term)`

Description

Term1 = Term2 unifies Term1 and Term2. No occurs check is done, i.e. this predicate does not check if a variable is unified with a compound term containing this variable (this can lead to an infinite loop).

= is a predefined infix operator (section 8.14.10 page 113).

Errors

None.

Portability

ISO predicate.

8.2.2 `unify_with_occurs_check/2`

Templates

`unify_with_occurs_check(?term, ?term)`

Description

`unify_with_occurs_check(Term1, Term2)` unifies Term1 and Term2. The occurs check test is done (i.e. the unification fails if a variable is unified with a compound term containing this variable).

Errors

None.

Portability

ISO predicate.
8.3 Term comparison

8.3.3 \((\neq)/2\) - not Prolog unifiable

Templates
\(\neq(?\text{term}, ?\text{term})\)

Description
\(\text{Term}_1 \neq \text{Term}_2\) succeeds if \(\text{Term}_1\) and \(\text{Term}_2\) are not unifiable (no occurs check is done).

\(\neq\) is a predefined infix operator (section 8.14.10 page 113).

Errors
None.

Portability
ISO predicate.

8.3 Term comparison

8.3.1 Standard total ordering of terms

The built-in predicates described in this section allows the user to compare Prolog terms. Prolog terms are totally ordered according to the standard total ordering of terms which is as follows (from the smallest term to the greatest):

- variables, oldest first.
- finite domain variables (section 9.1.1 page 183), oldest first.
- floating point numbers, in numeric order.
- integers, in numeric order.
- atoms, in alphabetical (i.e. character code) order.
- compound terms, ordered first by arity, then by the name of the principal functor and by the arguments in left-to-right order.

A list is treated as a compound term (whose principal functor is \(\text{', '}/2\)).

The portability of the order of variables is not guaranteed (in the ISO reference the order of variables is system dependent).

8.3.2 \((==)/2\) - term identical, \((\neq)/2\) - term not identical,
\((\langle\rangle)/2\) - term less than, \((\langle=\rangle)/2\) - term less than or equal to,
\((\langle\rangle)/2\) - term greater than, \((\langle=\rangle)/2\) - term greater than or equal to

Templates
Description

These predicates compare two terms according to the standard total ordering of terms (section 8.3.1, page 57).

Term1 == Term2 succeeds if Term1 and Term2 are equal.

Term1 \== Term2 succeeds if Term1 and Term2 are different.

Term1 @< Term2 succeeds if Term1 is less than Term2.

Term1 @=< Term2 succeeds if Term1 is less than or equal to Term2.

Term1 @> Term2 succeeds if Term1 is greater than Term2.

Term1 @>= Term2 succeeds if Term1 is greater than or equal to Term2.

==, \==, @<, @=<, @> and @>= are predefined infix operators (section 8.14.10, page 113).

Errors

None.

Portability

ISO predicates.

8.3.3 compare/3

Templates

\texttt{compare(?atom, +term, +term)}

Description

\texttt{compare(Order, Term1, Term2)} compares Term1 and Term2 according to the standard (section 8.3.1, page 57) and unifies Order with:

- the atom \texttt{<} if Term1 is less than Term2.
- the atom \texttt{=} if Term1 and Term2 are equal.
- the atom \texttt{>} if Term1 is greater than Term2.

Errors

| Order is neither a variable nor an atom | type_error(atom, Order) |
| Order is an atom but not \texttt{<, = or >} | domain_error(order, Order) |

Portability

ISO predicate.
8.4 Term processing

8.4.1 functor/3

Templates

functor(+nonvar, ?atomic, ?integer)
functor(-nonvar, +atomic, +integer)

Description

functor(Term, Name, Arity) succeeds if the principal functor of Term is Name and its arity is Arity. This predicate can be used in two ways:

- Term is not a variable: extract the name (an atom or a number if Term is a number) and the arity of Term (if Term is atomic Arity = 0).
- Term is a variable: unify Term with a general term whose principal functor is given by Name and arity is given by Arity.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term and Name are both variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Term and Arity are both variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Term is a variable and Name is neither a variable nor an atomic term</td>
<td>type_error(atomic, Name)</td>
</tr>
<tr>
<td>Term is a variable and Arity is neither a variable nor an integer</td>
<td>type_error(integer, Arity)</td>
</tr>
<tr>
<td>Term is a variable, Name is a constant but not an atom and Arity is an integer &gt; 0</td>
<td>type_error(atom, Name)</td>
</tr>
<tr>
<td>Term is a variable and Arity is an integer &gt; max arity flag (section 8.22.1, page 148)</td>
<td>representation_error(max_arity)</td>
</tr>
<tr>
<td>Term is a variable and Arity is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Arity)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.4.2 arg/3

Templates

arg(+integer, +compound_term, ?term)

Description

arg(N, Term, Arg) succeeds if the Nth argument of Term is Arg.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>N is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Term is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>N is neither a variable nor an integer</td>
<td>type_error(integer, N)</td>
</tr>
<tr>
<td>Term is neither a variable nor a compound term</td>
<td>type_error(compound, Term)</td>
</tr>
<tr>
<td>N is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, N)</td>
</tr>
</tbody>
</table>
Portability

ISO predicate.

8.4.3  (=..)/2 - univ

Templates

  =..(+nonvar, ?list)
  =..(-nonvar, +list)

Description

Term =.. List succeeds if List is a list whose head is the atom corresponding to the principal functor of Term and whose tail is a list of the arguments of Term.

=.. is a predefined infix operator (section 8.14.10 page 113).

Errors

| Term is a variable and List is a partial list | instantiation_error |
| List is a variable and List is a list whose head is a variable | instantiation_error |
| List is a list whose head H is neither an atom nor a variable and whose tail is not the empty list | type_error(atom, H) |
| List is a list whose head H is a compound term and whose tail is the empty list | type_error(atomic, H) |
| Term is a variable and List is the empty list | domain_error(non_empty_list, []) |
| Term is a variable and the tail of List has a length > max_arity flag (section 8.22.1 page 148) | representation_error(max_arity) |

Portability

ISO predicate.

8.4.4  copy_term/2

Templates

  copy_term(?term, ?term)

Description

copy_term(Term1, Term2) succeeds if Term2 unifies with a term T which is a renamed copy of Term1.

Errors

None.

Portability

ISO predicate.
8.4 Term processing

8.4.5 term_variables/2, term_variables/3

Templates

```
term_variables(?term, ?list)
term_variables(?term, ?list, ?list)
```

Description

term_variables(Term, List) succeeds if List unifies with a list of variables (including FD variables), each sharing with a unique variable of Term. The variables in List are ordered in order of appearance traversing Term depth-first and left-to-right.

term_variables(Term, List, Tail) is a difference-list version of the above predicate, i.e. Tail is the tail of the variable-list List.

Errors

```
in term_variables/2 List is neither a partial list nor a list type_error(list, List)
```

Portability

term_variables/2 is an ISO Predicate. term_variables/3 is a GNU Prolog predicate.

8.4.6 subsumes_term/2

Templates

```
subsumes_term(?term, ?term)
```

Description

subsumes_term(General, Specific) succeeds if General can be made equivalent to Specific by binding variables in General leaving Specific unaffected. The current implementation performs the unification (with occurs check) and ensures that the variable set of Specific is not changed by the unification (which is then undone). Note that this predicate fails in the presence of FD variables in Specific.

Errors

None.

Portability

ISO predicate.

8.4.7 acyclic_term/1

Templates

```
acyclic_term(?term)
```
Description

`acyclic_term(Term)` succeeds if `Term` does not contain a cyclic (sub-)term. In this case, `Term` may be processed safely. If `acyclic_term(Term)` fails, `Term` contains a cycle and processing `Term` is not safe, because GNU Prolog does not support the unification of cyclic terms but permits their creation. Cycles can be safely undone by failing over their creation. The use of `acyclic_term/1` shall thus be reserved to protect critical predicates against cyclic terms.

Errors

None.

Portability

ISO predicate.

8.4.8  `term_hash/4, term_hash/2`

Templates

- `term_hash(?term, +integer, +integer, ?integer)`
- `term_hash(?term, ?integer)`

Description

`term_hash(Term, Depth, Range, Hash)` succeeds if `Hash` is the hash code of `Term`. If `Term` is not ground (see `ground/1` (section 8.1.1, page 55)), the predicate simply succeeds (`Hash` is not unified). `Depth` is the depth limit to scan `Term` (starting from 1 for the top-level term). With `Depth = 0` nothing is hashed, with 1 only atomic terms and the main functors/arity are hashed,... With `Depth = -1` the full term is considered.

The hash code is as follows: $0 \leq Hash < Range$. If `Range = 0` then `Hash` is not restricted (currently it is $< 268435456$).

`term_hash(Term, Hash)` is equivalent to `term_hash(Term, -1, 0, Hash)`. 

NB: the computed hash code is independent of any runtime context (i.e. it is constant across different executions). It is also independent on the underlying machine.

These predicates are useful to implement hash tables or argument indexing.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Depth is neither a variable nor an integer</td>
<td>type_error(integer, Depth)</td>
</tr>
<tr>
<td>Range is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Range is neither a variable nor an integer</td>
<td>type_error(integer, Range)</td>
</tr>
<tr>
<td>Range is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Range)</td>
</tr>
<tr>
<td>Hash is neither a variable nor an integer</td>
<td>type_error(integer, Hash)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.4.9  setarg/4, setarg/3

Templates

\[
\begin{align*}
& \text{setarg(+integer, +compound_term, +term, +boolean)} \\
& \text{setarg(+integer, +compound_term, +term)}
\end{align*}
\]

Description

\[
\text{setarg}(N, \text{Term}, \text{NewValue}, \text{Undo}) \text{ replaces destructively the } N\text{th argument of } \text{Term} \text{ with } \text{NewValue}. \text{ This assignment is undone on backtracking if } \text{Undo} = \text{true}. \text{ This should only used if there is no further use of the old value of the replaced argument. If } \text{Undo} = \text{false} \text{ then } \text{NewValue} \text{ must be either an atom or an integer.}
\]

\[
\text{setarg}(N, \text{Term}, \text{NewValue}) \text{ is equivalent to } \text{setarg}(N, \text{Term}, \text{NewValue}, \text{true}).
\]

Errors

\[
\begin{array}{|c|c|}
\hline
\text{N is a variable} & \text{instantiation_error} \\
\text{N is neither a variable nor an integer} & \text{type_error(integer, N)} \\
\text{N is an integer < 0} & \text{domain_error(not_less_than_zero, N)} \\
\text{Term is a variable} & \text{instantiation_error} \\
\text{Term is neither a variable nor a compound term} & \text{type_error(compound, Term)} \\
\text{NewValue is neither an atom nor an integer and } \text{Undo} = \text{false} & \text{type_error(atomic, NewValue)} \\
\text{Undo is a variable} & \text{instantiation_error} \\
\text{Undo is neither a variable nor a boolean} & \text{type_error(boolean, Undo)} \\
\hline
\end{array}
\]

Portability

GNU Prolog predicate.

8.5  Variable naming/numbering

8.5.1  name_singleton_vars/1

Templates

\[
\text{name_singleton_vars(?term)}
\]

Description

\[
\text{name_singleton_vars}(\text{Term}) \text{ binds each singleton variable appearing in } \text{Term} \text{ with a term of the form } \text{’$VARNAME’(’_’)}. \text{ Such a term can be output by write_term/3 as a variable name (section 8.14.6 page 108).}
\]

Errors

None.

Portability

GNU Prolog predicates.
8.5.2 name_query_vars/2

Templates

name_query_vars(+list, ?list)

Description

name_query_vars(List, Rest) for each element of List of the form Name = Var where Name is an atom and Var a variable, binds Var with the term ’$VARNAME’(Name). Such a term can be output by write_term/3 as a variable name (section 8.14.6 page 108). Rest is unified with the list of elements of List that have not given rise to a binding. This predicate is provided as a way to name the variable lists obtained returned by read_term/3 with variable_names(List) or singletons(List) options (section 8.14.1 page 104).

Errors

<table>
<thead>
<tr>
<th>List is a partial list</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>List is neither a partial list nor a list</td>
<td>type_error(list, List)</td>
</tr>
<tr>
<td>Rest is neither a partial list nor a list</td>
<td>type_error(list, Rest)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.5.3 bind_variables/2, numbervars/3, numbervars/1

Templates

bind_variables(?term, +var_binding_option_list)
numbervars(?term, +integer, ?integer)
numbervars(?term)

Description

bind_variables(Term, Options) binds each variable appearing in Term according to the options given by Options.

Variable binding options: Options is a list of variable binding options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- **numbervars**: specifies that each variable appearing in Term should be bound to a term of the form ’$VAR’(N) where N is an integer. Such a term can be output by write_term/3 as a variable name (section 8.14.6 page 108). This is the default.
- **namevars**: specifies that each variables appearing in Term shall be bound to a term of the form ’$VARNAME’(Name) where Name is the atom that would be output by write_term/3 seeing a term of the ’$VAR’(N) where N is an integer. Such a term can be output by write_term/3 as a variable name (section 8.14.6 page 108). This is the alternative to numbervars.
- **from(From)**: the first integer N to use for number/name variables of Term is From. The default value is 0.
- **next(Next)**: when bind_variables/2 succeeds, Next is unified with the (last integer N)+1 used to bind the variables of Term.
• **exclude(List)**: collects all variable names appearing in List to avoid a clash when binding a variable of Term. Precisely a number \( N \geq \text{From} \) will not be used to bind a variable of Term if:
  - there is a sub-term of List of the form `'\$VAR'(N)` or `'\$VARNAME'(Name)` where Name is the constant that would be output by `write_term/3` seeing a term of the `'\$VAR'(N)`.  
  - an element of List is of the form Name = Var where Name is an atom that would be output by `write_term/3` on seeing a term of the from `'\$VAR'(N)`. This case allows for lists returned by `read_term/3` (with `variable_names(List)` or `singletons(List)` options) (section 8.14.1 page 101) and by `name_query_vars/2` (section 8.5.2 page 64).

\[
\text{numbervars(Term, From, Next)}\]

is equivalent to \(\text{bind_variables(Term, [from(From), next(Next)]}, \) i.e. each variable of Term is bound to `'\$VAR'(N)` where \(\text{From} \leq N < \text{Next}\).

\[
\text{numbervars(Term)}\]

is equivalent to \(\text{numbervars(Term, 0, _)}\).

See also `term_variables` (section 8.4.5 page 61) which returns the set of variables of a term.

**Errors**

<table>
<thead>
<tr>
<th>Options</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>is neither a partial list nor a list an element E of the Options list is neither a variable nor a variable binding option</td>
<td>type_error(list, Options)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>is neither a variable nor an integer</td>
<td>type_error(integer, From)</td>
</tr>
<tr>
<td>Next</td>
<td></td>
</tr>
<tr>
<td>is a variable nor an integer</td>
<td>type_error(integer, Next)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>List</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>is neither a partial list nor a list</td>
<td>type_error(list, List)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.

8.5.4 **term_ref/2**

**Templates**

\[
\text{term_ref(+term, ?integer)}
\]

\[
\text{term_ref(?term, +integer)}
\]

**Description**

\(\text{term_ref(Term, Ref)}\) succeeds if the internal reference of Term is Ref. This predicate can be used either to obtain the internal reference of a term or to obtain the term associated with a given reference. Note that two identical terms can have different internal references. A good way to use this predicate is to first record the internal reference of a given term and to later re-obtain the term via this reference.

**Errors**

<table>
<thead>
<tr>
<th>Term and Ref are both variables</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref is neither a variable nor an integer</td>
<td>type_error(integer, Ref)</td>
</tr>
<tr>
<td>Ref is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Ref)</td>
</tr>
</tbody>
</table>

**Portability**
8.6 Arithmetic

8.6.1 Evaluation of an arithmetic expression

An arithmetic expression is a Prolog term built from numbers, variables, and functors (or operators) that represent arithmetic functions. When an expression is evaluated each variable must be bound to a non-variable expression. An expression evaluates to a number, which may be an integer or a floating point number. The following table details the components of an arithmetic expression, how they are evaluated, the types expected/returned and if they are ISO or an extension:
<table>
<thead>
<tr>
<th>Expression</th>
<th>Result = eval(Expression)</th>
<th>Signature</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a variable</td>
<td>bound to an expression E, result is eval(E)</td>
<td>IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>an integer number</td>
<td>this number</td>
<td>I</td>
<td>Y</td>
</tr>
<tr>
<td>a floating point number</td>
<td>this number</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>pi</td>
<td>the value of π = 3.141592...</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>e</td>
<td>the value of e = 2.718281...</td>
<td>F</td>
<td>N</td>
</tr>
<tr>
<td>epsilon</td>
<td>difference between 1.0 and minimum float &gt; 1.0</td>
<td>F</td>
<td>N</td>
</tr>
<tr>
<td>+ E</td>
<td>eval(E)</td>
<td>IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>- E</td>
<td>- eval(E)</td>
<td>IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>inc(E)</td>
<td>eval(E) + 1</td>
<td>IF → IF</td>
<td>N</td>
</tr>
<tr>
<td>dec(E)</td>
<td>eval(E) - 1</td>
<td>IF → IF</td>
<td>N</td>
</tr>
<tr>
<td>E1 + E2</td>
<td>eval(E1) + eval(E2)</td>
<td>IF, IF → IF</td>
<td>N</td>
</tr>
<tr>
<td>E1 - E2</td>
<td>eval(E1) - eval(E2)</td>
<td>IF, IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>E1 * E2</td>
<td>eval(E1) * eval(E2)</td>
<td>IF, IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>E1 / E2</td>
<td>eval(E1) / eval(E2)</td>
<td>IF, IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>E1 // E2</td>
<td>rnd(eval(E1) / eval(E2))</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 rem E2</td>
<td>eval(E1) - (rnd(eval(E1) / eval(E2)) * eval(E2))</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 div E2</td>
<td>[(eval(E1) - eval(E1) mod eval(E2)) / eval(E2)]</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 mod E2</td>
<td>eval(E1) - ((eval(E1) / eval(E2)) * eval(E2))</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 /\ E2</td>
<td>eval(E1) bitwise_and eval(E2)</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 / E2</td>
<td>eval(E1) bitwise_or eval(E2)</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>xor(E1,E2)</td>
<td>eval(E1) bitwise_xor eval(E2)</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>\ E</td>
<td>bitwise_not eval(E)</td>
<td>I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 &lt;&lt; E2</td>
<td>eval(E1) integer_shift_left eval(E2)</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>E1 &gt;&gt; E2</td>
<td>eval(E1) integer_shift_right eval(E2)</td>
<td>I, I → I</td>
<td>Y</td>
</tr>
<tr>
<td>lsb(E)</td>
<td>least significant bit (from 0) of eval(E) or -1</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>msb(E)</td>
<td>most significant bit (from 0) of eval(E) or -1</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>popcount(E)</td>
<td>number of 1-bits in eval(E)</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>abs(E)</td>
<td>absolute value of eval(E)</td>
<td>IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>sign(E)</td>
<td>sign of eval(E) (-1 if &lt; 0, 0 if = 0, +1 if &gt; 0)</td>
<td>IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>min(E1,E2)</td>
<td>minimal value between eval(E1) and eval(E2)</td>
<td>IF, IF → ?</td>
<td>Y</td>
</tr>
<tr>
<td>max(E1,E2)</td>
<td>maximal value between eval(E1) and eval(E2)</td>
<td>IF, IF → ?</td>
<td>Y</td>
</tr>
<tr>
<td>gcd(E1,E2)</td>
<td>greatest common divisor of eval(E1) and eval(E2)</td>
<td>I, I → I</td>
<td>N</td>
</tr>
<tr>
<td>E1 ^ 2</td>
<td>eval(E1) raised to the power of eval(E2)</td>
<td>IF, IF → IF</td>
<td>Y</td>
</tr>
<tr>
<td>E1 ** E2</td>
<td>eval(E1) raised to the power of eval(E2)</td>
<td>IF, IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>sqrt(E)</td>
<td>square root of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>tan(E)</td>
<td>tangent of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>atan(E)</td>
<td>arc tangent of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>atan2(Y,X)</td>
<td>principal value of arc tangent of eval(Y) / eval(X) using both signs for the quadrant</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>cos(E)</td>
<td>cosine of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>acos(E)</td>
<td>arc cosine of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>sin(E)</td>
<td>sine of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>asin(E)</td>
<td>arc sine of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>tanh(E)</td>
<td>hyperbolic tangent of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
<tr>
<td>atanh(E)</td>
<td>hyperbolic arc tangent of eval(E)</td>
<td>IF → F</td>
<td>N</td>
</tr>
<tr>
<td>cosh(E)</td>
<td>hyperbolic cosine of eval(E)</td>
<td>IF → F</td>
<td>N</td>
</tr>
<tr>
<td>acosh(E)</td>
<td>hyperbolic arc cosine of eval(E)</td>
<td>IF → F</td>
<td>N</td>
</tr>
<tr>
<td>sinh(E)</td>
<td>hyperbolic sine of eval(E)</td>
<td>IF → F</td>
<td>N</td>
</tr>
<tr>
<td>asinh(E)</td>
<td>hyperbolic arc sine of eval(E)</td>
<td>IF → F</td>
<td>N</td>
</tr>
<tr>
<td>exp(E)</td>
<td>( e ) raised to the power of eval(E)</td>
<td>IF → F</td>
<td>Y</td>
</tr>
</tbody>
</table>
The meaning of the signature field is as follows:

- **I → I**: unary function, the operand must be an integer and the result is an integer.
- **F → F**: unary function, the operand must be a floating point number and the result is a floating point number.
- **F → I**: unary function, the operand must be a floating point number and the result is an integer.
- **IF → F**: unary function, the operand can be an integer or a floating point number and the result is a floating point number.
- **IF → IF**: unary function, the operand can be an integer or a floating point number and the result has the same type as the operand.
- **I, I → I**: binary function: each operand must be an integer and the result is an integer.
- **IF, IF → IF**: binary function: each operand can be an integer or a floating point number and the result is a floating point number if at least one operand is a floating point number, an integer otherwise.
- **IF, IF → ?**: binary function: each operand can be an integer or a floating point number and the result has the same type as the selected operand. This is used for \texttt{min} and \texttt{max}. Note that in case of equality between an integer and a floating point number the result is an integer.

\textbf{Integer division rounding function}: the integer division rounding function \texttt{rnd} \((X)\) rounds the floating point number \(X\) to an integer. There are two possible definitions (depending on the target machine) for this function which differ on negative numbers:

- \(\texttt{rnd} \((X)\) = \text{integer part of } X\), e.g. \(\texttt{rnd} \((-1.5)\) = \(-1\) (round toward 0)
- \(\texttt{rnd} \((X)\) = \lfloor X \rfloor\), e.g. \(\texttt{rnd} \((-1.5)\) = \(-2\) (round toward \(-\infty\))

The definition of this function determines the definition of the integer division and remainder \((//)/2\) and \((\texttt{rem})/2\). It is possible to test the value \((\texttt{toward zero or down})\) of the \texttt{integer_rounding_function} Prolog flag to determine which function being used (section 8.22.1 page 148). Since rounding toward zero is the most common case, two additional evaluable functors \((\texttt{div})/2\) and \((\texttt{mod})/2\) are available which consider rounding toward \(-\infty\).

\textbf{Fast mathematical mode}: in order to speed-up integer computations, the GNU Prolog compiler can generate faster code when invoked with the \(--\texttt{fast-math}\) option (section 4.4.3 page 24). In this mode only integer operations are allowed and a variable in an expression must be bound at evaluation time to an integer. No type checking is done.
8.6 Arithmetic

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>a sub-expression E is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>a sub-expression E is neither a number nor an evaluable functor</td>
<td>type_error(evaluable, E)</td>
</tr>
<tr>
<td>a sub-expression E is a floating point number while an integer is expected</td>
<td>type_error(integer, E)</td>
</tr>
<tr>
<td>a sub-expression E is an integer while a floating point number is expected</td>
<td>type_error(float, E)</td>
</tr>
<tr>
<td>a division by zero occurs</td>
<td>evaluation_error(zero_divisor)</td>
</tr>
</tbody>
</table>

Portability

Refer to the above table to determine which evaluable functors are ISO and which are GNU Prolog extensions. For efficiency reasons, GNU Prolog does not detect the following ISO arithmetic errors: float_overflow, int_overflow, int_underflow, and undefined.

8.6.2 (is)/2 - evaluate expression

Templates

\[ \text{is}(?\text{term}, \text{+evaluable}) \]

Description

Result is Expression succeeds if Result can be unified with eval(Expression). Refer to the evaluation of an arithmetic expression for the definition of the eval function (section 8.6.1 page 66).

is is a predefined infix operator (section 8.14.10 page 113).

Errors

Refer to the evaluation of an arithmetic expression for possible errors (section 8.6.1 page 66).

Portability

ISO predicate.

8.6.3 (\=\=)/2 - arithmetic equal, (=\\=/)/2 - arithmetic not equal,
\(<\)/2 - arithmetic less than, (=\<\)/2 - arithmetic less than or equal to,
\(>\)/2 - arithmetic greater than, (\=>\)/2 - arithmetic greater than or equal to

Templates

\[ =\=(+\text{evaluable}, +\text{evaluable}) \]
\[ =\!(+\text{evaluable}, +\text{evaluable}) \]
\[ <(+\text{evaluable}, +\text{evaluable}) \]
\[ ==(+\text{evaluable}, +\text{evaluable}) \]
\[ >(+\text{evaluable}, +\text{evaluable}) \]
\[ >=(+\text{evaluable}, +\text{evaluable}) \]

Description

Expr1 =:= Expr2 succeeds if eval(Expr1) = eval(Expr2).
Expr1 =\= Expr2 succeeds if eval(Expr1) \neq eval(Expr2).

Expr1 < Expr2 succeeds if eval(Expr1) < eval(Expr2).

Expr1 =< Expr2 succeeds if eval(Expr1) \leq eval(Expr2).

Expr1 > Expr2 succeeds if eval(Expr1) > eval(Expr2).

Expr1 >= Expr2 succeeds if eval(Expr1) \geq eval(Expr2).

Refer to the evaluation of an arithmetic expression for the definition of the eval function (section 8.6.1 page 66).

=:=, =\=, <, =<, > and >= are predefined infix operators (section 8.14.10 page 113).

Errors

Refer to the evaluation of an arithmetic expression for possible errors (section 8.6.1 page 66).

Portability

ISO predicates.

8.6.4 succ/2

Templates

succ(+integer, ?integer)
succ(-integer, +integer)

Description

succ(X, Y) is true iff Y is the successor of the non-negative integer X.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>X and Y are both variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>X is neither a variable nor an integer</td>
<td>type_error(integer, X)</td>
</tr>
<tr>
<td>Y is neither a variable nor an integer</td>
<td>type_error(integer, Y)</td>
</tr>
<tr>
<td>X is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, X)</td>
</tr>
<tr>
<td>Y is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Y)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.7 Dynamic clause management

8.7.1 Introduction

Static and dynamic procedures: a procedure is either dynamic or static. All built-in predicates are static. A user-defined procedure is static by default unless a dynamic/1 directive precedes its definition.
Adding a clause to a non-existent procedure creates a dynamic procedure. The clauses of a dynamic procedure can be altered (e.g. using `asserta/1`), the clauses of a static procedure cannot be altered.

**Private and public procedures:** each procedure is either public or private. A dynamic procedure is always public. Each built-in predicate is private, and a static user-defined procedure is private by default unless a `public/1` directive precedes its definition (section 7.1.3, page 45). If a dynamic declaration exists it is unnecessary to add a public declaration since a dynamic procedure is also public. A clause of a public procedure can be inspected (e.g. using `clause/2`), a clause of a private procedure cannot be inspected.

**A logical database update view:** any change in the database that occurs as the result of executing a goal (e.g. when a sub-goal is a call of `assertz/1` or `retract/1`) only affects subsequent activations. The change does not affect any activation that is currently being executed. Thus the database is frozen during the execution of a goal, and the list of clauses defining a predication is fixed at the moment of its execution.

### 8.7.2 asserta/1, assertz/1

**Templates**

```
asserta(+clause)
assertz(+clause)
```

**Description**

`asserta(Clause)` first converts the term `Clause` to a clause and then adds it to the current internal database. The predicate concerned must be dynamic (section 8.7.1 page 70) or undefined and the clause is inserted before the first clause of the predicate. If the predicated is undefined it is created as a dynamic procedure.

`assertz(Clause)` acts like `asserta/1` except that the clause is added at the end of all existing clauses of the concerned predicate.

**Converting a term Clause to a clause Clause1:**

- extract the head and the body of `Clause`: either `Clause = (Head :- Body)` or `Clause = Head` and `Body = true`.
- `Head` must be a callable term (or else the conversion fails).
- convert `Body` to a body clause (i.e. a goal) `Body1`.
- the converted clause `Clause1 = (Head :- Body1)`.

**Converting a term T to a goal:**

- if `T` is a variable it is replaced by the term `call(T)`.
- if `T` is a control construct (`','`)/2, `(;)`/2 or `(->)`/2 each argument of the control construct is recursively converted to a goal.
- if `T` is a callable term it remains unchanged.
- otherwise the conversion fails (T is neither a variable nor a callable term).
Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Head is neither a variable nor a callable term</td>
<td>type_error(callable, Head)</td>
</tr>
<tr>
<td>Body cannot be converted to a goal</td>
<td>type_error(callable, Body)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Head is that of a</td>
<td>permission_error(modify,</td>
</tr>
<tr>
<td>static procedure</td>
<td>static_procedure, Pred)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.

8.7.3 retract/1

Templates

retract(+clause)

Description

retract(Clause) erases the first clause of the database that unifies with Clause. The concerned predicate must be a dynamic procedure (section 8.7.1 page 70). Removing all clauses of a procedure does not erase the procedure definition. To achieve this use abolish/1 (section 8.7.6 page 73). retract/1 is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Head is neither a variable nor a callable term</td>
<td>type_error(callable, Head)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Head is that of a</td>
<td>permission_error(modify,</td>
</tr>
<tr>
<td>static procedure</td>
<td>static_procedure, Pred)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate. In the ISO reference, the operation associated with the permission_error is access while it is modify in GNU Prolog. This seems to be an error of the ISO reference since for asserta/1 (which is similar in spirit to retract/1) the operation is also modify.

8.7.4 retractall/1

Templates

retractall(+head)

Description

retractall(Head) erases all clauses whose head unifies with Head. The concerned predicate must be a dynamic procedure (section 8.7.1 page 70). The procedure definition is not removed so that it is found by current_predicate/1 (section 8.8.1 page 74). abolish/1 should be used to remove the procedure (section 8.7.6 page 73).

Errors
8.7 Dynamic clause management

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Head is not a callable term</td>
<td>type_error(callable, Head)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Head is that of a static procedure</td>
<td>permission_error(modify, static_procedure, Pred)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.7.5 clause/2

Templates

\[
\text{clause}(+\text{head}, ?\text{callable_term})
\]

Description

\[\text{clause}(\text{Head}, \text{Body})\] succeeds if there exists a clause in the database that unifies with \[\text{Head} : - \text{Body}\]. The predicate in question must be a public procedure (section 8.7.1, page 70). Clauses are delivered from the first to the last. This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Head is neither a variable nor a callable term</td>
<td>type_error(callable, Head)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Head is that of a private procedure</td>
<td>permission_error(access, private_procedure, Pred)</td>
</tr>
<tr>
<td>Body is neither a variable nor a callable term</td>
<td>type_error(callable, Body)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.7.6 abolish/1

Templates

\[
\text{abolish}(+\text{predicate_indicator})
\]

Description

\[\text{abolish}(\text{Pred})\] removes from the database the procedure whose predicate indicator is \text{Pred}. The concerned predicate must be a dynamic procedure (section 8.7.1, page 70).

Errors
### Portability

ISO predicate.

## 8.8 Predicate information

### 8.8.1 current_predicate/1

**Templates**

`current_predicate(?predicate_indicator)`

**Description**

`current_predicate(Pred)` succeeds if there exists a predicate indicator of a defined procedure that unifies with `Pred`. All user defined procedures are found, whether static or dynamic. Internal system procedures whose name begins with `$` are not found. A user-defined procedure is found even when it has no clauses. A user-defined procedure is not found if it has been abolished. To conform to the ISO reference, built-in predicates are not found except if the `strict_iso` Prolog flag is switched off (section 8.22.1 page 148). This predicate is re-executable on backtracking.

**Errors**

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Pred</code> is neither a variable nor a predicate indicator</td>
<td><code>type_error(predicate_indicator, Pred)</code></td>
</tr>
<tr>
<td><code>Pred</code> is a term <code>Name/Arity</code> and <code>Arity</code> is neither a variable nor an integer</td>
<td><code>type_error(integer, Arity)</code></td>
</tr>
<tr>
<td><code>Pred</code> is a term <code>Name/Arity</code> and <code>Name</code> is neither a variable nor an atom</td>
<td><code>type_error(atom, Name)</code></td>
</tr>
<tr>
<td><code>Pred</code> is a term <code>Name/Arity</code> and <code>Arity</code> is an integer &lt; 0</td>
<td><code>domain_error(not_less_than_zero, Arity)</code></td>
</tr>
<tr>
<td><code>Pred</code> is a term <code>Name/Arity</code> and <code>Arity</code> is an integer &gt; <code>max arity</code> flag (section 8.22.1 page 148)</td>
<td><code>representation_error(max arity)</code></td>
</tr>
</tbody>
</table>

**Portability**

The predicate indicator `Pred` is that of a static procedure.

```prolog
permission_error(modify, static_procedure, Pred)
```
ISO predicate.

8.8.2 predicate_property/2

Templates

\texttt{predicate_property(?callable, ?predicate_property)}

Description

\texttt{predicate_property(Head, Property)} succeeds if \texttt{Head} refers to a predicate that has a property \texttt{Property}. All user defined procedures and built-in predicates are found. Internal system procedures whose name begins with \texttt{'$'} are not found. This predicate is re-executable on backtracking.

Since version 1.4.0, \texttt{predicate_property/2} no longer accepts a predicate indicator. Control constructs are now returned. Properties \texttt{built_in_fd} and \texttt{control_construct} now imply the property \texttt{built_in}.

Predicate properties:

- \texttt{static}: if the procedure is static.
- \texttt{dynamic}: if the procedure is dynamic.
- \texttt{private}: if the procedure is private.
- \texttt{public}: if the procedure is public.
- \texttt{monofile}: if the procedure is monofile.
- \texttt{multifile}: if the procedure is multifile.
- \texttt{user}: if the procedure is a user-defined procedure.
- \texttt{built_in}: if the procedure is a built-in predicate or a control construct.
- \texttt{built_in_fd}: if the procedure is an FD built-in predicate.
- \texttt{control_construct}: if the procedure is a control construct (section 7.2 page 51).
- \texttt{native_code}: if the procedure is compiled in native code.
- \texttt{prolog_file(File)}: source file from which the procedure has been read.
- \texttt{prolog_line(Line)}: line number of the source file.
- \texttt{meta_predicate(Head)}: if the procedure is a meta-predicate unify \texttt{Head} with the head-pattern. The head-pattern is a compound term with the same name and arity as the predicate where each argument of the term is a meta argument specifier as follows:

  \texttt{integer N} the argument is a term that is used to reference a predicate with \texttt{N} more arguments than the given argument term (e.g. \texttt{call(0)}).
  : the argument is module sensitive, but does not directly refer to a predicate (e.g. \texttt{consult(;}).
  - the argument is not module sensitive and unbound on entry.
  ? the argument is not module sensitive and the mode is unspecified.
  + the argument is not module sensitive and bound (i.e., nonvar) on entry.
Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head is neither a variable nor a callable term</td>
<td>type_error(callable, Head)</td>
</tr>
<tr>
<td>Property is neither a variable nor a predicate property term</td>
<td>domain_error(predicate_property, Property)</td>
</tr>
<tr>
<td>Property = prolog_file(File) and File is neither a variable nor an atom</td>
<td>type_error(atom, File)</td>
</tr>
<tr>
<td>Property = prolog_line(Line) and Line is neither a variable nor an integer</td>
<td>type_error(integer, Line)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.9 All solutions

8.9.1 Introduction

It is sometimes useful to collect all solutions for a goal. This can be done by repeatedly backtracking and gradually building the list of solutions. The following built-in predicates are provided to automate this process.

The built-in predicates described in this section invoke call/1 (section 7.2.3 page 52) on the argument Goal. When efficiency is crucial and Goal is complex it is better to define an auxiliary predicate which can then be compiled, and have Goal call this predicate.

8.9.2 findall/4, findall/3

Templates

\[\text{findall}(?, \text{+callable_term}, ?, \text{list}, ?)\]

Description

\(\text{findall} (\text{Template, Goal, Instances})\) succeeds if \(\text{Instances}\) unifies with the list of values to which a variable \(X\) not occurring in \text{Template} or \text{Goal} would be instantiated by successive re-executions of \(\text{call} \text{(Goal)}\), \(X = \text{Template}\) after systematic replacement of all variables in \(X\) by new variables. Thus, the order of the list \text{Instances} corresponds to the order in which the proofs are found.

\(\text{findall} \text{(Template, Goal, Instances, Tail)}\) is the difference list version of \(\text{findall}/3\). The result is the difference list \text{Instances-Tail}. Thus \(\text{findall} \text{(Template, Goal, Instances)}\) is equivalent to \(\text{findall} \text{(Template, Goal, Instances, [])}\).

Errors
Portability

findall/3 is an ISO predicate. findall/4 is a GNU Prolog predicate.

8.9.3 bagof/3, setof/3

Templates

\[
\text{bagof}(\text{?term}, \text{+callable term}, \text{?list}) \\
\text{setof}(\text{?term}, \text{+callable term}, \text{?list})
\]

Description

\text{bagof(Template, Goal, Instances)} assembles as a list the set of solutions of \text{Goal} for each different instantiation of the free variables in \text{Goal}. The elements of each list are in order of solution, but the order in which each list is found is undefined. This predicate is re-executable on backtracking.

\text{Free variable set: bagof/3} groups the solutions of \text{Goal} according to the free variables in \text{Goal}. This set corresponds to all variables occurring in \text{Goal} but not in \text{Template}. It is sometimes useful to exclude some additional variables of \text{Goal}. For that, \text{bagof/3} recognizes a goal of the form \( \mathsf{T^Goal} \) and exclude all variables occurring in \( \mathsf{T} \) from the free variable set. (\(^\)/2 can be viewed as an \textit{existential quantifier} (the logical reading of \( \mathsf{X^Goal} \) being “there exists an \( \mathsf{X} \) such that \text{Goal} is true”). The use of this existential qualifier is superfluous outside \text{bagof/3} (and \text{setof/3}) and then is not recognized.

\((\,)^\)/2 is a predefined infix operator (section \[8.14.10\] page \[113\]).

\text{setof(Template, Goal, Instances)} is equivalent to \text{bagof(Template,Goal,I), sort(I,Instances)}. Each list is then a sorted list (duplicate elements are removed).

From the implementation point of view \text{setof/3} is as fast as \text{bagof/3}. Both predicates use an in-place (i.e. destructive) sort (section \[8.20.15\] page \[140\]) and require the same amount of memory.

Errors

<table>
<thead>
<tr>
<th>Goal is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is neither a variable nor a callable term</td>
<td>type_error(callable, Goal)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Goal does not correspond to an existing procedure and the value of the unknown Prolog flag is error (section [8.22.1] page [148])</td>
<td>existence_error(procedure, Pred)</td>
</tr>
<tr>
<td>Instances is neither a partial list nor a list</td>
<td>type_error(list, Instances)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.
8.10 Streams

8.10.1 Introduction

A stream provides a logical view of a source/sink.

Sources and sinks: a program can output results to a sink or input data from a source. A source/sink may be a file (regular file, terminal, device,...), a constant term, a pipe, a socket,...

Associating a stream to a source/sink: to manipulate a source/sink it must be associated with a stream. This provides a logical and uniform view of the source/sink whatever its type. Once this association has been established, i.e. a stream has been created, all subsequent references to the source/sink are made by referring the stream. A stream is unidirectional: it is either an input stream or an output stream. For a classical file, the association is done by opening the file (whose name is specified as an atom) with the \texttt{open/4} (section 8.10.6 page 81). GNU Prolog makes it possible to treat a Prolog constant term as a source/sink and provides built-in predicates to associate a stream to such a term (section 8.11 page 94). GNU Prolog provides operating system interface predicates defining pipes between GNU Prolog and child processes with streams associated with these pipes, e.g. \texttt{popen/3} (section 8.27.21 page 170). Similarly, socket interface predicates associate streams to a socket to allow the communication, e.g. \texttt{socket_connect/4} (section 8.28.5 page 178).

Stream-term: a stream-term identifies a stream during a call of an input/output built-in predicate. It is created as a result of associating a stream to a source/sink (section above). A stream-term is a compound term of the form \'$\texttt{stream}$(I)$ where $I$ is an integer.

Stream aliases: any stream may be associated with a stream alias which is an atom which may be used to refer to that stream. The association can be done at open time or using \texttt{add_stream_alias/2} (section 8.10.20 page 90). Such an association automatically ends when the stream is closed. A particular alias only refers to at most one stream at any one time. However, more than one alias can be associated with a stream. Most built-in predicates which have a stream-term as an input argument also accept a stream alias as that argument. However, built-in predicates which return a stream-term do not accept a stream alias.

Standard streams: three streams are predefined and open during the execution of every goal: the standard input stream which has the alias \texttt{user_input}, the standard output stream which has the alias \texttt{user_output} and the standard error stream which has the alias \texttt{user_error}. A goal which attempts to close either standard stream succeeds, but does not close the stream.

Current streams: during execution there is a current input stream and a current output stream. By default, the current input and output streams are the standard input and output streams, but the built-in predicates \texttt{set_input/1} (section 8.10.4 page 80) and \texttt{set_output/1} (section 8.10.5 page 80) can be used to change them. When the current input stream is closed, the standard input stream becomes the current input stream. When the current output stream is closed, the standard output stream becomes the current output stream.

Text streams and binary streams: a text stream is a sequence of characters. A text stream is also regarded as a sequence of lines where each line is a possibly empty sequence of characters followed by a new line character. GNU Prolog may add or remove space characters at the ends of lines in order to conform to the conventions for representing text streams in the operating system. A binary stream is a sequence of bytes. Only a few built-in predicates can deal with binary streams, e.g. \texttt{get_byte/2} (section 8.13 page 101).

Stream positions: the stream position of a stream identifies an absolute position of the source/sink to
which the stream is connected and defines where in the source/sink the next input or output will take place. A stream position is a ground term of the form  
\( \text{stream_position}(I_1, I_2, I_3, I_4) \) where  
\( I_1, I_2, I_3 \) and  
\( I_4 \) are integers. Stream positions are used to reposition a stream (when possible) using for instance  
\( \text{set_stream_position}(\text{stream_position})/2 \) (section 8.10.13 page 86).

The position end of stream: when all data of a stream  
\( S \) has been input  
\( S \) has a stream position  
end-of-stream. At this stream position a goal to input more data will return a specific value to indicate that end of stream has been reached (e.g.  
\( -1 \) for  
\( \text{get_code} \) or  
\( \text{end_of_file} \) for  
\( \text{get_char} \), ...). When this terminating value has been input, the stream has a stream position past-end-of-stream.

Buffering mode: input/output on a stream can be buffered (line-buffered or block-buffered) or not buffered at all. The buffering mode can be specified at open time or using  
\( \text{set_stream_buffering}(\text{stream_buffering})/2 \) (section 8.10.27 page 93). Line buffering is used on output streams, output data are only written to the sink when a new-line character is output (or at the close time). Block buffering is used on input or output. On input streams, when an input is requested on the source, if the buffer is empty, all available characters are read (within the limits of the size of the buffer), subsequent reads will first use the characters in the buffer. On output streams, output data are stored in the buffer and only when the buffer is full is it physically written on the sink. Thus, an output to a buffered stream may not be sent immediately to the sink connected to that stream. When it is necessary to be certain that output has been delivered, the built-in predicate  
\( \text{flush_output} \) (section 8.10.8 page 83) should be used. Finally, it is also possible to use non-buffered streams, in that case input/output are directly done on the connected source/sink. This can be useful for communication purposes (e.g. sockets) or when a precise control is needed, e.g.  
\( \text{select}(\text{select})/5 \) (section 8.27.25 page 173).

Stream mirrors: any stream may be associated with mirror streams specified at open time or using  
\( \text{add_stream_mirror}(\text{stream_mirror})/2 \) (section 8.10.22 page 91). Then, all characters/bytes read from/written to the stream are also written on each mirror stream. The association automatically ends when either the stream or the mirror stream is closed. It is also possible to explicitly remove a mirror stream using  
\( \text{remove_stream_mirror}(\text{remove_mirror})/2 \) (section 8.10.23 page 91).

8.10.2 current_input/1

Templates

\[ \text{current_input}(\text{stream}) \]

Description

current_input(Stream) unifies Stream with the stream-term identifying the current input stream.

Errors

\[ \text{Stream is neither a variable nor a stream} \]

\[ \text{domain_error(stream, Stream)} \]

Portability

ISO predicate.

8.10.3 current_output/1

Templates

\[ \text{current_output}(\text{stream}) \]
current_output(Stream) unifies Stream with the stream-term identifying the current output stream.

Errors

| Stream is neither a variable nor a stream | domain_error(stream, Stream) |

Portability

ISO predicate.

8.10.4 set_input/1

Templates

set_input(+stream_or_alias)

Description

set_input(SorA) sets the current input stream to be the stream associated with the stream-term or alias SorA.

Errors

| SorA is a variable | instantiation_error |
| SorA is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA) |
| SorA is not associated with an open stream | existence_error(stream, SorA) |
| SorA is an output stream | permission_error(output, stream, SorA) |

Portability

ISO predicate.

8.10.5 set_output/1

Templates

set_output(+stream_or_alias)

Description

set_output(SorA) sets the current output stream to be the stream associated with the stream-term or alias SorA.

Errors

| SorA is a variable | instantiation_error |
| SorA is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA) |
| SorA is not associated with an open stream | existence_error(stream, SorA) |
| SorA is an input stream | permission_error(output, stream, SorA) |
Portability

ISO predicate.

8.10.6 open/4, open/3

Templates

\[
\begin{align*}
\text{open}(+\text{source\_sink}, +\text{io\_mode}, -\text{stream}, +\text{stream\_option\_list}) \\
\text{open}(+\text{source\_sink}, +\text{io\_mode}, -\text{stream})
\end{align*}
\]

Description

\text{open}(\text{SourceSink}, \text{Mode}, \text{Stream}, \text{Options}) opens the source/sink \text{SourceSink} for input or output as indicated by \text{Mode} and the list of stream-options \text{Options} and unifies \text{Stream} with the stream-term which is associated with this stream. See \text{absolute\_file\_name/2} for information about the syntax of \text{SourceSink} (section 8.26.1, page 158).

Input/output modes: \text{Mode} is an atom which defines the input/output operations that may be performed the stream. Possible modes are:

- \text{read}: the source/sink is a source and must already exist. Input starts at the beginning of the source.
- \text{write}: the source/sink is a sink. If the sink already exists then it is emptied else an empty sink is created. Output starts at the beginning of that sink.
- \text{append}: the source/sink is a sink. If the sink does not exist it is created. Output starts at the end of that sink.

Stream options: \text{Options} is a list of stream options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- \text{type(text/binary)}: specifies whether the stream is a text stream or a binary stream. The default value is \text{text}.
- \text{reposition(true/false)}: specifies whether it is possible to reposition the stream. The default value is \text{true} except if the stream cannot be repositioned (e.g. a terminal).
- \text{eof\_action(error/eof\_code/reset)}: specifies the effect of attempting to input from a stream whose stream position is past-end-of-stream:
  - \text{error}: a \text{permission\_error} is raised signifying that no more input exists in this stream.
  - \text{eof\_code}: the result of input is as if the stream position is end-of-stream.
  - \text{reset}: the stream position is reset so that it is not past-end-of-stream, and another attempt is made to input from it (this is useful when inputting from a terminal). The default value is \text{eof\_code}.
- \text{alias(Alias)}: specifies that the atom \text{Alias} is to be an alias for the stream. By default no alias is attached to the stream. Several aliases can be defined for a same stream.
- \text{mirror(Mirror)}: specifies the stream associated with the stream-term or alias \text{Mirror} is a mirror for the stream. By default no mirror is attached to the stream. Several mirrors can be defined for a same stream.
- \text{buffering(none/line/block)}: specifies which type of buffering is used by input/output operations on this stream:
  - \text{none}: no buffering.
– \textbf{line}: output operations buffer data emitted until a new-line occurs
– \textbf{block}: input/output operations buffer data until a given number (implementation dependant) of characters/bytes have been treated.

The default value is \textit{line} for a terminal (TTY), \textit{block} otherwise.

\texttt{open(SourceSink, Mode, Stream)} is equivalent to \texttt{open(SourceSink, Mode, Stream, [])}.

\textbf{Errors}

<table>
<thead>
<tr>
<th>SourceSink is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>\textbf{Options} is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>\textbf{Mode} is neither a variable nor an atom</td>
<td>type_error(atom, Mode)</td>
</tr>
<tr>
<td>\textbf{Options} is neither a partial list nor a list</td>
<td>type_error(list, Options)</td>
</tr>
<tr>
<td>Stream is not a variable</td>
<td>uninstantiation_error(Stream)</td>
</tr>
<tr>
<td>SourceSink is neither a variable nor a source/sink</td>
<td>domain_error(source_sink, SourceSink)</td>
</tr>
<tr>
<td>\textbf{Mode} is an atom but not an input/output mode</td>
<td>domain_error(io_mode, Mode)</td>
</tr>
<tr>
<td>an element E of the \textbf{Options} list is neither a variable nor a stream-option</td>
<td>domain_error(stream_option, E)</td>
</tr>
<tr>
<td>the source/sink specified by SourceSink does not exist</td>
<td>existence_error(source_sink, SourceSink)</td>
</tr>
<tr>
<td>the source/sink specified by SourceSink cannot be opened</td>
<td>permission_error(open, source_sink, SourceSink)</td>
</tr>
<tr>
<td>an element E of the \textbf{Options} list is alias(A) and A is already associated with an open stream</td>
<td>permission_error(open, source_sink, alias(A))</td>
</tr>
<tr>
<td>an element E of the \textbf{Options} list is mirror(M) and M is not associated with an open stream</td>
<td>existence_error(stream, M)</td>
</tr>
<tr>
<td>an element E of the \textbf{Options} list is mirror(M) and M is an input stream</td>
<td>permission_error(output, stream, M)</td>
</tr>
<tr>
<td>an element E of the \textbf{Options} list is reposition(true) and it is not possible to reposition this stream</td>
<td>permission_error(open, source_sink, reposition(true))</td>
</tr>
</tbody>
</table>

\textbf{Portability}

ISO predicates. The \texttt{mirror} and \texttt{buffering} stream options are GNU Prolog extensions.

8.10.7 \texttt{close/2, close/1}

\textbf{Templates}

\begin{verbatim}
close(+stream_or_alias, +close_option_list)
close(+stream_or_alias)
\end{verbatim}

\textbf{Description}

\texttt{close(Source, Options)} closes the stream associated with the stream-term or alias Source. If Source is the standard input stream or the standard output stream \texttt{close/2} simply succeeds else the associated source/sink is physically closed. If Source is the current input stream the current input stream becomes the standard input stream \texttt{user_input}. If Source is the current output stream the current output stream becomes the standard output stream \texttt{user_output}.
8.10 Streams

Close options: **Options** is a list of close options. For the moment only one option is available:

- **force(true/false)**: with false, if an error occurs when trying to close the source/sink, the stream is not closed and an error (system_error or resource_error) is raised (but close/2 succeeds). With true, if an error occurs it is ignored and the stream is closed. The purpose of force/1 option is to allow an error handling routine to do its best to reclaim resources. The default value is false.

\[\text{close}(\text{SoR\texttt{A}})\text{ is equivalent to close(\text{SoR\texttt{A}}, [])}\].

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SoR\texttt{A}</strong> is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td><strong>Options</strong> is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td><strong>Options</strong> is neither a partial list nor a list</td>
<td>type_error(list, Options)</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SoR\texttt{A})</td>
</tr>
<tr>
<td>an element E of the Options list is neither a variable nor a close-option</td>
<td>domain_error(close_option, E)</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> is not associated with an open stream</td>
<td>existence_error(stream, SoR\texttt{A})</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> needs a special close (section 8.11 page 94)</td>
<td>system_error(needs_special_close)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates. The system_error(needs_special_close) is a GNU Prolog extension.

8.10.8 flush_output/1, flush_output/0

Templates

*flush_output(+stream_or_alias)*

flush_output

Description

flush_output(SoR\texttt{A}) sends any buffered output characters/bytes to the stream.

flush_output/0 applies to the current output stream.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SoR\texttt{A}</strong> is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SoR\texttt{A})</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> is not associated with an open stream</td>
<td>existence_error(stream, SoR\texttt{A})</td>
</tr>
<tr>
<td><strong>SoR\texttt{A}</strong> is an input stream</td>
<td>permission_error(output, stream, SoR\texttt{A})</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.

8.10.9 current_stream/1

Templates
current_stream(?stream)

Description

current_stream(Stream) succeeds if there exists a stream-term that unifies with Stream. This predicate is re-executable on backtracking.

Errors

Stream is neither a variable nor a stream-term  domain_error(stream, Stream)

Portability

GNU Prolog predicate.

8.10.10  stream_property/2

Templates

stream_property(?stream, ?stream_property)

Description

stream_property(Stream, Property) succeeds if current_stream(Stream) succeeds (section 8.10.9 page 83) and if Property unifies with one of the properties of the stream. This predicate is re-executable on backtracking.

Stream properties:

- file_name(F): the name of the connected source/sink.
- mode(M): M is the open mode (read, write, append).
- input: if it is an input stream.
- output: if it is an output stream.
- alias(A): A is an alias of the stream.
- mirror(M): M is a mirror stream of the stream.
- type(T): T is the type of the stream (text, binary).
- reposition(R): R is the reposition boolean (true, false).
- eof_action(A): A is the end-of-file action (error, eof_code, reset).
- buffering(B): B is the buffering mode (none, line, block).
- end_of_stream(E): E is the current end-of-stream status (not, at, past). If the stream position is end-of-stream then E is unified with at else if the stream position is past-end-of-stream then E is unified with past else E is unified with not.
- position(P): P is the stream-position term associated with the current position.
8.10 Streams

Errors

<table>
<thead>
<tr>
<th>Property</th>
<th>Domain Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Stream is neither a variable nor a stream-term</td>
<td>domain_error(stream, Stream)</td>
</tr>
<tr>
<td>Property is neither a variable nor a stream property</td>
<td>domain_error(stream_property, Property)</td>
</tr>
<tr>
<td>Property = file_name(E), mode(E), alias(E), end_of_stream(E), eof_action(E), reposition(E), type(E) or buffering(E) and E is neither a variable nor an atom</td>
<td>type_error(atom, E)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate. The buffering/1 property is a GNU Prolog extension.

8.10.11 at_end_of_stream/1, at_end_of_stream/0

Templates

\[
\text{at_end_of_stream}(+\text{stream_or_alias})
\]
\[
\text{at_end_of_stream}
\]

Description

\text{at_end_of_stream}(\text{SorA})\text{ succeeds if the stream associated with stream-term or alias SorA has a stream position end-of-stream or past-end-of-stream. This predicate can be defined using stream_property/2 (section 8.10.10, page 84).}

\text{at_end_of_stream/0 applies to the current input stream.}

Errors

<table>
<thead>
<tr>
<th>Property</th>
<th>Domain Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates. The permission_error(input, stream, SorA) is a GNU Prolog extension.

8.10.12 stream_position/2

Templates

\[
\text{stream_position}(+\text{stream_or_alias}, \?\text{stream_position})
\]

Description

\text{stream_position(SorA, Position) succeeds unifying Position with the stream-position term associated with the current position of the stream-term or alias SorA. This predicate can be defined using stream_property/2 (section 8.10.10, page 84).}
Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>Position is neither a variable nor a stream-position term</td>
<td>domain_error(stream_position, Position)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.13  set_stream_position/2

Templates

set_stream_position(+stream_or_alias, +stream_position)

Description

set_stream_position(SorA, Position) sets the position of the stream associated with the stream-term or alias SorA to Position. Position should have previously been returned by stream_property/2 (section 8.10.10 page 84) or by stream_position/2 (section 8.10.12 page 85).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Position is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>Position is neither a variable nor a stream-position term</td>
<td>domain_error(stream_position, Position)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA has stream property reposition(false)</td>
<td>permission_error(reposition, stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.10.14  seek/4

Templates

seek(+stream_or_alias, +stream_seek_method, +integer, ?integer)

Description

seek(SorA, Whence, Offset, NewOffset) sets the position of the stream associated with the stream-term or alias SorA to Offset according to Whence and unifies NewOffset with the new offset from the beginning of the file. seek/4 can only be used on binary streams. Whence is an atom from:
• \texttt{bof}: the position is set relatively to the begin of the file (\texttt{Offset} should be \geq 0).

• \texttt{current}: the position is set relatively to the current position (\texttt{Offset} can be \geq 0 or \leq 0).

• \texttt{eof}: the position is set relatively to the end of the file (\texttt{Offset} should be \leq 0).

This predicate is an interface to the C Unix function \texttt{lseek(2)}.

Errors

\begin{tabular}{|l|l|}
  \hline
  \texttt{SorA} is a variable & \texttt{instantiation\_error} \\
  \texttt{Whence} is a variable & \texttt{instantiation\_error} \\
  \texttt{Offset} is a variable & \texttt{instantiation\_error} \\
  \texttt{SorA} is neither a variable nor a stream-term or alias & \texttt{domain\_error(stream\_or\_alias, SorA)} \\
  \texttt{Whence} is neither a variable nor an atom & \texttt{type\_error(atom, Whence)} \\
  \texttt{Offset} is an atom but not a valid stream seek method & \texttt{domain\_error(stream\_seek\_method, Whence)} \\
  \texttt{NewOffset} is neither a variable nor an integer & \texttt{type\_error(integer, NewOffset)} \\
  \texttt{SorA} is not associated with an open stream & \texttt{existence\_error(stream, SorA)} \\
  \texttt{SorA} has stream property \texttt{reposition(false)} & \texttt{permission\_error(reposition, stream, SorA)} \\
  \texttt{SorA} is associated with a text stream & \texttt{permission\_error(reposition, text\_stream, SorA)} \\
  \hline
\end{tabular}

Portability

GNU Prolog predicate.

\section*{8.10.15 \ smallcopyspan{character\_count/2}}

Templates

\begin{verbatim}
  character\_count(+stream\_or\_alias, ?integer)
\end{verbatim}

Description

\texttt{character\_count(SorA, Count)} unifies \texttt{Count} with the number of characters/bytes read/written on the stream associated with stream-term or alias \texttt{SorA}.

Errors

\begin{tabular}{|l|l|}
  \hline
  \texttt{SorA} is a variable & \texttt{instantiation\_error} \\
  \texttt{Count} is neither a variable nor an integer & \texttt{type\_error(integer, Count)} \\
  \texttt{SorA} is neither a variable nor a stream-term or alias & \texttt{domain\_error(stream\_or\_alias, SorA)} \\
  \texttt{SorA} is not associated with an open stream & \texttt{existence\_error(stream, SorA)} \\
  \hline
\end{tabular}

Portability

GNU Prolog predicate.
8.10.16  line_count/2

Templates

\[
\text{line_count(+stream\_or\_alias, \ ?integer)}
\]

Description

\[
\text{line_count(SorA, Count)} \text{ unifies Count with the number of lines read/written on the stream associated with the stream-term or alias SorA. This predicate can only be used on text streams.}
\]

Errors

<table>
<thead>
<tr>
<th>SorA is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count is neither a variable nor an integer</td>
<td>type_error(integer, Count)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(access, binary_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.17  line_position/2

Templates

\[
\text{line_position(+stream\_or\_alias, \ ?integer)}
\]

Description

\[
\text{line_position(SorA, Count)} \text{ unifies Count with the number of characters read/written on the current line of the stream associated with the stream-term or alias SorA. This predicate can only be used on text streams.}
\]

Errors

<table>
<thead>
<tr>
<th>SorA is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count is neither a variable nor an integer</td>
<td>type_error(integer, Count)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(access, binary_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.10.18 stream_line_column/3

Templates

    stream_line_column(+stream_or_alias, ?integer, ?integer)

Description

stream_line_column(SorA, Line, Column) unifies Line (resp. Column) with the current line number (resp. column number) of the stream associated with the stream-term or alias SorA. This predicate can only be used on text streams. Note that Line corresponds to the value returned by line_count/2 + 1 (section 8.10.16 page 88) and Column to the value returned by line_position/2 + 1 (section 8.10.17 page 88).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Line is neither a variable nor an integer</td>
<td>type_error(integer, Line)</td>
</tr>
<tr>
<td>Column is neither a variable nor an integer</td>
<td>type_error(integer, Column)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(access, binary_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.19 set_stream_line_column/3

Templates

    set_stream_line_column(+stream_or_alias, +integer, +integer)

Description

set_stream_line_column(SorA, Line, Column) sets the stream position of the stream associated with the stream-term or alias SorA according to the line number Line and the column number Column. This predicate can only be used on text streams. It first repositions the stream to the beginning of the file and then reads character by character until the required position is reached.

Errors
**SorA** is a variable | instantiation_error
---|---
**Line** is a variable | instantiation_error
**Column** is a variable | instantiation_error
**Line** is neither a variable nor an integer | type_error(integer, Line)
**Column** is neither a variable nor an integer | type_error(integer, Column)
**SorA** is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA)
**SorA** is not associated with an open stream | existence_error(stream, SorA)
**SorA** is associated with a binary stream | permission_error(reposition, binary_stream, SorA)
**SorA** has stream property reposition(false) | permission_error(reposition, stream, SorA)

**Portability**

GNU Prolog predicate.

### 8.10.20 add_stream_alias/2

**Templates**

```
add_stream_alias(+stream_or_alias, +atom)
```

**Description**

`add_stream_alias(SorA, Alias)` adds `Alias` as a new alias to the stream associated with the stream-term or alias `SorA`.

**Errors**

| **SorA** is a variable | instantiation_error |
| **Alias** is a variable | instantiation_error |
| **Alias** is neither a variable nor an atom | type_error(atom, Alias) |
| **SorA** is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA) |
| **SorA** is not associated with an open stream | existence_error(stream, SorA) |
| **Alias** is already associated with an open stream | permission_error(add_alias, source_sink, alias(Alias)) |

**Portability**

GNU Prolog predicate.

### 8.10.21 current_alias/2

**Templates**

```
current_alias(?stream, ?atom)
```

**Description**

`current_alias(Stream, Alias)` succeeds if `current_stream(Stream)` succeeds (section 8.10.9 page 83)
and if Alias unifies with one of the aliases of the stream. It can be defined using stream_property/2 (section 8.10.10, page 84). This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Prolog Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream is neither a variable nor a stream-term</td>
<td>domain_error(stream, Stream)</td>
</tr>
<tr>
<td>Alias is neither a variable nor an atom</td>
<td>type_error(atom, Alias)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.22 add_stream_mirror/2

Templates

```
add_stream_mirror(+stream_or_alias, +stream_or_alias)
```

Description

add_stream_mirror(SorA, Mirror) adds the stream associated with the stream-term or alias Mirror as a new mirror to the stream associated with the stream-term or alias SorA. After this, all characters (or bytes) read from (or written to) SorA are also written to Mirror. This mirroring occurs until Mirror is explicitly removed using remove_stream_mirror/2 (section 8.10.23, page 91) or implicitly when Mirror is closed. Several mirror streams can be associated with a same stream. If Mirror represents the same stream as SorA or if Mirror is already a mirror for SorA, no mirror is added.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Prolog Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>Mirror is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Mirror is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, Mirror)</td>
</tr>
<tr>
<td>Mirror is not associated with an open stream</td>
<td>existence_error(stream, Mirror)</td>
</tr>
<tr>
<td>Mirror is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>Mirror is an input stream</td>
<td>permission_error(output, stream, Mirror)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.23 remove_stream_mirror/2

Templates

```
remove_stream_mirror(+stream_or_alias, +stream_or_alias)
```

Description

remove_stream_mirror(SorA, Mirror) removes the stream associated with the stream-term or alias Mirror from the list of mirrors of the stream associated with the stream-term or alias SorA. This predicate fails if Mirror is not a mirror stream for SorA.
Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Mirror is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>Mirror is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, Mirror)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>Mirror is not associated with an open stream</td>
<td>existence_error(stream, Mirror)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.24 current_mirror/2

Templates

current_mirror(?stream, ?stream)

Description

current_mirror(Stream, M) succeeds if current_stream(Stream) succeeds (section 8.10.9 page 83) and if M unifies with one of the mirrors of the stream. It can be defined using stream_property/2 (section 8.10.10 page 84). This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream is neither a variable nor a stream-term</td>
<td>domain_error(stream, Stream)</td>
</tr>
<tr>
<td>M is neither a variable nor a stream-term</td>
<td>domain_error(stream, M)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.10.25 set_stream_type/2

Templates

set_stream_type(+stream_or_alias, +atom)

Description

set_stream_type(SorA, Type) updates the type associated with stream-term or alias SorA. The value of Type is an atom in text or binary as for open/4 (section 8.10.6 page 81). The type of a stream can only be changed before any input/output operation is executed.

Errors
8.10 Streams

SorA is a variable | instantiation_error
Type is a variable | instantiation_error
Type is neither a variable nor a valid type | domain_error(stream_type, Type)
SorA is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA)
SorA is not associated with an open stream | existence_error(stream, SorA)
An I/O operation has already been executed on SorA | permission_error(modify, stream, SorA)

Portability
GNU Prolog predicate.

8.10.26 set_stream_eof_action/2

Templates

set_stream_eof_action(+stream_or_alias, +atom)

Description

set_stream_eof_action(SorA, Action) updates the eof_action option associated with the stream-term or alias SorA. The value of Action is one of the atoms error, eof_code, reset as for open/4 (section 8.10.6 page 81).

Errors

SorA is a variable | instantiation_error
Action is a variable | instantiation_error
Action is neither a variable nor a valid eof action | domain_error(eof_action, Action)
SorA is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA)
SorA is not associated with an open stream | existence_error(stream, SorA)
SorA is an output stream | permission_error(modify, stream, SorA)

Portability
GNU Prolog predicate.

8.10.27 set_stream_buffering/2

Templates

set_stream_buffering(+stream_or_alias, +atom)

Description

set_stream_buffering(SorA, Buffering) updates the buffering mode associated with the stream-term or alias SorA. The value of Buffering is one of the atoms none, line or block as for open/4 (section 8.10.6 page 81). This predicate may only be used after opening a stream and before any other operations have been performed on it.

Errors
Portability

GNU Prolog predicate.

8.11 Constant term streams

8.11.1 Introduction

Constant term streams allow the user to consider a constant term (atom, character list or character code list) as a source/sink by associating to them a stream. Reading from a constant term stream will deliver the characters of the constant term as if they had been read from a standard file. Characters written on a constant term stream are stored to form the final constant term when the stream is closed. The built-in predicates described in this section allow the user to open and close a constant term stream for input or output. However, very often, a constant term stream is created to be only read or written once and then closed. To avoid the creation and the destruction of such a stream, GNU Prolog offers several built-in predicates to perform single input/output from/to constant terms (section 8.15, page 117).

8.11.2 open_input_atom_stream/2, open_input_chars_stream/2, open_input_codes_stream/2

Templates

open_input_atom_stream(+atom, -stream)
open_input_chars_stream(+character_list, -stream)
open_input_codes_stream(+character_code_list, -stream)

Description

open_input_atom_stream(Atom, Stream) unifies Stream with the stream-term which is associated with a new input text-stream whose data are the characters of Atom.

open_input_chars_stream(Chars, Stream) is similar to open_input_atom_stream/2 except that data are the content of the character list Chars.

open_input_codes_stream(Codes, Stream) is similar to open_input_atom_stream/2 except that data are the content of the character code list Codes.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Buffering is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Buffering is neither a variable nor a valid buffering mode</td>
<td>domain_error(buffering_mode, Buffering)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
</tbody>
</table>
Stream is not a variable  uninstantiation_error(Stream)
Atom is a variable  instantiation_error
Chars is a partial list or a list with an element E which is a variable  instantiation_error
Codes is a partial list or a list with an element E which is a variable  instantiation_error
Atom is neither a variable nor a an atom  type_error(atom, Atom)
Chars is neither a partial list nor a list  type_error(list, Chars)
Codes is neither a partial list nor a list  type_error(list, Codes)
an element E of the Chars list is neither a variable nor a character  type_error(character, E)
an element E of the Codes list is neither a variable nor an integer  type_error(integer, E)
an element E of the Codes list is an integer but not a character code  representation_error(character_code)

Portability

GNU Prolog predicates.

8.11.3  close_input_atom_stream/1, close_input_chars_stream/1,
       close_input_codes_stream/1

Templates

    close_input_atom_stream(+stream_or_alias)
    close_input_chars_stream(+stream_or_alias)
    close_input_codes_stream(+stream_or_alias)

Description

close_input_atom_stream(SorA) closes the constant term stream associated with the stream-term or alias SorA. SorA must a stream open with open_input_atom_stream/2 (section 8.11.1 page 94).

close_input_chars_stream(SorA) acts similarly for a character list stream.

close_input_codes_stream(SorA) acts similarly for a character code list stream.

Errors

<table>
<thead>
<tr>
<th>SorA is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(close, stream, SorA)</td>
</tr>
<tr>
<td>SorA is a stream-term or alias but does not refer to a constant term stream.</td>
<td>domain_error(term_stream_or_alias, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.
8.11.4 open_output_atom_stream/1, open_output_chars_stream/1, open_output_codes_stream/1

Templates

open_output_atom_stream(-stream)
open_output_chars_stream(-stream)
open_output_codes_stream(-stream)

Description

open_output_atom_stream(Stream) unifies Stream with the stream-term which is associated with a new output text-stream. All characters written to this stream are collected and will be returned as an atom when the stream is closed by close_output_atom_stream/2 (section 8.11.5, page 96).

open_output_chars_stream(Stream) is similar to open_output_atom_stream/1 except that the result will be a character list.

open_output_codes_stream(Stream) is similar to open_output_atom_stream/1 except that the result will be a character code list.

Errors

| Stream is not a variable | uninstantiation_error(Stream) |

Portability

GNU Prolog predicates.

8.11.5 close_output_atom_stream/2, close_output_chars_stream/2, close_output_codes_stream/2

Templates

close_output_atom_stream(+stream_or_alias, ?atom)
close_output_chars_stream(+stream_or_alias, ?character_list)
close_output_codes_stream(+stream_or_alias, ?character_code_list)

Description

close_output_atom_stream(SorA, Atom) closes the constant term stream associated with the stream-term or alias SorA. SorA must be associated with a stream open with open_output_atom_stream/1 (section 8.11.4, page 96). Atom is unified with an atom formed with all characters written on the stream.

close_output_chars_stream(SorA, Chars) acts similarly for a character list stream.

close_output_codes_stream(SorA, Codes) acts similarly for a character code list stream.

Errors
8.12 Character input/output

These built-in predicates enable a single character or character code to be input from and output to a text stream. The atom end_of_file is returned as character to indicate the end-of-file. -1 is returned as character code to indicate the end-of-file.

8.12.1 get_char/2, get_char/1, get_code/1, get_code/2

Templates

\[
\begin{align*}
\text{get_char(+stream_or_alias, ?in_character)} \\
\text{get_char(?in_character)} \\
\text{get_code(+stream_or_alias, ?in_character_code)} \\
\text{get_code(?in_character_code)}
\end{align*}
\]

Description

get_char(SorA, Char) succeeds if Char unifies with the next character read from the stream associated with the stream-term or alias SorA.

get_code/2 is similar to get_char/2 but deals with character codes.

get_char/1 and get_code/1 apply to the current input stream.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>Chars is neither a partial list nor a list</td>
<td>type_error(list, Chars)</td>
</tr>
<tr>
<td>Codes is neither a partial list nor a list</td>
<td>type_error(list, Codes)</td>
</tr>
<tr>
<td>an element E of the Chars list is neither a variable nor a character</td>
<td>type_error(character, E)</td>
</tr>
<tr>
<td>an element E of the Codes list is neither a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
<tr>
<td>an element E of the Codes list is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an input stream</td>
<td>permission_error(close, stream, SorA)</td>
</tr>
<tr>
<td>SorA is a stream-term or alias but does not refer to a constant term stream</td>
<td>domain_error(term_stream_or_alias, SorA)</td>
</tr>
</tbody>
</table>
SorA is a variable 
\hspace*{1cm} \text{instantiation\_error}

Char is neither a variable nor an in-character 
\hspace*{1cm} \text{type\_error(in\_character, Char)}

Code is neither a variable nor an integer 
\hspace*{1cm} \text{type\_error(integer, Code)}

SorA is neither a variable nor a stream-term or alias 
\hspace*{1cm} \text{domain\_error(stream\_or\_alias, SorA)}

SorA is not associated with an open stream 
\hspace*{1cm} \text{existence\_error(stream, SorA)}

SorA is an output stream 
\hspace*{1cm} \text{permission\_error(input, stream, SorA)}

SorA is associated with a binary stream 
\hspace*{1cm} \text{permission\_error(input, binary\_stream, SorA)}

SorA has stream properties 
\hspace*{1cm} end\_of\_stream(past) andeof\_action(error) 
\hspace*{1cm} \text{permission\_error(input, past\_end\_of\_stream, SorA)}

The entity input from the stream is not a character 
\hspace*{1cm} \text{representation\_error(character)}

Code is an integer but not an in-character code 
\hspace*{1cm} \text{representation\_error(in\_character\_code)}

Portability

ISO predicates.

\textbf{8.12.2 get\_key/2, get\_key/1 get\_key\_no\_echo/2, get\_key\_no\_echo/1}

Templates

\texttt{get\_key(+stream\_or\_alias, ?integer)}
\texttt{get\_key(?integer)}
\texttt{get\_key\_no\_echo(+stream\_or\_alias, ?integer)}
\texttt{get\_key\_no\_echo(?integer)}

Description

\texttt{get\_key(SorA, Code)} succeeds if \texttt{Code} unifies with the character code of the next key read from the stream associated with the stream-term or alias \texttt{SorA}. It is intended to read a single key from the keyboard (thus \texttt{SorA} should refer to current input stream). No buffering is performed (a character is read as soon as available) and function keys can also be read (in that case, \texttt{Code} is an integer $> 255$). The read character is echoed if it is printable.

This facility is only possible if the \texttt{linedit} facility has been installed (section 4.2.6 page 18) otherwise \texttt{get\_key/2} behaves similarly to \texttt{get\_code/2} (section 8.12.1 page 97) (the code of the first character is returned) but also pumps remaining characters until a character $<$ space (0x20) is read (in particular RETURN). The same behavior occurs if \texttt{SorA} does not refer to the current input stream or if this stream is not attached to a terminal.

\texttt{get\_key\_no\_echo/2} behaves similarly to \texttt{get\_key/2} except that the read character is not echoed.

\texttt{get\_key/1} and \texttt{get\_key\_no\_echo/1} apply to the current input stream.

Errors
8.12 Character input/output

Portability

GNU Prolog predicates.

8.12.3 peek_char/2, peek_char/1, peek_code/1, peek_code/2

Templates

peek_char(+stream_or_alias, ?in_character)
peek_char(?in_character)
peek_code(+stream_or_alias, ?in_character_code)
peek_code(?in_character_code)

Description

peek_char(SorA, Char) succeeds if Char unifies with the next character that will be read from the stream associated with the stream-term or alias SorA. The character is not read.

peek_code/2 is similar to peek_char/2 but deals with character codes.

peek_char/1 and peek_code/1 apply to the current input stream.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Code is neither a variable nor an integer</td>
<td>type_error(integer, Code)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(input, binary_stream, SorA)</td>
</tr>
<tr>
<td>SorA has stream properties end_of_stream(past) and eof_action(error)</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>The entity input from the stream is not a character</td>
<td>representation_error(character)</td>
</tr>
<tr>
<td>Code is an integer but not an in-character code</td>
<td>representation_error(in_character_code)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.
8.12.4  
unget_char/2, unget_char/1, unget_code/2, unget_code/1

Templates

unget_char(+stream_or_alias, +character)
unget_char(+character)
unget_code(+stream_or_alias, +character_code)
unget_code(+character_code)

Description

unget_char(SorA, Char) pushes back Char onto the stream associated with the stream-term or alias SorA. Char will be the next character read by get_char/2. The maximum number of characters that can be cumulatively pushed back is given by the max_unget Prolog flag (section 8.22.1 page 148).

unget_code/2 is similar to unget_char/2 but deals with character codes.

unget_char/1 and unget_code/1 apply to the current input stream.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Char is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Code is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Char is neither a variable nor a character</td>
<td>type_error(character, Char)</td>
</tr>
<tr>
<td>Code is neither a variable nor an integer</td>
<td>type_error(integer, Code)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(input, binary_stream, SorA)</td>
</tr>
<tr>
<td>Code is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.12.5  
put_char/2, put_char/1, put_code/1, put_code/2, nl/1, nl/0

Templates

put_char(+stream_or_alias, +character)
put_char(+character)
put_code(+stream_or_alias, +character_code)
put_code(+character_code)
nl(+stream_or_alias)
nl

Description

put_char(SorA, Char) writes Char onto the stream associated with the stream-term or alias SorA.

put_code/2 is similar to put_char/2 but deals with character codes.
8.13 Byte input/output

nl(SorA) writes a new-line character onto the stream associated with the stream-term or alias SorA. This is equivalent to put_char(SorA, ‘\n’).

put_char/1, put_code/1 and nl/0 apply to the current output stream.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Char is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Code is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Char is neither a variable nor a character</td>
<td>type_error(character, Char)</td>
</tr>
<tr>
<td>Code is neither a variable nor an integer</td>
<td>type_error(integer, Code)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an input stream</td>
<td>permission_error(output, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(output, binary_stream, SorA)</td>
</tr>
<tr>
<td>Code is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.

8.13 Byte input/output

These built-in predicates enable a single byte to be input from and output to a binary stream. -1 is returned to indicate the end-of-file.

8.13.1 get_byte/2, get_byte/1

Templates

```
get_byte(+stream_or_alias, ?in_byte)
get_byte(?in_byte)
```

Description

get_byte(SorA, Byte) succeeds if Byte unifies with the next byte read from the stream associated with the stream-term or alias SorA.

get_byte/1 applies to the current input stream.

Errors
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<table>
<thead>
<tr>
<th>Predicates</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Byte is neither a variable nor an in-byte</td>
<td>type_error(in_byte, Byte)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a text stream</td>
<td>permission_error(input, text_stream, SorA)</td>
</tr>
<tr>
<td>SorA has stream properties</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
<tr>
<td>end_of_stream(past) and eof_action(error)</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.

8.13.2  peek_byte/2, peek_byte/1

Templates

```
peek_byte(+stream_or_alias, ?in_byte)
peek_byte(?in_byte)
```

Description

`peek_byte(SorA, Byte)` succeeds if `Byte` unifies with the next byte that will be read from the stream associated with the stream-term or alias `SorA`. The byte is not read.

`peek_byte/1` applies to the current input stream.

Errors

<table>
<thead>
<tr>
<th>Predicates</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Byte is neither a variable nor an in-byte</td>
<td>type_error(in_byte, Byte)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a text stream</td>
<td>permission_error(input, text_stream, SorA)</td>
</tr>
<tr>
<td>SorA has stream properties</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
<tr>
<td>end_of_stream(past) and eof_action(error)</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates.

8.13.3  unget_byte/2, unget_byte/1

Templates

```
unget_byte(+stream_or_alias, +byte)
unget_byte(+byte)
```
8.13 Byte input/output

Description

unget_byte(SorA, Byte) pushes back Byte onto the stream associated with the stream-term or alias SorA. Byte will be the next byte read by get_byte/2. The maximum number of bytes that can be successively pushed back is given by the max_unget Prolog flag (section 8.22.1, page 148).

unget_byte/1 applies to the current input stream.

Errors

<table>
<thead>
<tr>
<th>SorA is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Byte is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Byte is neither a variable nor a byte</td>
<td>type_error(byte, Byte)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(output, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a text stream</td>
<td>permission_error(output, text_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.13.4 put_byte/2, put_byte/1

Templates

put_byte(+stream_or_alias, +byte)
put_byte(+byte)

Description

put_byte(SorA, Byte) writes Byte onto the stream associated with the stream-term or alias SorA.

put_byte/1 applies to the current output stream.

Errors

<table>
<thead>
<tr>
<th>SorA is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Byte is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Byte is neither a variable nor a byte</td>
<td>type_error(byte, Byte)</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(output, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a text stream</td>
<td>permission_error(output, text_stream, SorA)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.
8.14 Term input/output

These built-in predicates enable a Prolog term to be input from or output to a text stream. The atom `end_of_file` is returned as term to indicate the end-of-file. The syntax of such terms can also be altered by changing the operators (section 8.14.10, page 113), and making some characters equivalent to others (section 8.14.12, page 116) if the `char_conversion` Prolog flag is on (section 8.22.1, page 148). Double quoted tokens will be returned as an atom or a character list or a character code list depending on the value of the `double_quotes` Prolog flag (section 8.22.1, page 148). Similarly, back quoted tokens are returned depending on the value of the `back_quotes` Prolog flag.

8.14.1 read_term/3, read_term/2, read/2, read/1

Templates

```
read_term(+stream_or_alias, ?term, +read_option_list)
read_term(?term, +read_option_list)
read(+stream_or_alias, ?term)
read(?term)
```

Description

`read_term(SorA, Term, Options)` is true if `Term` unifies with the next term read from the stream associated with the stream-term or alias `SorA` according to the options given by `Options`.

**Read options**: `Options` is a list of read options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- `variables(VL)`: `VL` is unified with the list of all variables of the input term, in left-to-right traversal order. Anonymous variables are included in the list `VL`.

- `variable_names(VNL)`: `VNL` is unified with the list of pairs `Name = Var` where `Var` is a named variable of the term and `Name` is the atom associated with the name of `Var`. Anonymous variables are not included in the list `VNL`. The pairs appear in left-to-right traversal order of their `Var` in the term.

- `singletons(SL)`: `SL` is unified with the list of pairs `Name = Var` where `Var` is a named variable which occurs only once in the term and `Name` is the atom associated to the name of `Var`. Anonymous variables are not included in the list `SL`.

- `syntax_error(error/warning/fail)`: specifies the effect of a syntax error:
  - `error`: a `syntax_error` is raised.
  - `warning`: a warning message is displayed and the predicate fails.
  - `fail`: the predicate quietly fails.
  The default value is the value of the `syntax_error` Prolog flag (section 8.22.1, page 148).

- `end_of_term(dot/eof)`: specifies the end-of-term delimiter: `dot` is the classical full-stop delimiter (a dot followed with a layout character), `eof` is the end-of-file delimiter. This option is useful for predicates like `read_term_from_atom/3` (section 8.15.1, page 117) to avoid to add a terminal dot at the end of the atom. The default value is `dot`.

`read(SorA, Term)` is equivalent to `read_term(SorA, Term, [])`.

`read_term/2` and `read/1` apply to the current input stream.

Errors
### Term input/output

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Options is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>Options is neither a partial list nor a list</td>
<td>type_error(list, Options)</td>
</tr>
<tr>
<td>an element E of the Options list is neither a variable nor a valid read option</td>
<td>domain_error(read_option, E)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an output stream</td>
<td>permission_error(input, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(input, binary_stream, SorA)</td>
</tr>
<tr>
<td>SorA has stream properties end_of_stream(past) and eof_action(error)</td>
<td>permission_error(input, past_end_of_stream, SorA)</td>
</tr>
<tr>
<td>a syntax error occurs and the value of the syntax_error Prolog flag is error</td>
<td>syntax_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

#### Portability

ISO predicates. The ISO reference raises a representation_error(Flag) where Flag is max arity, max integer, or min integer when the read term breaches an implementation defined limit specified by Flag. GNU Prolog detects neither min integer nor max integer violation and treats a max arity violation as a syntax error. The read options syntax_error and end_of_term are GNU Prolog extensions.

### 8.14.2 read_atom/2, read_atom/1, read_integer/2, read_integer/1, read_number/2, read_number/1

#### Templates

```prolog
read_atom(+stream_or_alias, ?atom)
read_atom(?atom)
read_integer(+stream_or_alias, ?integer)
read_integer(?integer)
read_number(+stream_or_alias, ?number)
read_number(?number)
```

#### Description

`read_atom(SorA, Atom)` succeeds if `Atom` unifies with the next atom read from the stream associated with the stream-term or alias `SorA`.

`read_integer(SorA, Integer)` succeeds if `Integer` unifies with the next integer read from the stream associated with the stream-term or alias `SorA`.

`read_number(SorA, Number)` succeeds if `Number` unifies with the next number (integer or floating point number) read from the stream associated with the stream-term or alias `SorA`.

`read_atom/1`, `read_integer/1` and `read_number/1` apply to the current input stream.

#### Errors
Portability

GNU Prolog predicates.

8.14.3  read_token/2, read_token/1

Templates

\[
\begin{align*}
\text{read_token}(+\text{stream_or_alias}, \text{?nonvar}) \\
\text{read_token}(\text{?nonvar})
\end{align*}
\]

Description

\text{read_token}(\text{SorA}, \text{Token}) \text{ succeeds if Token unifies with the encoding of the next Prolog token read from the stream associated with stream-term or alias SorA.}

Token encoding:

- \text{var}(A): a variable is read whose name is the atom A.
- an atom A: an atom A is read.
- integer N: an integer N is read.
- floating point number N: a floating point number N is read.
- \text{string}(A): a string (double quoted item) is read whose characters forms the atom A.
- \text{punct}(P): a punctuation character P is read (P is a one-character atom in ()[]{}\, the atom full_stop or the atom end_of_file).
- \text{back_quotes}(A): a back quoted item is read whose characters forms the atom A.
- \text{extended}(A): an extended character A (an atom) is read.

As for \text{read_term}/3, the behavior of \text{read_token}/2 can be affected by some Prolog flags (section 8.14 page 104).

\text{read_token}/1 applies to the current input stream.

Errors
### 8.14 Term input/output

#### Syntax Error Info/4

**Templates**

```prolog
syntax_error_info(?atom, ?integer, ?integer, ?atom)
```

**Description**

The `syntax_error_info(FileName, Line, Column, Error)` predicate returns the information associated with the last syntax error. *FileName* is the name of the file, *Line* is the line number of the error, *Column* is the column number of the error, and *Error* is an atom explaining the error.

**Errors**

- **FileName** is neither a variable nor an atom: `type_error(atom, FileName)`
- **Line** is neither a variable nor an integer: `type_error(integer, Line)`
- **Column** is neither a variable nor an integer: `type_error(integer, Column)`
- **Error** is neither a variable nor an atom: `type_error(atom, Error)`

**Portability**

GNU Prolog predicate.

#### Last Read Start Line Column/2

**Templates**

```prolog
last_read_start_line_column(?integer, ?integer)
```

**Description**

The `last_read_start_line_column(Line, Column)` predicate unifies *Line* and *Column* with the line number and the column number associated with the start of the last read predicate. This predicate can be used after calling one of the following predicates: `read_term/3, read_term/2, read/2, read/1` (section 8.14.1 page 104), `read_atom/2, read_atom/1, read_integer/2, read_integer/1, read_number/2, read_number/1` (section 8.14.2 page 105) or `read_token/2, read_token/1` (section 8.14.3 page 106).
Errors

<table>
<thead>
<tr>
<th>Line is neither a variable nor an integer</th>
<th>type_error(integer, Line)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column is neither a variable nor an integer</td>
<td>type_error(integer, Column)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.14.6 write_term/3, write_term/2, write/2, write/1, writeq/2, writeq/1, write_canonical/2, write_canonical/1, display/2, display/1, print/2, print/1

Templates

write_term(+stream_or_alias, ?term, +write_option_list)
write_term(?term, +write_option_list)
write(+stream_or_alias, ?term)
write(?term)
writeq(+stream_or_alias, ?term)
writeq(?term)
write_canonical(+stream_or_alias, ?term)
write_canonical(?term)
display(+stream_or_alias, ?term)
display(?term)
print(+stream_or_alias, ?term)
print(?term)

Description

write_term(SorA, Term, Options) writes Term to the stream associated with the stream-term or alias SorA according to the options given by Options.

Write options: Options is a list of write options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- quoted(true/false): if true each atom and functor is quoted if this would be necessary for the term to be input by read_term/3. If false no extra quotes are written. The default value is false.
- ignore_ops(true/false): if true each compound term is output in functional notation (neither operator notation nor list notation is used). If false operator and list notations are used. The default value is false.
- numbervars(true/false): if true a term of the form '$VAR'(N), where N is an integer, is output as a variable name (see below). If false such a term is output normally (according to the other options). The default value is false.
- namevars(true/false): if true a term of the form '$VARNAME'(Name), where Name is an atom respecting the syntax of variable names, is output as a variable name (see below). If false such a term is output normally (according to the other options). The default value is false.
- variable_names(VNL): VNL is a list of pairs Name = Var where Var is a variable and Name is the atom associated with the name of Var. Each variable Var is written as the atom Name (with quoted(false)) iff a term Name = Var is an element of the list VNL. If several pairs exist for the same variable name the first one applies.
• **space**\_args(true/false): if true an extra space character is emitted after each comma separating the arguments of a compound term in functional notation or of a list. If false no extra space is emitted. The default value is false.

• **portrayed**\_args(true/false): if true and if there exists a predicate portray/1, write\_term/3 acts as follows: if Term is a variable it is simply written. If Term is non-variable then it is passed to portray/1. If this succeeds then it is assumed that Term has been output. Otherwise write\_term/3 outputs the principal functor of Term (Term itself if it is atomic) according to other options and recursively calls portray/1 on the components of Term (if it is a compound term). With ignore\_ops(false) a list is first passed to portray/1 and only if this call fails each element of the list is passed to portray/1 (thus every sub-list is not passed). The default value is false.

• **max**\_depth(N): controls the depth of output for compound terms. N is an integer specifying the depth. The output of a term whose depth is greater than N gives rise to the output of ... (3 dots). By default there is no depth limit.

• **priority**\_args(N): specifies the starting priority to output the term. This option controls if Term should be enclosed in brackets. N is a positive integer \( \leq 1200 \). By default \( N = 1200 \).

**Variable numbering:** when the numbervars(true) option is passed to write\_term/3 any term of the form 'VAR'(N) where N is an integer is output as a variable name consisting of a capital letter possibly followed by an integer. The capital letter is the \((I+1)th\) letter of the alphabet and the integer is \( J \), where \( I = N \mod 26 \) and \( J = N \div 26 \). The integer J is omitted if it is zero. For example:

- '$VAR'(0) is written as A
- '$VAR'(1) is written as B
- ...
- '$VAR'(25) is written as Z
- '$VAR'(26) is written as A1
- '$VAR'(27) is written as B1

**Variable naming:** when the namevars(true) option is passed to write\_term/3 any term of the form 'VARNAME'(Name) where Name is an atom is output as a variable name consisting of the characters Name. For example: 'VARNAME'(A) is written as A (even in the presence of the quoted(true) option).

write(SorA, Term) is equivalent to write\_term(SorA, Term, [numbervars(true), namevars(true)])

writeq(SorA, Term) is equivalent to write\_term(SorA, Term, [quoted(true), numbervars(true), namevars(true)])

write\_canonical(SorA, Term) is equivalent to write\_term(SorA, Term, [quoted(true), ignore\_ops(true), numbervars(false), namevars(false)])

display(SorA, Term) is equivalent to write\_term(SorA, Term, [ignore\_ops(true), numbervars(false), namevars(false)])

print(SorA, Term) is equivalent to write\_term(SorA, Term, [numbervars(false), portrayed(true)])

write\_term/2, write/1, writeq/1, write\_canonical/1, display/1 and print/1 apply to the current output stream.

**Errors**
<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{SorA}$ is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>$\text{Options}$ is a partial list or a list with an element $E$ which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>$\text{Options}$ is neither a partial list nor a list</td>
<td>type_error(list, Options)</td>
</tr>
<tr>
<td>$\text{SorA}$ is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>an element $E$ of the $\text{Options}$ list is neither a variable nor a valid write-option</td>
<td>domain_error(write_option, E)</td>
</tr>
<tr>
<td>$\text{SorA}$ is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>$\text{SorA}$ is an input stream</td>
<td>permission_error(output, stream, SorA)</td>
</tr>
<tr>
<td>$\text{SorA}$ is associated with a binary stream</td>
<td>permission_error(output, binary_stream, SorA)</td>
</tr>
</tbody>
</table>

**Portability**

ISO predicates except `display/1-2` and `print/1-2` that are GNU Prolog predicates. `namevars`, `variable\_names`, `space\_args`, `portrayed`, `max\_depth` and `priority` options are GNU Prolog extensions.

### 8.14.7 *format/3, format/2*

**Templates**

```
format(+stream\_or\_alias, +character\_code\_list\_or\_atom, +list)
format(+character\_code\_list\_or\_atom, +list)
```

**Description**

`format(SorA, Format, Arguments)` writes the `Format` string replacing each format control sequence $F$ by the corresponding element of `Arguments` (formatted according to $F$) to the stream associated with the stream-term or alias `SorA`.

**Format control sequences**: the general format of a control sequence is '\"NC\"'. The character $C$ determines the type of the control sequence. $N$ is an optional numeric argument. An alternative form of $N$ is '\*\*'. '\*\*' implies that the next argument $Arg$ in `Arguments` should be used as a numeric argument in the control sequence. The use of C `printf()` formatting sequence (beginning by the character `%`) is also allowed. The following control sequences are available:
<table>
<thead>
<tr>
<th>Format sequence</th>
<th>type of the argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>~Na</code></td>
<td>atom</td>
<td>print the atom without quoting. ( N ) is minimal number of characters to print using spaces on the right if needed (default: the length of the atom)</td>
</tr>
<tr>
<td><code>~Nc</code></td>
<td>character code</td>
<td>print the character associated with the code. ( N ) is the number of times to print the character (default: 1)</td>
</tr>
<tr>
<td><code>~Nf</code></td>
<td>float expression</td>
<td>pass the argument ( \text{Arg} ) and ( N ) to the C \texttt{printf()} function as: if ( N ) is not specified \texttt{printf(&quot;%f&quot;,\text{Arg})} else \texttt{printf(&quot;%.Nf&quot;,\text{Arg})}. Similarly for <code>~Ne</code> , <code>~NE</code> , <code>~Ng</code> and <code>~NG</code></td>
</tr>
<tr>
<td><code>~Nd</code></td>
<td>integer expression</td>
<td>print the argument. ( N ) is the number of digits after the decimal point. If ( N ) is 0 no decimal point is printed (default: 0)</td>
</tr>
<tr>
<td><code>~ND</code></td>
<td>integer expression</td>
<td>identical to <code>~Nd</code> except that the letters ( \text{a-z} ) denote digits ( &gt; 9 )</td>
</tr>
<tr>
<td><code>~Nr</code></td>
<td>integer expression</td>
<td>print the argument according to the radix ( N ). ( 2 \leq N \leq 36 ) (default: 8). The letters ( \text{a-z} ) denote digits ( &gt; 9 )</td>
</tr>
<tr>
<td><code>~NR</code></td>
<td>integer expression</td>
<td>identical to <code>~Nr</code> except that the letters ( \text{A-Z} ) denote digits ( &gt; 9 )</td>
</tr>
<tr>
<td><code>~Ns</code></td>
<td>character code list</td>
<td>print exactly ( N ) characters (default: the length of the list)</td>
</tr>
<tr>
<td><code>~NS</code></td>
<td>character list</td>
<td>print exactly ( N ) characters (default: the length of the list)</td>
</tr>
<tr>
<td><code>~i</code></td>
<td>term</td>
<td>ignore the current argument</td>
</tr>
<tr>
<td><code>~k</code></td>
<td>term</td>
<td>pass the argument to \texttt{write_canonical/1} (section 8.14.6, page 108)</td>
</tr>
<tr>
<td><code>~p</code></td>
<td>term</td>
<td>pass the argument to \texttt{print/1} (section 8.14.6, page 108)</td>
</tr>
<tr>
<td><code>~q</code></td>
<td>term</td>
<td>pass the argument to \texttt{writeq/1} (section 8.14.6, page 108)</td>
</tr>
<tr>
<td><code>~w</code></td>
<td>term</td>
<td>pass the argument to \texttt{write/1} (section 8.14.6, page 108)</td>
</tr>
<tr>
<td><code>~~</code></td>
<td>none</td>
<td>print the character <code>~</code></td>
</tr>
<tr>
<td><code>~Nn</code></td>
<td>none</td>
<td>print ( N ) new-line characters (default: 1)</td>
</tr>
<tr>
<td><code>~N</code></td>
<td>none</td>
<td>print a new-line character if not at the beginning of a line</td>
</tr>
<tr>
<td><code>~?</code></td>
<td>atom</td>
<td>use the argument as a nested format string</td>
</tr>
<tr>
<td><code>%F</code></td>
<td>atom, integer or float expression</td>
<td>interface to the C function \texttt{printf(3)} for outputting atoms (C string), integers and floating point numbers. * are also allowed.</td>
</tr>
</tbody>
</table>

\[\text{format/2 applies to the current output stream.}\]

**Errors**
SorA is a variable | instantiation_error
Format is a partial list or a list with an element E which is a variable | instantiation_error
Arguments is a partial list | instantiation_error
Format is neither a partial list nor a list or an atom | type_error(list, Format)
Arguments is neither a partial list nor a list | type_error(list, Arguments)
an element E of the Format list is neither a variable nor a character code | representation_error(character_code, E)
SorA is neither a variable nor a stream-term or alias | domain_error(stream_or_alias, SorA)
an element E of Format is not a valid format control sequence | domain_error(format_control_sequence, E)
the Arguments list does not contain sufficient elements | domain_error(non_empty_list, [])
an element E of the Arguments list is a variable while a non-variable term was expected | instantiation_error
an element E of the Arguments list is neither variable nor an atom while an atom was expected | type_error(atomic, E)
an element E of the Arguments cannot be evaluated as an arithmetic expression while an integer or a floating point number was expected | an arithmetic error (section 8.6.1 page 66)
an element E of the Arguments list is neither variable nor character code while a character code was expected | representation_error(character_code, E)
SorA is not associated with an open stream | existence_error(stream, SorA)
SorA is an input stream | permission_error(output, stream, SorA)
SorA is associated with a binary stream | permission_error(output, binary_stream, SorA)

Portability

GNU Prolog predicates.

8.14.8 portray_clause/2, portray_clause/1

Templates

portray_clause(+stream_or_alias, +clause)
portray_clause(+clause)

Description

portray_clause(SorA, Clause) pretty prints Clause to the stream associated with the stream-term or alias SorA. portray_clause/2 uses the variable binding predicates name_singleton_vars/1 (section 8.5.1 page 63) and numbervars/1 (section 8.5.3, page 64). This predicate is used by listing/1 (section 8.23.3, page 154).

portray_clause/1 applies to the current output stream.

Errors
### 8.14 Term input/output

<table>
<thead>
<tr>
<th>Clause is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clause is neither a variable nor a callable term</td>
<td>type_error(callable, Clause)</td>
</tr>
<tr>
<td>SorA is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>SorA is neither a variable nor a stream-term or alias</td>
<td>domain_error(stream_or_alias, SorA)</td>
</tr>
<tr>
<td>SorA is not associated with an open stream</td>
<td>existence_error(stream, SorA)</td>
</tr>
<tr>
<td>SorA is an input stream</td>
<td>permission_error(output, stream, SorA)</td>
</tr>
<tr>
<td>SorA is associated with a binary stream</td>
<td>permission_error(output, binary_stream, SorA)</td>
</tr>
</tbody>
</table>

#### Portability

GNU Prolog predicates.

### 8.14.9 get_print_stream/1

**Templates**

```
get_print_stream(?stream)
```

**Description**

get_print_stream(Stream) unifies Stream with the stream-term associated with the output stream used by print/2 (section 8.14.6, page 108). The purpose of this predicate is to allow a user-defined portray/1 predicate to identify the output stream in use.

**Errors**

| Stream is neither a variable nor a stream-term | domain_error(stream, Stream) |

#### Portability

GNU Prolog predicate.

### 8.14.10 op/3

**Templates**

```
op(+integer, +operator_specifier, +atom_or_atom_list)
```

**Description**

op(Priority, OpSpecifier, Operator) alters the operator table. Operator is declared as an operator with properties defined by specifier OpSpecifier and Priority. Priority must be an integer ≥ 0 and ≤ 1200. If Priority is 0 then the operator properties of Operator (if any) are canceled. Operator may also be a list of atoms in which case all of them are declared to be operators. In general, operators can be removed from the operator table and their priority or specifier can be changed. However, it is an error to attempt to change the ',' operator from its initial status. An atom can have multiple operator definitions (e.g. prefix and infix like +) however an atom cannot have both an infix and a postfix operator definitions.

**Operator specifiers**: the following specifiers are available:
### Specifier | Type | Associativity
---|---|---
fx | prefix | no
fy | prefix | yes
xf | postfix | no
yf | postfix | yes
xfx | infix | no
yfx | infix | left
xfy | infix | right

**Prolog predefined operators:**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Specifier</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>xfx</td>
<td>:- --&gt;</td>
</tr>
<tr>
<td>1200</td>
<td>fx</td>
<td>:-</td>
</tr>
<tr>
<td>1105</td>
<td>xfy</td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td>xfy</td>
<td>;</td>
</tr>
<tr>
<td>1050</td>
<td>xfy</td>
<td>-&gt; *-&gt;</td>
</tr>
<tr>
<td>1000</td>
<td>xfy</td>
<td>,</td>
</tr>
<tr>
<td>900</td>
<td>fy</td>
<td>*</td>
</tr>
<tr>
<td>700</td>
<td>xfx</td>
<td>= = .= == @= @&lt; @&lt;= @&gt; @&gt;= is =:= =&lt; &lt; =&lt; &gt; &gt;=</td>
</tr>
<tr>
<td>600</td>
<td>xfy</td>
<td>:</td>
</tr>
<tr>
<td>500</td>
<td>yfx</td>
<td>+ - / \ /</td>
</tr>
</tbody>
</table>
| 400      | yfx       | * / // rem mod div << >>
| 200      | xfx       | ** ~      |
| 200      | fy        | + - \ |

**FD predefined operators:**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Specifier</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>xfy</td>
<td>#&lt;&lt;&gt; #&lt;&lt;&gt;</td>
</tr>
<tr>
<td>740</td>
<td>xfy</td>
<td>#&lt;&lt;&gt; #&lt;&lt;&gt;</td>
</tr>
</tbody>
</table>
| 730      | xfy       | ## #\/ #\/
| 720      | yfx       | #\/ #\/ |
| 710      | fy        | #\ |
| 700      | xfx       | #* #\ #< #=< #> #=> #== #\# #\< #<= #> #>=# |
| 500      | yfx       | + - |
| 400      | yfx       | * / // rem |
| 200      | xfy       | ** |
| 200      | fy        | + - |

**Errors**
8.14 Term input/output

Priority is a variable
OpSpecifier is a variable
Operator is a partial list or a list with an element \( E \) which is a variable
Priority is neither a variable nor an integer
OpSpecifier is neither a variable nor an atom
Operator is neither a partial list nor a list nor an atom
an element \( E \) of the Operator list is neither a variable nor an atom
Priority is an integer not \( \geq 0 \) and \( \leq 1200 \)
OpSpecifier is not a valid operator specifier
Operator (or an element of the Operator list) is ",",
OpSpecifier is a specifier such that Operator would have a postfix and an infix definition.
Operator (or an element of the Operator list) is | and it would have a prefix or a postfix definition or its Priority would be \( \leq 1100 \).
Operator (or an element of the Operator list) is [[]] or {}.

Portability

ISO predicate.

The ISO reference implies that if a program calls current_op/3, then modifies an operator definition by calling op/3 and backtracks into the call to current_op/3, then the changes are guaranteed not to affect that current_op/3 goal. This is not guaranteed by GNU Prolog.

8.14.11 current_op/3

Templates

\[
current\_op(?integer, \_operator\_specifier, \_atom)
\]

Description

current_op(Priority, OpSpecifier, Operator) succeeds if Operator is an operator with properties defined by specifier OpSpecifier and Priority. This predicate is re-executable on backtracking.

Errors

Priority is neither a variable nor an operator priority
OpSpecifier is neither a variable nor an operator specifier
Operator is neither a variable nor an atom

Portability

ISO predicate.
8.14.12  char_conversion/2

Templates

\texttt{char\_conversion(+character, +character)}

Description

\texttt{char\_conversion(InChar, OutChar)} alters the character-conversion mapping. This mapping is used by the following read predicates: \texttt{read\_term/3} (section 8.14.1 page 104), \texttt{read\_atom/2}, \texttt{read\_integer/2}, \texttt{read\_number/2} (section 8.14.2 page 105) and \texttt{read\_token/2} (section 8.14.3 page 106) to replace any occurrence of a character \texttt{InChar} by \texttt{OutChar}. However the conversion mechanism should have been previously activated by switching on the \texttt{char\_conversion} Prolog flag (section 8.22.1 page 148). When \texttt{InChar} and \texttt{OutChar} are the same, the effect is to remove any conversion of a character \texttt{InChar}.

Note that the single character read predicates (e.g. \texttt{get\_char/2}) never do character conversion. If such behavior is required, it must be explicitly done using \texttt{current\_char\_conversion/2} (section 8.14.13 page 116).

Errors

| InChar is a variable | instantiation\_error |
| OutChar is a variable | instantiation\_error |
| InChar is neither a variable nor a character | type\_error(character, InChar) |
| OutChar is neither a variable nor a character | type\_error(character, OutChar) |

Portability

ISO predicate. The type\_error(character,...) is a GNU Prolog behavior, the ISO reference instead defines a representation\_error(character) in this case. This seems to be an error of the ISO reference since, for many other built-in predicates accepting a character (e.g. char\_code/2, put\_char/2), a type\_error is raised.

The ISO reference implies that if a program calls \texttt{current\_char\_conversion/2}, then modifies the character mapping by calling \texttt{char\_conversion/2}, and backtracks into the call to \texttt{current\_char\_conversion/2} then the changes are guaranteed not to affect that \texttt{current\_char\_conversion/2} goal. This is not guaranteed by GNU Prolog.

8.14.13  current\_char\_conversion/2

Templates

\texttt{current\_char\_conversion(?character, ?character)}

Description

\texttt{current\_char\_conversion(InChar, OutChar)} succeeds if the conversion of \texttt{InChar} is \texttt{OutChar} according to the character-conversion mapping. In that case, \texttt{InChar} and \texttt{OutChar} are different. This predicate is re-executable on backtracking.

Errors

| InChar is neither a variable nor a character | type\_error(character, InChar) |
| OutChar is neither a variable nor a character | type\_error(character, OutChar) |
8.15 Input/output from/to constant terms

These built-in predicates enable a Prolog term to be input from or output to a Prolog constant term (atom, character list or character code list). All these predicates can be defined using constant term streams (section 8.11, page 94). They are however simpler to use.

8.15.1 read_term_from_atom/3, read_from_atom/2, read_token_from_atom/2

Templates

read_term_from_atom(+atom ?term, +read_option_list)
read_from_atom(+atom, ?term)
read_token_from_atom(+atom, ?nonvar)

Description

Like read_term/3, read/2 (section 8.14.1, page 104) and read_token/2 (section 8.14.3, page 106) except that characters are not read from a text-stream but from Atom; the atom given as first argument.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atom is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>see associated predicate errors</td>
<td>see associated predicate errors</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.15.2 read_term_from_chars/3, read_from_chars/2, read_token_from_chars/2

Templates

read_term_from_chars(+character_list ?term, +read_option_list)
read_from_chars(+character_list, ?term)
read_token_from_chars(+character_list, ?nonvar)

Description

Like read_term/3, read/2 (section 8.14.1, page 104) and read_token/2 (section 8.14.3, page 106) except that characters are not read from a text-stream but from Chars; the character list given as first argument.

Errors
**Chars** is a partial list or a list with an element \( E \) which is a variable | instantiation_error
---|---
**Chars** is neither a partial list nor a list | type_error(list, Chars)

an element \( E \) of the **Chars** list is neither a variable nor a character | type_error(character, E)

see associated predicate errors | (section 8.14.1 page 104 and (section 8.14.3 page 106)

## Portability

GNU Prolog predicates.

### 8.15.3 read_term_from_codes/3, read_from_codes/2, read_token_from_codes/2

#### Templates

read_term_from_codes(+character_code_list ?term, +read_option_list)  
read_from_codes(+character_code_list, ?term)  
read_token_from_codes(+character_code_list, ?nonvar)

#### Description

Like **read_term/3, read/2** (section 8.14.1 page 104 and **read_token/2** (section 8.14.3 page 106) except that characters are not read from a text-stream but from **Codes**; the character code list given as first argument.

#### Errors

**Codes** is a partial list or a list with an element \( E \) which is a variable | instantiation_error
---|---
**Codes** is neither a partial list nor a list | type_error(list, Codes)

an element \( E \) of the **Codes** list is neither a variable nor an integer | type_error(integer, E)

an element \( E \) of the **Codes** list is an integer but not a character code | representation_error(character_code, E)

see associated predicate errors | (section 8.14.1 page 104 and (section 8.14.3 page 106)

## Portability

GNU Prolog predicates.

### 8.15.4 write_term_to_atom/3, write_to_atom/2, writeq_to_atom/2,  
write_canonical_to_atom/2, display_to_atom/2, print_to_atom/2,  
format_to_atom/3

#### Templates

write_term_to_atom(?atom, ?term, +write_option_list)  
write_to_atom(?atom, ?term)  
writeq_to_atom(?atom, ?term)  
write_canonical_to_atom(?atom, ?term)
display_to_atom(?atom, ?term)
print_to_atom(?atom, ?term)
format_to_atom(?atom, +character_code_list_or_atom, +list)

**Description**

Similar to write_term/3, write/2, writeq/2, write_canonical/2, display/2, print/2 (section 8.14.6 page 108) and format/3 (section 8.14.7 page 110) except that characters are not written onto a text-stream but are collected as an atom which is then unified with the first argument Atom.

**Errors**

<table>
<thead>
<tr>
<th>Atom is neither a variable nor an atom</th>
<th>type_error(atom, Atom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>see associated predicate errors</td>
<td>(section 8.14.6 page 108) and (section 8.14.7 page 110)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.

8.15.5 write_to_chars/3, write_to_chars/2, writeq_to_chars/2, write_canonical_to_chars/2, display_to_chars/2, print_to_chars/2, format_to_chars/3

**Templates**

write_term_to_chars(?character_list, ?term, +write_option_list)
write_to_chars(?character_list, ?term)
writeq_to_chars(?character_list, ?term)
write_canonical_to_chars(?character_list, ?term)
display_to_chars(?character_list, ?term)
print_to_chars(?character_list, ?term)
formt_to_chars(?character_list, +character_code_list_or_atom, +list)

**Description**

Similar to write_term/3, write/2, writeq/2, write_canonical/2, display/2, print/2 (section 8.14.6 page 108) and format/3 (section 8.14.7 page 110) except that characters are not written onto a text-stream but are collected as a character list which is then unified with the first argument Chars.

**Errors**

<table>
<thead>
<tr>
<th>Chars is neither a partial list nor a list</th>
<th>type_error(list, Chars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>An element E of the list Chars is neither a variable nor a one-char atom</td>
<td>type_error(character, E)</td>
</tr>
<tr>
<td>see associated predicate errors</td>
<td>(section 8.14.6 page 108) and (section 8.14.7 page 110)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.
8.15.6  write_term_to_codes/3, write_to_codes/2, writeq_to_codes/2, write_canonical_to_codes/2, display_to_codes/2, print_to_codes/2, format_to_codes/3

Templates

write_term_to_codes(?character_code_list, ?term, +write_option_list)
write_to_codes(?character_code_list, ?term)
writeq_to_codes(?character_code_list, ?term)
write_canonical_to_codes(?character_code_list, ?term)
display_to_codes(?character_code_list, ?term)
print_to_codes(?character_code_list, ?term)
format_to_codes(?character_code_list, +character_code_list_or_atom, +list)

Description

Similar to write_term/3, write/2, writeq/2, write_canonical/2, display/2, print/2 (section 8.14.6, page 108) and format/3 (section 8.14.7, page 110) except that characters are not written onto a text-stream but are collected as a character code list which is then unified with the first argument Codes.

Errors

| Codes is neither a partial list nor a list | type_error(list, Codes) |
| An element E of the list Codes is neither a variable nor an integer | type_error(integer, E) |
| An element E of the list Codes is an integer but not a character code | representation_error(character_code) |
| see associated predicate errors | (section 8.14.6, page 108) and (section 8.14.7, page 110) |

Portability

GNU Prolog predicates.

8.16  DEC-10 compatibility input/output

8.16.1  Introduction

The DEC-10 Prolog I/O predicates manipulate streams implicitly since they only refer to current input/output streams (section 8.10.1, page 78). The current input and output streams are initially set to user_input and user_output respectively. The predicate see/1 (resp. tell/1, append/1) can be used for setting the current input (resp. output) stream to newly opened streams for particular files. The predicate seen/0 (resp. told/0) close the current input (resp. output) stream, and resets it to the standard input (resp. output). The predicate seeing/1 (resp. telling/1) is used for retrieving the file name associated with the current input (resp. output) stream. The file name user stands for the standard input or output, depending on context (user_input and user_output can also be used). The DEC-10 Prolog I/O predicates are only provided for compatibility, they are now obsolete and their use is discouraged. The predicates for explicit stream manipulation should be used instead (section 8.10, page 78).
8.16 DEC-10 compatibility input/output

8.16.2 see/1, tell/1, append/1

Templates

```
see(+source_sink)
see(+stream)
tell(+source_sink)
tell(+stream)
append(+source_sink)
append(+stream)
```

Description

`see(FileName)` sets the current input stream to `FileName`. If there is a stream opened by `see/1` associated with the same `FileName` already, then it becomes the current input stream. Otherwise, `FileName` is opened for reading and becomes the current input stream.

`tell(FileName)` sets the current output stream to `FileName`. If there is a stream opened by `tell/1` associated with the same `FileName` already, then it becomes the current output stream. Otherwise, `FileName` is opened for writing and becomes the current output stream.

`append(FileName)` like `tell/1` but `FileName` is opened for writing + append.

A stream-term (obtained with any other built-in predicate) can also be provided as `FileName` to these predicates.

Errors

See errors associated with `open/4` (section 8.10.6 page 81).

Portability

GNU Prolog predicates. Deprecated.

8.16.3 seeing/1, telling/1

Templates

```
seeing(?source_sink)
telling(?source_sink)
```

Description

`seeing(FileName)` succeeds if `FileName` unifies with the name of the current input file, if it was opened by `see/1`; else with the current input stream-term, if this is not `user_input`, otherwise with `user`.

`telling(FileName)` succeeds if `FileName` unifies with the name of the current output file, if it was opened by `tell/1` or `append/1`; else with the current output stream-term, if this is not `user_output`, otherwise with `user`.

Errors

None.
8.16.4 seen/0, told/0

Templates

seen
told

Description

seen closes the current input, and resets it to user_input.
told closes the current output, and resets it to user_output.

Errors

None.

Portability

GNU Prolog predicates. Deprecated.

8.16.5 get0/1, get/1, skip/1

Templates

get0(?in_character_code)
get(?in_character_code)
skip(+character_code)

Description

get0(Code) succeeds if Code unifies with the next character code read from the current input stream. Thus it is equivalent to get_code(Code) (section 8.12.1 page 97).

get(Code) succeeds if Code unifies with the next character code read from the current input stream that is not a layout character.

skip(Code) skips just past the next character code Code from the current input stream.

Errors

See errors for get_code/2 (section 8.12.1 page 97).

Portability

GNU Prolog predicates. Deprecated.
8.16.6 put/1, tab/1

Templates

```prolog
put(+character_code)  
  tab(+evaluable)
```

Description

`put(Code)` writes the character whose code is `Code` onto the current output stream. It is equivalent to `put_code(Code)` (section 8.12.5, page 100).

`tab(N)` writes `N` spaces onto the current output stream. `N` may be an arithmetic expression.

Errors

See errors for `put_code/2` (section 8.12.5, page 100) and for arithmetic expressions (section 8.6.1, page 66).

Portability

GNU Prolog predicates. Deprecated.

8.17 Term expansion

8.17.1 Definite clause grammars

Definite clause grammars are a useful notation to express grammar rules. However the ISO reference does not include them, so they should be considered as a system dependent feature. Definite clause grammars are an extension of context-free grammars. A grammar rule is of the form:

```
head --> body.
```

`-->` is a predefined infix operator (section 8.14.10, page 113).

Here are some features of definite clause grammars:

- a non-terminal symbol may be any callable term.
- a terminal symbol may be any Prolog term and is written as a list. The empty list represents an empty sequence of terminals.
- a sequence is expressed using the Prolog conjunction operator (`,`/2).
- the head of a grammar rule consists of a non-terminal optionally followed by a sequence of terminals (i.e. a Prolog list).
- the body of a grammar rule consists of a sequence of non-terminals, terminals, predicate call, disjunction (using ;/2), if-then (using (->)/2) or cut (using !).
- a predicate call must be enclosed in curly brackets (using {}/1). This makes it possible to express an extra condition.

A grammar rule is nothing but a “syntactic sugar” for a Prolog clause. Each grammar rule accepts as input a list of terminals (tokens), parses a prefix of this list and gives as output the rest of this list (possibly enlarged). This rest is generally parsed later. So, each a grammar rule is translated into a Prolog clause that explicitly the manages the list. Two arguments are then added: the input list (`Start`) and the output list (`End`). For instance:
p --> q.
is translated into:

\[ p(\text{Start}, \text{End}) \leftarrow q(\text{Start}, \text{End}). \]

Extra arguments can be provided and the body of the rule can contain several non-terminals. Example:

\[ p(X, Y) \leftarrow \]
\[ q(X), r(X, Y), s(Y). \]
is translated into:

\[ p(X, Y, \text{Start}, \text{End}) \leftarrow \]
\[ q(X, \text{Start}, A), r(X, Y, A, B), s(Y, B, \text{End}). \]

Terminals are translated using unification:

\[ \text{assign}(X,Y) \leftarrow \left \langle \text{left}(X), \text{[:]=}, \text{right}(Y), \text{[;]} \right \rangle. \]
is translated into:

\[ \text{assign}(X,Y,\text{Start},\text{End}) \leftarrow \]
\[ \text{left}(X, \text{Start}, A), A=\text{[:]=|B]}, \text{right}(Y, B, C), C=\text{[;|End]}]. \]

Terminals appearing on the left-hand side of a rule are connected to the output argument of the head.

It is possible to include a call to a prolog predicate enclosing it in curly brackets (to distinguish them from non-terminals):

\[ \text{assign}(X,Y) \leftarrow \text{left}(X), \text{[:]=}, \text{right}(Y0), \{Y \text{ is } Y0 \}, \text{[;]}. \]
is translated into:

\[ \text{assign}(X,Y,\text{Start},\text{End}) \leftarrow \]
\[ \text{left}(X, \text{Start}, A), A=\text{[:]=|B]}, \text{right}(Y0, B, C), Y \text{ is } Y0, C=\text{[;|End]}]. \]

Cut, disjunction and if-then(-else) are translated literally (and do not need to be enclosed in curly brackets).

8.17.2 expand_term/2, term_expansion/2

Templates

\[ \text{expand_term}(\text{?term, ?term}) \]
\[ \text{term_expansion}(\text{?term, ?term}) \]
8.17 Term expansion

Description

\texttt{expand\_term(Term1, Term2)} succeeds if \texttt{Term2} is a transformation of \texttt{Term1}. The transformation steps are as follows:

- if \texttt{Term1} is a variable, it is unified with \texttt{Term2}
- if \texttt{term\_expansion(Term1, Term2)} succeeds \texttt{Term2} is assumed to be the transformation of \texttt{Term1}.
- if \texttt{Term1} is a DCG then \texttt{Term2} is its translation (section [8.17.1 page 123]).
- otherwise \texttt{Term2} is unified with \texttt{Term1}.

\texttt{term\_expansion(Term1, Term2)} is a hook predicate allowing the user to define a specific transformation.

The GNU Prolog compiler (section [4.4 page 21]) automatically calls \texttt{expand\_term/2} on each \texttt{Term1} read in. However, in the current release, only DCG transformation are done by the compiler (i.e. \texttt{term\_expansion/2} cannot be used). To use \texttt{term\_expansion/2}, it is necessary to call \texttt{expand\_term/2} explicitly.

Errors

None.

Portability

GNU Prolog predicate.

8.17.3 phrase/3, phrase/2

Templates

\begin{verbatim}
phrase(?term, ?list, ?list)
phrase(?term, ?list)
\end{verbatim}

Description

\texttt{phrase(Phrase, List, Remainder)} succeeds if the list \texttt{List} is in the language defined by the grammar rule body \texttt{Phrase}. \texttt{Remainder} is what remains of the list after a phrase has been found.

\texttt{phrase(Phrase, List)} is equivalent to \texttt{phrase(Phrase, List, [])}.

Errors

\begin{verbatim}
\begin{tabular}{|l|l|}
\hline
Phrase is a variable & instantiation_error \\
Phrase is neither a variable nor a callable term & type_error(callable, Phrase) \\
List is neither a list nor a partial list & type_error(list, List) \\
Remainder is neither a list nor a partial list & type_error(list, Remainder) \\
\hline
\end{tabular}
\end{verbatim}

Portability

GNU Prolog predicates.
8.18 Logic, control and exceptions

8.18.1 abort/0, stop/0, top_level/0, break/0, halt/1, halt/0

Templates

abort
stop
top_level
break
halt(+integer)
halt

Description

abort aborts the current execution. If this execution was initiated under a top-level the control is given back to the top-level and the message {execution aborted} is displayed. Otherwise, e.g. execution started by a initialization/1 directive (section 7.1.14 page 50), abort/0 is equivalent to halt(1) (see below).

stop stops the current execution. If this execution was initiated under a top-level the control is given back to the top-level. Otherwise, stop/0 is equivalent to halt(0) (see below).

top_level starts a new recursive top-level (including the banner display). To end this new top-level simply type the end-of-file key sequence (Ctl-D) or its term representation: end_of_file.

break invokes a recursive top-level (no banner is displayed). To end this new level simply type the end-of-file key sequence (Ctl-D) or its term representation: end_of_file.

halt(Status) causes the GNU Prolog process to immediately exit back to the shell with the return code Status.

halt is equivalent to halt(0).

Errors

| Status is a variable | instantiation_error |
| Status is neither a variable nor an integer | type_error(integer, Status) |

Portability

halt/1 and halt/0 are ISO predicates. abort/0, stop/0, top_level/0 and break/0 are GNU Prolog predicates.

8.18.2 false/0, once/1, (\+)/1 - not provable, call/2-11, call_with_args/1-11, call_det/2,forall/2

Templates

false
once(+callable_term)
\+)/1(+callable_term)
call(+callable_term, +term,..., +term)
call_with_args(+atom, +term,..., +term)
call_det(+callable_term, ?boolean)
forall(+callable_term, +callable_term)

Description

false always fails and enforces backtracking. It is equivalent to the fail/0 control construct (section 7.2.1 page 51).

once(Goal) succeeds if call(Goal) succeeds. However once/1 is not re-executable on backtracking since all alternatives of Goal are cut. once(Goal) is equivalent to call(Goal), !.

\+ Goal succeeds if call(Goal) fails and fails otherwise. This built-in predicate gives negation by failure.

call(Closure, Arg1,..., ArgN) calls the goal call(Goal) where Goal is constructed by appending Arg1,..., ArgN (1 ≤ N ≤ 10) additional arguments to the arguments (if any) of Closure.

call_with_args(Functor, Arg1,..., ArgN) calls the goal whose functor is Functor and whose arguments are Arg1,..., ArgN (0 ≤ N ≤ 10).

call_det(Goal, Deterministic) succeeds if call(Goal) succeeds and unifies Deterministic with true if Goal has not created any choice-points, with false otherwise.

forall(Condition, Action) succeeds if for all alternative bindings of Condition, Action can be proven. It is equivalent to \+(Condition, \+ Action).

\+ is a predefined prefix operator (section 8.14.10 page 113).

Errors

| Goal (or Condition or Action) is a variable                     | instantiation_error |
| Goal (or Condition or Action) is neither a variable nor a callable term | type_error(callable, Goal) |
| The predicate indicator Pred of Goal does not correspond to an existing procedure and the value of the unknown Prolog flag is error (section 8.22.1 page 148) | existence_error(procedure, Pred) |
| Functor is a variable                                         | instantiation_error |
| Functor is neither a variable nor an atom                      | type_error(atom, Functor) |
| Deterministic is neither a variable nor a boolean             | type_error(boolean, Deterministic) |
| for call/2-11 the resulting arity of Goal (arity of Closure + N) is an integer > max arity flag (section 8.22.1 page 148) | representation_error(max arity) |

Portability

false/0, call/2-8, once/1 and \+(\+)/1 are ISO predicates. call/9-11, call_with_args/1-11, call_det/2 and forall/2 are GNU Prolog predicates.

8.18.3 repeat/0

Templates
### repeat

**Description**

`repeat` generates an infinite sequence of backtracking choices. The purpose is to repeatedly perform some action on elements which are somehow generated, e.g. by reading them from a stream, until some test becomes true. Repeat loops cannot contribute to the logic of the program. They are only meaningful if the action involves side-effects. The only reason for using repeat loops instead of a more natural tail-recursive formulation is efficiency: when the test fails back, the Prolog engine immediately reclaims any working storage consumed since the call to `repeat/0`.

**Errors**

None.

**Portability**

ISO predicate.

### 8.18.4 between/3, for/3

**Templates**

- `between(+integer, +integer, ?integer)`
- `for(?integer, +integer, +integer)`

**Description**

`between(Lower, Upper, Counter)` generates a sequence of backtracking choices instantiating `Counter` to the values `Lower`, `Lower+1`, ..., `Upper`.

`for(Counter, Lower, Upper)` is equivalent to `between(Lower, Upper, Counter)`. This predicate is deprecated and new code should use `between/3`.

**Errors**

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Type Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Counter</code> is neither a variable nor an integer</td>
<td><code>type_error(integer, Counter)</code></td>
</tr>
<tr>
<td><code>Lower</code> is a variable</td>
<td><code>instantiation_error</code></td>
</tr>
<tr>
<td><code>Lower</code> is neither a variable nor an integer</td>
<td><code>type_error(integer, Lower)</code></td>
</tr>
<tr>
<td><code>Upper</code> is a variable</td>
<td><code>instantiation_error</code></td>
</tr>
<tr>
<td><code>Upper</code> is neither a variable nor an integer</td>
<td><code>type_error(integer, Upper)</code></td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicate.

### 8.19 Atomic term processing

These built-in predicates enable atomic terms to be processed as a sequence of characters and character codes. Facilities exist to split and join atoms, to convert a single character to and from the corresponding character code, and to convert a number to and from a list of characters and character codes.
8.19 Atomic term processing

8.19.1 atom_length/2

Templates

atom_length(+atom, ?integer)

Description

atom_length(Atom, Length) succeeds if Length unifies with the number of characters of the name of Atom.

Errors

<table>
<thead>
<tr>
<th>Error Condition</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atom is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>Length is neither a variable nor an integer</td>
<td>type_error(integer, Length)</td>
</tr>
<tr>
<td>Length is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Length)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.19.2 atom_concat/3

Templates

atom_concat(+atom, +atom, ?atom)
atom_concat(?atom, ?atom, +atom)

Description

atom_concat(Atom1, Atom2, Atom12) succeeds if the name of Atom12 is the concatenation of the name of Atom1 with the name of Atom2. This predicate is re-executable on backtracking (e.g. if Atom12 is instantiated and both Atom1 and Atom2 are variables).

Errors

<table>
<thead>
<tr>
<th>Error Condition</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atom1 and Atom12 are variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom2 and Atom12 are variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom1 is neither a variable nor an atom</td>
<td>type_error(atom, Atom1)</td>
</tr>
<tr>
<td>Atom2 is neither a variable nor an atom</td>
<td>type_error(atom, Atom2)</td>
</tr>
<tr>
<td>Atom12 is neither a variable nor an atom</td>
<td>type_error(atom, Atom12)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.19.3 sub_atom/5

Templates

Description

\texttt{sub_atom(Atom, Before, Length, After, SubAtom)} succeeds if \texttt{atom Atom} can be split into three atoms, \texttt{AtomL}, \texttt{SubAtom} and \texttt{AtomR} such that \texttt{Before} is the number of characters of the name of \texttt{AtomL}, \texttt{Length} is the number of characters of the name of \texttt{SubAtom} and \texttt{After} is the number of characters of the name of \texttt{AtomR}. This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{Atom} is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>\texttt{Atom} is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>\texttt{SubAtom} is neither a variable nor an atom</td>
<td>type_error(atom, SubAtom)</td>
</tr>
<tr>
<td>\texttt{Before} is neither a variable nor an integer</td>
<td>type_error(integer, Before)</td>
</tr>
<tr>
<td>\texttt{Length} is neither a variable nor an integer</td>
<td>type_error(integer, Length)</td>
</tr>
<tr>
<td>\texttt{After} is neither a variable nor an integer</td>
<td>type_error(integer, After)</td>
</tr>
<tr>
<td>\texttt{Before} is an integer &lt; 0</td>
<td>domain_error(not less than zero, Before)</td>
</tr>
<tr>
<td>\texttt{Length} is an integer &lt; 0</td>
<td>domain_error(not less than zero, Length)</td>
</tr>
<tr>
<td>\texttt{After} is an integer &lt; 0</td>
<td>domain_error(not less than zero, After)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.19.4 \texttt{char_code/2}

Templates

\texttt{char_code(+character, ?character_code)}
\texttt{char_code(-character, +character_code)}

Description

\texttt{char_code(Char, Code)} succeeds if the character code for the one-char atom \texttt{Char} is \texttt{Code}.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{Char} and \texttt{Code} are variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>\texttt{Char} is neither a variable nor a one-char atom</td>
<td>type_error(character, Char)</td>
</tr>
<tr>
<td>\texttt{Code} is neither a variable nor an integer</td>
<td>type_error(integer, Code)</td>
</tr>
<tr>
<td>\texttt{Code} is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.19.5 \texttt{lower_upper/2}

Templates

\texttt{lower_upper(+character, ?character)}
\texttt{lower_upper(-character, +character)}

Description
lower_upper(Char1, Char2) succeeds if Char1 and Char2 are one-char atoms and if Char2 is the upper conversion of Char1. If Char1 (resp. Char2) is a character that is not a lower (resp. upper) letter then Char2 is equal to Char1.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Char1 and Char2 are variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Char1 is neither a variable nor a one-char atom</td>
<td>type_error(character, Char1)</td>
</tr>
<tr>
<td>Char2 is neither a variable nor a one-char atom</td>
<td>type_error(character, Char2)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.19.6 atom_chars/2, atom_codes/2

Templates

atom_chars(+atom, ?character_list)
atom_chars(-atom, +character_list)
atom_codes(+atom, ?character_code_list)
atom_codes(-atom, +character_code_list)

Description

atom_chars(Atom, Chars) succeeds if Chars is the list of one-char atoms whose names are the successive characters of the name of Atom.

atom_codes(Atom, Codes) is similar to atom_chars/2 but deals with a list of character codes.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atom is a variable and Chars (or Codes) is a partial list or a list with an element which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Atom is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>Chars is neither a list nor a partial list</td>
<td>type_error(list, Chars)</td>
</tr>
<tr>
<td>Codes is neither a list nor a partial list</td>
<td>type_error(list, Codes)</td>
</tr>
<tr>
<td>An element E of the list Chars is neither a variable nor a one-char atom</td>
<td>type_error(character, E)</td>
</tr>
<tr>
<td>An element E of the list Codes is neither a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
<tr>
<td>An element E of the list Codes is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
</tbody>
</table>

Portability

ISO predicates. The ISO reference only causes a type_error(list, Chars) if Atom is a variable and Chars is neither a list nor a partial list. GNU Prolog always checks if Chars is a list. Similarly for Codes. The type_error(integer, E) when an element E of the Codes is not an integer is a GNU Prolog extension. This seems to be an omission in the ISO reference since this error is detected for many other built-in predicates accepting a character code (e.g. char_code/2, put_code/2).
8.19.7  number_atom/2, number_chars/2, number_codes/2

Templates

number_atom(+number, ?atom)
number_atom(-number, +atom)
number_chars(+number, ?character_list)
number_chars(-number, +character_list)
number_codes(+number, ?character_code_list)
number_codes(-number, +character_code_list)

Description

number_atom(Number, Atom) succeeds if Atom is an atom whose name corresponds to the characters of Number.

number_chars(Number, Chars) is similar to number_atom/2 but deals with a list of characters.

number_codes(Number, Codes) is similar to number_atom/2 but deals with a list of character codes.

Errors

<table>
<thead>
<tr>
<th>Number and Atom are variables</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number is a variable and Chars (or Codes) is a partial list or a list with an element which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Number is neither a variable nor an number</td>
<td>type_error(number, Number)</td>
</tr>
<tr>
<td>Atom is neither a variable nor an atom</td>
<td>type_error(atom, Atom)</td>
</tr>
<tr>
<td>Chars is neither a list nor a partial list</td>
<td>type_error(list, Chars)</td>
</tr>
<tr>
<td>Codes is neither a list nor a partial list</td>
<td>type_error(list, Codes)</td>
</tr>
<tr>
<td>An element E of the list Chars is neither a variable nor a one-char atom</td>
<td>type_error(character, E)</td>
</tr>
<tr>
<td>An element E of the list Codes is neither a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
<tr>
<td>An element E of the list Codes is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
<tr>
<td>Number is a variable, Atom (or Chars or Codes) cannot be parsed as a number and the value of the syntax_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>syntax_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

number_atom/2 is a GNU Prolog predicate. number_chars/2 and number_codes/2 are ISO predicates.

GNU Prolog only raises an error about an element E of the Chars (or Codes) list when Number is a variable while the ISO reference always check this. This seems an error since the list itself is only checked if Number is a variable.

The type_error(integer, E) when an element E of the Codes is not an integer is a GNU Prolog extension. This seems to be an omission in the ISO reference since this error is detected for many other built-in predicates accepting a character code (e.g. char_code/2, put_code/2).
8.19.8  name/2

Templates

\[
\text{name}(+\text{atomic, ?character\_code\_list}) \\
\text{name}(-\text{atomic, +character\_code\_list})
\]

Description

\(\text{name}(\text{Constant, Codes})\) succeeds if \(\text{Codes}\) is a list whose elements are the character codes corresponding to the successive characters of \(\text{Constant}\) (a number or an atom). However, there atoms are for which \(\text{name}(\text{Constant, Codes})\) is true, but which will not be constructed if \(\text{name}/2\) is called with \(\text{Constant}\) uninstantiated, e.g. the atom ‘1024’. For this reason the use of \(\text{name}/2\) is discouraged and should be limited to compatibility purposes. It is preferable to use \(\text{atom\_codes}/2\) (section 8.19.6, page 131) or \(\text{number\_chars}/2\) (section 8.19.7, page 132).

Errors

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Constant}) is a variable and (\text{Codes}) is a partial list or a list with an element which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>(\text{Constant}) is neither a variable nor an atomic term</td>
<td>type_error(atomic, (\text{Constant}))</td>
</tr>
<tr>
<td>(\text{Constant}) is a variable and (\text{Codes}) is neither a list nor a partial list</td>
<td>type_error(list, (\text{Codes}))</td>
</tr>
<tr>
<td>(\text{Constant}) is a variable and an element (E) of the list (\text{Codes}) is neither a variable nor an integer</td>
<td>type_error(integer, (E))</td>
</tr>
<tr>
<td>(\text{Constant}) is a variable and an element (E) of the list (\text{Codes}) is an integer but not a character code</td>
<td>representation_error(character_code)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.19.9  new\_atom/2, new\_atom/1

Templates

\[
\text{new\_atom}(+\text{atom, -atom}) \\
\text{new\_atom}(-\text{atom})
\]

Description

\(\text{new\_atom}(\text{Prefix, Atom})\) unifies \(\text{Atom}\) with a new atom whose name begins with the characters of the name of \(\text{Prefix}\). This predicate is then a symbol generator. It is guaranteed that \(\text{Atom}\) does not exist before the invocation of \(\text{new\_atom}/3\). The characters appended to \(\text{Prefix}\) to form \(\text{Atom}\) are in: \(A-Z\) (capital letter), \(a-z\) (small letter) and \(0-9\) (digit).

\(\text{new\_atom}/1\) is similar to \(\text{new\_atom}(\text{term\_\_, Atom})\), i.e. the generated atom begins with \(\text{term\_}\).

Errors

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Prefix}) is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>(\text{Prefix}) is neither a variable nor an atom</td>
<td>type_error(atom, (\text{Prefix}))</td>
</tr>
<tr>
<td>(\text{Atom}) is not a variable</td>
<td>uninstantiation_error((\text{Atom}))</td>
</tr>
</tbody>
</table>
Portability

GNU Prolog predicate.

8.19.10 current_atom/1

Templates

    current_atom(?atom)

Description

current_atom(Atom) succeeds if there exists an atom that unifies with Atom. All atoms are found except those beginning with a ‘$’ (system atoms). This predicate is re-executable on backtracking.

Errors

| Atom is neither a variable nor an atom | type_error(atom, Atom) |

Portability

GNU Prolog predicate.

8.19.11 atom_property/2

Templates

    atom_property(?atom, ?atom_property)

Description

atom_property(Atom, Property) succeeds if current_atom(Atom) succeeds (section 8.19.10, page 134) and if Property unifies with one of the properties of the atom. This predicate is re-executable on backtracking.

Atom properties:

- length(Length): Length is the length of the name of the atom.
- hash(Hash): Hash is the hash code of the atom, see also term_hash/2 (section 8.4.8, page 62).
- prefix_op: if there is a prefix operator currently defined with this name.
- infix_op: if there is an infix operator currently defined with this name.
- postfix_op: if there is a postfix operator currently defined with this name.
- needs_quotes: if the atom must be quoted to be read later.
- needs_scan: if the atom must be scanned when output to be read later (e.g. contains special characters that must be output with a \ escape sequence).

Errors
8.20 List processing

These predicates manipulate lists. They are bootstrapped predicates (i.e. written in Prolog) and no error cases are tested (for the moment). However, since they are written in Prolog using other built-in predicates, some errors can occur due to those built-in predicates.

8.20.1 append/3

Templates

\texttt{append(?list, ?list, ?list)}

Description

\texttt{append(List1, List2, List12)} succeeds if the concatenation of the list \texttt{List1} and the list \texttt{List2} is the list \texttt{List12}. This predicate is re-executable on backtracking (e.g. if \texttt{List12} is instantiated and both \texttt{List1} and \texttt{List2} are variable).

Errors

None.

Portability

GNU Prolog predicate.

8.20.2 member/2, memberchk/2

Templates

\texttt{member(?term, ?list)}
\texttt{memberchk(?term, ?list)}

Description

\texttt{member(Element, List)} succeeds if \texttt{Element} belongs to the \texttt{List}. This predicate is re-executable on backtracking and can be thus used to enumerate the elements of \texttt{List}.

\texttt{memberchk/2} is similar to \texttt{member/2} but only succeeds once.

Errors
None.

Portability

GNU Prolog predicate.

8.20.3 reverse/2

Templates

\[ reverse(?list, ?list) \]

Description

\[ reverse(List1, List2) \text{ succeeds if } List2 \text{ unifies with the list } List1 \text{ in reverse order.} \]

Errors

None.

Portability

GNU Prolog predicate.

8.20.4 delete/3, select/3

Templates

\[
\begin{align*}
& \text{delete(?list, ?term, ?list)} \\
& \text{select(?term, ?list, ?list)}
\end{align*}
\]

Description

\[ \text{delete(List1, Element, List2) removes all occurrences of Element in List1 to provide List2. A strict term equality is required, cf. (==)/2 (section 8.3.2, page 57).} \]

\[ \text{select(Element, List1, List2) removes one occurrence of Element in List1 to provide List2. This predicate is re-executable on backtracking.} \]

Errors

None.

Portability

GNU Prolog predicate.

8.20.5 subtract/3

Templates

\[ \text{subtract(+list, +list, ?list)} \]
Description

\texttt{subtract(List1, List2, List3)} removes all elements in \texttt{List2} from \texttt{List1} to provide \texttt{List3}. Membership is tested using \texttt{memberchk/2} (section 8.20.2 page 135). The predicate runs in $O(|\texttt{List2}| \times |\texttt{List1}|)$.

Errors

None.

Portability

GNU Prolog predicate.

\subsection{8.20.6 \texttt{permutation/2}}

Templates

\begin{verbatim}
permutation(?list, ?list)
\end{verbatim}

Description

\texttt{permutation(List1, List2)} succeeds if \texttt{List2} is a permutation of the elements of \texttt{List1}. This predicate is re-executable on backtracking.

Errors

None.

Portability

GNU Prolog predicate.

\subsection{8.20.7 \texttt{prefix/2, suffix/2}}

Templates

\begin{verbatim}
prefix(?list, ?list)
suffix(?list, ?list)
\end{verbatim}

Description

\texttt{prefix(Prefix, List)} succeeds if \texttt{Prefix} is a prefix of \texttt{List}. This predicate is re-executable on backtracking.

\texttt{suffix(Suffix, List)} succeeds if \texttt{Suffix} is a suffix of \texttt{List}. This predicate is re-executable on backtracking.

Errors

None.

Portability

GNU Prolog predicate.
8.20.8 sublist/2

**Templates**

```
sublist(?list, ?list)
```

**Description**

sublist(List1, List2) succeeds if all elements of List1 appear in List2 in the same order. This predicate is re-executable on backtracking.

**Errors**

None.

**Portability**

GNU Prolog predicate.

8.20.9 last/2

**Templates**

```
last(?list, ?term)
```

**Description**

last(List, Element) succeeds if Element is the last element of List.

**Errors**

None.

**Portability**

GNU Prolog predicate.

8.20.10 flatten/2

**Templates**

```
flatten(?term, ?list)
```

**Description**

flatten(List1, List2) succeeds if List2 is the flatten version of List1.

**Errors**

None.

**Portability**

GNU Prolog predicate.
8.20 List processing

8.20.11 length/2

Templates

\[
\text{length}(\text{list}, \text{integer})
\]

Description

\text{length(List, Length)} succeeds if \text{Length} is the length of \text{List}.

Errors

| Length is an integer < 0 | domain_error(not_less_than_zero, Length) |

GNU Prolog predicate.

8.20.12 nth/3

Templates

\[
\text{nth}(\text{integer}, \text{list}, \text{term})
\]

Description

\text{nth}(N, \text{List}, \text{Element}) succeeds if the \text{Nth} argument of \text{List} is \text{Element}.

Errors

None.

Portability

GNU Prolog predicate.

8.20.13 max_list/2, min_list/2, sum_list/2

Templates

\[
\text{min_list}(\text{list}, \text{number})
\]
\[
\text{max_list}(\text{list}, \text{number})
\]
\[
\text{sum_list}(\text{list}, \text{number})
\]

Description

\text{min_list}(\text{List}, \text{Min}) succeeds if \text{Min} is the smallest number in \text{List}.

\text{max_list}(\text{List}, \text{Max}) succeeds if \text{Max} is the largest number in \text{List}.

\text{sum_list}(\text{List}, \text{Sum}) succeeds if \text{Sum} is the sum of all the elements in \text{List}.

\text{List} must be a list of arithmetic evaluable terms (section 8.6.1 page 66).

Errors
8.20.14 maplist/2-8

**Templates**

\[
\text{maplist}(\text{callable_term}, \text{list}, \ldots, \text{list})
\]

**Description**

\(\text{maplist}(\text{Goal}, \text{List})\) succeeds if \(\text{Goal}\) can successfully be applied on all elements of \(\text{List}\).

\(\text{maplist}(\text{Goal}, \text{List1}, \text{List2})\) succeeds if \(\text{Goal}\) can successfully be applied to all pairs of elements of \(\text{List1}\) and \(\text{List2}\).

\(\text{maplist}(\text{Goal}, \text{List1}, \text{List2}, \text{List3})\) succeeds if \(\text{Goal}\) can successfully be applied to all triples of elements of \(\text{List1}..\text{List3}\).

\(\text{maplist}(\text{Goal}, \text{List1}, \text{List2}, \ldots, \text{ListN})\) succeeds if \(\text{Goal}\) can successfully be applied to all \(N\)-uples \((N \leq 8)\) of elements of \(\text{List1}..\text{ListN}\).

**Errors**

An error occurs executing a directive  
See call/1 errors (section 7.2.3, page 52)

8.20.15 sort/2, msort/2, keysort/2  sort/1, msort/1, keysort/1

**Templates**

\[
\begin{align*}
\text{sort}(\text{list}, \text{list}) \\
\text{msort}(\text{list}, \text{list}) \\
\text{keysort}(\text{list}, \text{list}) \\
\text{sort}(\text{list}) \\
\text{msort}(\text{list}) \\
\text{keysort}(\text{list})
\end{align*}
\]

**Description**

\(\text{sort}([\text{List1}], [\text{List2}])\) succeeds if \(\text{List2}\) is the sorted list corresponding to \(\text{List1}\) where duplicate elements are merged.

\(\text{msort}/2\) is similar to \(\text{sort}/2\) except that duplicate elements are not merged.

\(\text{keysort}(\text{List1}, \text{List2})\) succeeds if \(\text{List2}\) is the sorted list of \(\text{List1}\) according to the keys. The list \(\text{List1}\) consists of pairs (items of the form \(\text{Key-Value}\)). These items are sorted according to the value of
Key yielding the List2. Duplicate keys are not merged. This predicate is stable, i.e. if K=A occurs before K=B in the input, then K=A will occur before K=B in the output.

sort/1, msort/1 and keysort/1 are similar to sort/2, msort/2 and keysort/2 but achieve a sort in-place destructing the original List1 (this in-place assignment is not undone at backtracking). The sorted list occupies the same memory space as the original list (saving thus memory consumption).

The time complexity of these sorts is $O(N \log N)$, $N$ being the length of the list to sort.

These predicates refer to the standard ordering of terms (section 8.3.1, page 57).

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>List1 is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>List1 is neither a partial list nor a list</td>
<td>type_error(list, List1)</td>
</tr>
<tr>
<td>List2 is neither a partial list nor a list</td>
<td>type_error(list, List2)</td>
</tr>
<tr>
<td>for keysort/2: an element of List1 is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>for keysort/2: an element E of List1 is neither a variable nor a pair</td>
<td>type_error(pair, E)</td>
</tr>
<tr>
<td>for keysort/2: an element E of List2 is neither a variable nor a pair</td>
<td>type_error(pair, E)</td>
</tr>
</tbody>
</table>

Portability

sort/2 and keysort/2 are ISO predicates.

sort/1, keysort/1 and msort/1-2 are GNU Prolog predicates.

8.21 Global variables

8.21.1 Introduction

GNU Prolog provides a simple and powerful way to assign and read global variables. A global variable is associated with each atom, its initial value is the integer 0. A global variable can store 3 kinds of objects:

- a copy of a term (the assignment can be made backtrackable or not).
- a link to a term (the assignment is always backtrackable).
- an array of objects (recursively).

The space necessary for copies and arrays is dynamically allocated and recovered as soon as possible. For instance, when an atom is associated with a global variable whose current value is an array, the space for this array is recovered (unless the assignment is to be undone when backtracking occurs).

When a link to a term is associated with a global variable, the reference to this term is stored and thus the original term is returned when the content of the variable is read.

Global variable naming convention: a global variable is referenced by an atom.

If the variable contains an array, an index (ranging from 0) can be provided using a compound term whose principal functor is the corresponding atom and the argument is the index. In case of a multi-dimensional array, each index is given as the arguments of the compound term.
If the variable contains a term (link or copy), it is possible to only reference a sub-term by giving its argument number (also called argument selector). Such a sub-term is specified using a compound term whose principal functor is \(-/2\) and whose first argument is a global variable name and the second argument is the argument number (from 1). This can be applied recursively to specify a sub-term of any depth. In case of a list, a argument number I represents the Ith element of the list. In the rest of this section we use the operator notation since \(-\) is a predefined infix operator (section 8.14.10, page 113).

In the following, \(GVarName\) represents a reference to a global variable and its syntax is as follows:

\[
GVarName ::= \begin{align*}
\text{atom} & \quad \text{whole content of a variable} \\
\text{atom(Integer, \ldots, Integer)} & \quad \text{element of an array} \\
GVarName-Integer & \quad \text{sub-term selection} \\
\text{GVarName} & \quad \text{indirect value}
\end{align*}
\]

\[
Integer ::= \begin{align*}
\text{integer} & \quad \text{immediate value} \\
GVarName & \quad \text{indirect value}
\end{align*}
\]

When a \(GVarName\) is used as an index or an argument number (i.e. indirection), the value of this variable must be an integer.

Here are some examples of the naming convention:

- \(a\) the content of variable associated with \(a\) (any kind)
- \(t(1)\) the 2nd element of the array associated with \(t\)
- \(t(k)\) if the value associated with \(k\) is \(I\), the \(I\)th element of the array associated with \(t\)
- \(a-1-2\) if the value associated with \(a\) is \(f(g(a,b,c),2)\), the sub-term \(b\)

Here are the errors associated with global variable names and common to all predicates.

| \(GVarName\) is a variable | instantiation_error |
| \(GVarName\) is neither a variable nor a callable term | type_error(callable, \(GVarName\)) |
| \(GVarName\) contains an invalid argument number (or \(GVarName\) is an array) | domain_error(g_argument_selector, \(GVarName\)) |
| \(GVarName\) contains an invalid index (or \(GVarName\) is not an array) | domain_error(g_array_index, \(GVarName\)) |
| \(GVarName\) is used as an indirect index or argument selector and is not an integer | type_error(integer, \(GVarName\)) |

**Arrays**: the predicates \(g\_assign/2\), \(g\_assignb/2\) and \(g\_link/2\) (section 8.21.2, page 143) can be used to create an array. They recognize some terms as values. For instance, a compound term with principal functor \(g\_array\) is used to define an array of fixed size. There are 3 forms for the term \(g\_array\):

- \(g\_array\)(Size): if \(Size\) is an integer > 0 then defines an array of Size elements which are all initialized with the integer 0.
- \(g\_array\)(Size, Initial): as above but the elements are initialized with the term Initial instead of 0. Initial can contain other array definitions allowing thus for multi-dimensional arrays.
- \(g\_array\)(List): as above if List is a list of length Size except that the elements of the array are initialized according to the elements of List (which can contain other array definitions).

An array can be extended explicitly using a compound term with principal functor \(g\_array\_extend\) which accept the same 3 forms detailed above. In that case, the existing elements of the array are not initialized. If \(g\_array\_extend\) is used with an object which is not an array it is similar to \(g\_array\).

Finally, an array can be automatically expanded when needed. The programmer does not need to explicitly control the expansion of an automatic array. An array is expanded as soon as an index is outside the current size of this array. Such an array is defined using a compound term with principal functor \(g\_array\_auto\):
• **g_array_auto**(Size): if Size is an integer > 0 then defines an automatic array whose initial size is Size. All elements are initialized with the integer 0. Elements created during implicit expansions will be initialized with 0.

• **g_array_auto**(Size, Initial): as above but the elements are initialized with the term Initial instead of 0. Initial can contain other array definitions allowing thus for multi-dimensional arrays. Elements created during implicit expansions will be initialized with Initial.

• **g_array_auto**(List): as above if List is a list of length Size except that the elements of the array are initialized according to the elements of List (which can contain other array definitions). Elements created during implicit expansions will be initialized with 0.

In any case, when an array is read, a term of the form `g_array([Elem0, ..., ElemSize-1])` is returned.

Some examples using global variables are presented later (section 8.21.7, page 146).

### 8.21.2 g_assign/2, g_assignb/2, g_link/2

**Templates**

- `g_assign(+callable_term, ?term)`
- `g_assignb(+callable_term, ?term)`
- `g_link(+callable_term, ?term)`

**Description**

- `g_assign(GVarName, Value)` assigns a copy of the term Value to GVarName. This assignment is not undone when backtracking occurs.

- `g_assignb/2` is similar to `g_assign/2` but the assignment is undone at backtracking.

- `g_link(GVarName, Value)` makes a link between GVarName to the term Value. This allows the user to give a name to any Prolog term (in particular non-ground terms). Such an assignment is always undone when backtracking occurs (since the term may no longer exist). If Value is an atom or an integer, `g_link/2` and `g_assignb/2` have the same behavior. Since `g_link/2` only handles links to existing terms it does not require extra memory space and is not expensive in terms of execution time.

NB: argument selectors can only be used with `g_assign/2` (i.e. when using an argument selector inside an assignment, this one must not be backtrackable).

**Errors**

See common errors detailed in the introduction (section 8.21.1, page 141)

| GVarName contains an argument selector and the assignment is backtrackable | domain_error(g_argument_selector, GVarName) |

**Portability**

GNU Prolog predicates.

### 8.21.3 g_read/2

**Templates**
g_read(+callable_term, ?term)

Description

\[ g_{\text{read}}(\text{GVarName}, \text{Value}) \] unifies \text{Value} with the term assigned to \text{GVarName}.

Errors

See common errors detailed in the introduction (section 8.21.1, page 141)

Portability

GNU Prolog predicate.

8.21.4 \ g_{\text{array.size}}/2

Templates

\[ g_{\text{array.size}}(+\text{callable_term}, ?\text{integer}) \]

Description

\[ g_{\text{array.size}}(\text{GVarName}, \text{Value}) \] unifies \text{Size} with the dimension (an integer > 0) of the array assigned to \text{GVarName}. Fails if \text{GVarName} is not an array.

Errors

See common errors detailed in the introduction (section 8.21.1, page 141)

| \text{Size} is neither a variable nor an integer | type_error(integer, \text{Size}) |

Portability

GNU Prolog predicate.

8.21.5 \ g_{\text{inc}}/3, g_{\text{inc}}/2, g_{\text{inco}}/2, g_{\text{inc}}/1, g_{\text{dec}}/3, g_{\text{dec}}/2, g_{\text{deco}}/2, g_{\text{dec}}/1

Templates

\[ g_{\text{inc}}(+\text{callable_term}, ?\text{integer}, ?\text{integer}) \]
\[ g_{\text{inc}}(+\text{callable_term}, ?\text{integer}) \]
\[ g_{\text{inco}}(+\text{callable_term}, ?\text{integer}) \]
\[ g_{\text{inc}}(+\text{callable_term}) \]
\[ g_{\text{dec}}(+\text{callable_term}, ?\text{integer}, ?\text{integer}) \]
\[ g_{\text{dec}}(+\text{callable_term}, ?\text{integer}) \]
\[ g_{\text{deco}}(+\text{callable_term}, ?\text{integer}) \]
\[ g_{\text{dec}}(+\text{callable_term}) \]

Description

\[ g_{\text{inc}}(\text{GVarName}, \text{Old}, \text{New}) \] unifies \text{Old} with the integer assigned to \text{GVarName}, increments \text{GVarName} and then unifies \text{New} with the incremented value.
8.21 Global variables

\( \text{g.inc(GVarName, New)} \) is equivalent to \( \text{g.inc(GVarName, _, New)} \).

\( \text{g.inco(GVarName, Old)} \) is equivalent to \( \text{g.inc(GVarName, Old, _)} \).

\( \text{g.inc(GVarName)} \) is equivalent to \( \text{g.inc(GVarName, _, _)} \).

Predicates \( \text{g.dec} \) are similar but decrement the content of \( \text{GVarName} \) instead.

Errors

See common errors detailed in the introduction (section 8.21.1, page 141)

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old is neither a variable nor an integer</td>
<td>type_error(integer, Old)</td>
</tr>
<tr>
<td>New is neither a variable nor an integer</td>
<td>type_error(integer, New)</td>
</tr>
<tr>
<td>GVarName stores an array</td>
<td>type_error(integer, g_array)</td>
</tr>
<tr>
<td>GVarName stores a term ( T ) which is not an integer</td>
<td>type_error(integer, T)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.21.6 \( \text{g.set.bit/2, g.reset.bit/2, g.test_set.bit/2, g.test_reset.bit/2} \)

Templates

\[
\begin{align*}
\text{g.set.bit(+callable_term, +integer)} \\
\text{g.reset.bit(+callable_term, +integer)} \\
\text{g.test_set.bit(+callable_term, +integer)} \\
\text{g.test_reset.bit(+callable_term, +integer)}
\end{align*}
\]

Description

\( \text{g.set.bit(GVarName, Bit)} \) sets to 1 the bit number specified by \( \text{Bit} \) of the integer assigned to \( \text{GVarName} \) to 1. Bit numbers range from 0 to the maximum number allowed for integers (this is architecture dependent). If \( \text{Bit} \) is greater than this limit, the modulo with this limit is taken.

\( \text{g.reset.bit(GVarName, Bit)} \) is similar to \( \text{g.set.bit/2} \) but sets the specified bit to 0.

\( \text{g.test_set.bit/2} \) succeeds if the specified bit is set to 1.

\( \text{g.test_reset.bit/2} \) succeeds if the specified bit is set to 0.

Errors

See common errors detailed in the introduction (section 8.21.1, page 141)

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Bit is neither a variable nor an integer</td>
<td>type_error(integer, Bit)</td>
</tr>
<tr>
<td>Bit is an integer ( &lt; 0 )</td>
<td>domain_error(not_less_than_zero, Bit)</td>
</tr>
<tr>
<td>GVarName stores an array</td>
<td>type_error(integer, g_array)</td>
</tr>
<tr>
<td>GVarName stores a term ( T ) which is not an integer</td>
<td>type_error(integer, T)</td>
</tr>
</tbody>
</table>

Portability
GNU Prolog predicates.

8.21.7 Examples

Simulating g_inc/3: this predicate behaves like: global variable:

\[
\text{my_g_inc}(	ext{Var}, \text{Old}, \text{New}) : - \\
g\text{_read}(	ext{Var}, \text{Old}), \\
N \text{ is Value} + 1, \\
g\text{_assign}(	ext{Var}, X), \\
\text{New} = N.
\]

The query: \text{my_g_inc(c, X, _)} will succeed unifying \text{X} with 0, another call to \text{my_g_inc(a, Y, _)} will then unify \text{Y} with 1, and so on.

Difference between g_assign/2 and g_assignb/2: \text{g_assign/2} does not undo its assignment when backtracking occurs whereas \text{g_assignb/2} undoes it.

\[
\text{test}() : - \\
g\text{_assign}(x,1), \\
(\text{g_read}(x, \text{Old}), \\
g\text{_assign}(x, 2) \\
; \text{g_read}(x, \text{Old}), \\
g\text{_assign}(x, 3) \\
). \\
\text{testb}() : - \\
g\text{_assign}(x,1), \\
(\text{g_read}(x, \text{Old}), \\
g\text{_assignb}(x, 2) \\
; \text{g_read}(x, \text{Old}), \\
g\text{_assign}(x, 3) \\
). \\
\]

The query \text{test(Old)} will succeed unifying \text{Old} with 1 and on backtracking with 2 (i.e. the assignment of the value 2 has not been undone). The query \text{testb(Old)} will succeed unifying \text{Old} with 1 and on backtracking with 1 (i.e. the assignment of the value 2 has been undone).

Difference between g_assign/2 and g_link/2: \text{g_assign/2} (and \text{g_assignb/2}) creates a copy of the term whereas \text{g_link/2} does not. \text{g_link/2} can be used to avoid passing big data structures (e.g. dictionaries,…) as arguments to predicates.

\[
\text{test}(\text{B}) : - \\
g\text{_assign}(\text{b}, \text{f}(\text{X})), \\
g\text{_link}(\text{b}, \text{f}(\text{X})), \\
\text{X} = 12, \\
g\text{_read}(\text{b}, \text{B}). \\
\text{test}(\text{B}) : - \\
g\text{_assign}(\text{b}, \text{f}(\text{X})), \\
g\text{_link}(\text{b}, \text{f}(\text{X})), \\
\text{X} = 12, \\
g\text{_read}(\text{b}, \text{B}). \\
\]

The query \text{test(B)} will succeed unifying \text{B} with \text{f(12)} (\text{g_assign/2} assigns a copy of the value). The query \text{test(B)} will succeed unifying \text{B} with \text{f(12)} (\text{g_link/2} assigns a pointer to the term).

Simple array definition: here are some queries to show how arrays can be handled:

\[
| ?- \text{g_assign}(\text{w}, \text{g_array}(3)), \text{g_read}(\text{w}, \text{X}). \\
\text{X} = \text{g_array}([0,0,0]) \\
| ?- \text{g_assign}(\text{w}(0), 16), \text{g_assign}(\text{w}(1), 32), \text{g_assign}(\text{w}(2), 64), \text{g_read}(\text{w}, \text{X}). \\
\text{X} = \text{g_array}([16,32,64]) \\
\]

this is equivalent to:

\[
| ?- \text{g_assign}(\text{k}, \text{g_array}([16,32,64])), \text{g_read}(\text{k}, \text{X}). \\
\]
X = g_array([16,32,64])

?- g_assign(k, g_array(3,null)), g_read(k, X), g_array_size(k, S).
S = 3
X = g_array([null,null,null])

2-D array definition:

?- g_assign(w, g_array(2, g_array(3))), g_read(w, X).
X = g_array([[g_array([0,0,0]),g_array([0,0,0])]])

?- (for(I,0,1), for(J,0,2), K is I*3+J, g_assign(w(I,J), K), fail ; g_read(w, X)).
X = g_array([[g_array([0,1,2]),g_array([3,4,5])]])

?- g_read(w(1),X).
X = g_array([3,4,5])

Hybrid array:

?- g_assign(w, g_array([1,2,g_array([a,b,c]), g_array(2,z),5])), g_read(w, X).
X = g_array([1,2,g_array([a,b,c]), g_array([z,z]),5])

?- g_read(w(1), X), g_read(w(2,1), Y), g_read(w(3,1), Z).
X = 2
Y = b
Z = z

?- g_read(w(1,2),X).
uncaught exception: error(domain_error(g_array_index,w(1,2)),g_read/2)

Array extension:

?- g_assign(a, g_array([10,20,30])), g_read(a, X).
X = g_array([10,20,30])

?- g_assign(a, g_array_extend(5,null)), g_read(a, X).
X = g_array([10,20,30,null,null])

?- g_assign(a, g_array([10,20,30])), g_read(a, X).
X = g_array([10,20,30])

?- g_assign(a, g_array_extend([1,2,3,4,5,6])), g_read(a, X).
X = g_array([10,20,30,4,5,6])

Automatic array:
?- g_assign(t, g_array_auto(3)), g_assign(t(1), foo), g_read(t,X).
X = g_array([0,foo,0])

?- g_assign(t(5), bar), g_read(t,X).
X = g_array([0,foo,0,0,0,bar,0,0])

?- g_assign(t, g_array_auto(2, g_array(2))), g_assign(t(1,1), foo),
g_read(t,X).
X = g_array([g_array([0,0]),g_array([0,foo])])

?- g_assign(t(3,0), bar), g_read(t,X).
X = g_array([g_array([0,0]),g_array([0,foo]),g_array([0,0]),g_array([bar,0])])

?- g_assign(t(3,4), bar), g_read(t,X).
uncaught exception: error(domain_error(g_array_index,t(3,4)),g_assign/2)

?- g_assign(t, g_array_auto(2, g_array_auto(2))), g_assign(t(1,1), foo),
g_read(t,X).
X = g_array([g_array([0,0]),g_array([0,foo])])

?- g_assign(t(3,0), bar), g_read(t,X).
X = g_array([g_array([0,0]),g_array([0,foo]),g_array([0,0]),g_array([0,0,0,bar])])

?- g_assign(t, g_array_auto(2, g_array_auto(2), null)), g_read(t(2,3), U),
g_read(t, X).
U = null
X = g_array([g_array([null,null]),g_array([null,null]),
g_array([null,null,null,null]),g_array([null,null])])

8.22 Prolog state

8.22.1 set_prolog_flag/2

Templates

set_prolog_flag(+flag, +term)

Description

set_prolog_flag(Flag, Value) sets the value of the Prolog flag Flag to Value.

Prolog flags: a Prolog flag is an atom which is associated with a value that is either implementation defined or defined by the user. Each flag has a permitted range of values; any other value is a domain error. The following two tables present available flags, the possible values, a description and if they are ISO or an extension. The first table presents unchangeable flags while the second one the changeable flags. For
flags whose default values is machine independent, this value is underlined.

**Unchangeable flags:**

<table>
<thead>
<tr>
<th>Flag</th>
<th>Values</th>
<th>Description</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>prolog_name</td>
<td>an atom</td>
<td>name of the Prolog system</td>
<td>N</td>
</tr>
<tr>
<td>prolog_version</td>
<td>an atom</td>
<td>version number of the Prolog system</td>
<td>N</td>
</tr>
<tr>
<td>prolog_date</td>
<td>an atom</td>
<td>date of the Prolog system</td>
<td>N</td>
</tr>
<tr>
<td>prolog_copyright</td>
<td>an atom</td>
<td>copyright message of the Prolog system</td>
<td>N</td>
</tr>
<tr>
<td>dialect</td>
<td>an atom</td>
<td>fixed to gprolog</td>
<td>N</td>
</tr>
<tr>
<td>version</td>
<td>an integer</td>
<td>Major * 10000 + Minor * 100 + Patch</td>
<td>N</td>
</tr>
<tr>
<td>version_data</td>
<td>a structure</td>
<td>gprolog(Major,Minor,Patch,Extra)</td>
<td>N</td>
</tr>
<tr>
<td>bounded</td>
<td>true / false</td>
<td>are integers bounded ?</td>
<td>Y</td>
</tr>
<tr>
<td>max_integer</td>
<td>an integer</td>
<td>greatest integer</td>
<td>Y</td>
</tr>
<tr>
<td>min_integer</td>
<td>an integer</td>
<td>smallest integer</td>
<td>Y</td>
</tr>
<tr>
<td>integer_rounding_function</td>
<td></td>
<td><strong>RND</strong>(X) = integer part of X <strong>RND</strong>(X) =</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>max arity</td>
<td>an integer</td>
<td>maximum arity for compound terms (255)</td>
<td>Y</td>
</tr>
<tr>
<td>max atom</td>
<td>an integer</td>
<td>maximum number of atoms</td>
<td>N</td>
</tr>
<tr>
<td>max unget</td>
<td>an integer</td>
<td>maximum number of successive ungets</td>
<td>N</td>
</tr>
<tr>
<td>home</td>
<td>an atom</td>
<td>GNU Prolog home directory</td>
<td>N</td>
</tr>
<tr>
<td>host_os</td>
<td>an atom</td>
<td>Operating System identifier</td>
<td>N</td>
</tr>
<tr>
<td>host_vendor</td>
<td>an atom</td>
<td>Operating System vendor</td>
<td>N</td>
</tr>
<tr>
<td>host_cpu</td>
<td>an atom</td>
<td>processor identifier</td>
<td>N</td>
</tr>
<tr>
<td>host</td>
<td>an atom</td>
<td>a combination of the OS-vendor-cpu</td>
<td>N</td>
</tr>
<tr>
<td>arch</td>
<td>an atom</td>
<td>a combination of the OS-cpu</td>
<td>N</td>
</tr>
<tr>
<td>address_bits</td>
<td>an integer</td>
<td>address size of the machine (32 or 64)</td>
<td>N</td>
</tr>
<tr>
<td>unix</td>
<td>on/off</td>
<td>is the architecture an Unix-like OS ?</td>
<td>N</td>
</tr>
<tr>
<td>compiled_at</td>
<td>an atom</td>
<td>compilation date using <code>DATE</code> and <code>TIME</code> C compiler macros</td>
<td>N</td>
</tr>
<tr>
<td>c_cc</td>
<td>an atom</td>
<td>C compiler used to compile GNU Prolog (gcc, cc, clang, cl,...)</td>
<td>N</td>
</tr>
<tr>
<td>c_cc_version_data</td>
<td>a structure</td>
<td>c_cc(Major,Minor,Patch,Extra)</td>
<td>N</td>
</tr>
<tr>
<td>c_cflags</td>
<td>an atom</td>
<td>CFLAGS used to compile GNU Prolog</td>
<td>N</td>
</tr>
<tr>
<td>c_lflags</td>
<td>an atom</td>
<td>LDFLAGS used to compile GNU Prolog</td>
<td>N</td>
</tr>
<tr>
<td>argv</td>
<td>a list of atoms</td>
<td>list of command-line arguments</td>
<td>N</td>
</tr>
</tbody>
</table>

**Changeable flags:**
<table>
<thead>
<tr>
<th>Flag</th>
<th>Values</th>
<th>Description</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>char_conversion</td>
<td>on / off</td>
<td>is character conversion activated ?</td>
<td>Y</td>
</tr>
<tr>
<td>singleton_warning</td>
<td>on / off</td>
<td>warn about named singleton variables ?</td>
<td>N</td>
</tr>
<tr>
<td>suspicious_warning</td>
<td>on / off</td>
<td>warn about suspicious predicate ?</td>
<td>N</td>
</tr>
<tr>
<td>multifile_warning</td>
<td>on / off</td>
<td>warn about unsupported multifile directive ?</td>
<td>N</td>
</tr>
<tr>
<td>strict_iso</td>
<td>on / off</td>
<td>strict ISO behavior ?</td>
<td>N</td>
</tr>
<tr>
<td>debug</td>
<td>on / off</td>
<td>is the debugger activated ?</td>
<td>Y</td>
</tr>
<tr>
<td>double_quotes</td>
<td>atom(chars</td>
<td>a double quoted constant is returned as:</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>codes(atom_no_escape(chars_no_escape(codes_no_escape)</td>
<td>as atom but ignore escape sequences as chars but ignore escape sequences as code but ignore escape sequences</td>
<td>N</td>
</tr>
<tr>
<td>back_quotes</td>
<td>atom(chars</td>
<td>a back quoted constant is returned as:</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>codes(atom_no_escape(chars_no_escape(codes_no_escape)</td>
<td>as atom but ignore escape sequences as chars but ignore escape sequences as code but ignore escape sequences</td>
<td>N</td>
</tr>
<tr>
<td>unknown</td>
<td>error</td>
<td>a predicate calls an unknown procedure:</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>warning</td>
<td>an existence_error is raised</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fail</td>
<td>a message is displayed then fails quietly fails</td>
<td></td>
</tr>
<tr>
<td>syntax_error</td>
<td>error</td>
<td>a predicate causes a syntax error:</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>warning</td>
<td>a syntax_error is raised</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fail</td>
<td>a message is displayed then fails quietly fails</td>
<td></td>
</tr>
<tr>
<td>os_error</td>
<td>error</td>
<td>a predicate causes an O.S. error:</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>warning</td>
<td>a system_error is raised</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fail</td>
<td>a message is displayed then fails quietly fails</td>
<td></td>
</tr>
</tbody>
</table>

The strict_iso flag is introduced to allow a compatibility with other Prolog systems. When turned off the following relaxations apply:

- built-in predicates are found by current_predicate/1 (section 8.8.1 page 74).
- the term parser (read/1 and friends) is more indulgent, e.g. 0'' is accepted and returns 39, the escape sequence 's (space) and \e (escape) are accepted.
- the following arithmetic rounding functions: ceiling, floor, round, truncate also accept integers (section 8.6.1 page 66).

Errors

<table>
<thead>
<tr>
<th>Flag is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Flag is neither a variable nor an atom</td>
<td>type_error(atom, Flag)</td>
</tr>
<tr>
<td>Flag is an atom but not a valid flag</td>
<td>domain_error(prolog_flag, Flag)</td>
</tr>
<tr>
<td>Value is inappropriate for Flag</td>
<td>domain_error(flag_value, Flag+Value)</td>
</tr>
<tr>
<td>Value is appropriate for Flag but flag Flag is not modifiable</td>
<td>permission_error(modify, flag, Flag)</td>
</tr>
</tbody>
</table>
Portability

ISO predicate. All ISO flags are implemented.

8.22.2  current_prolog_flag/2

Templates

current_prolog_flag(?flag, ?term)

Description

current_prolog_flag(Flag, Value) succeeds if there exists a Prolog flag that unifies with Flag and
whose value unifies with Value. This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Flag is neither a variable nor an atom</th>
<th>type_error(atom, Flag)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flag is an atom but not a valid flag</td>
<td>domain_error(prolog_flag, Flag)</td>
</tr>
</tbody>
</table>

Portability

ISO predicate.

8.22.3  set_bip_name/2

Templates

set_bip_name(+atom, +arity)

Description

set_bip_name(Functor, Arity) initializes the context of the error (section 6.3.1, page 39) with Functor
and Arity (if Arity < 0 only Functor is significant).

Errors

<table>
<thead>
<tr>
<th>Functor is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arity is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Functor is neither a variable nor an atom</td>
<td>type_error(atom, Functor)</td>
</tr>
<tr>
<td>Arity is neither a variable nor an integer</td>
<td>type_error(integer, Arity)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.22.4  current_bip_name/2

Templates

current_bip_name(?atom, ?arity)
Description

current_bip_name(Functor, Arity) succeeds if Functor and Arity correspond to the context of the error (section 6.3.1 page 39) (if Arity < 0 only Functor is significant).

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Type Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functor is neither a variable nor an atom</td>
<td>type_error(atom, Functor)</td>
</tr>
<tr>
<td>Arity is neither a variable nor an integer</td>
<td>type_error(integer, Arity)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.22.5 write_pl_state_file/1, read_pl_state_file/1

Templates

write_pl_state_file(+source_sink)
read_pl_state_file(+source_sink)

Description

write_pl_state_file(FileName) writes onto FileName all information that influences the parsing of a term (section 8.14 page 104). This allows a sub-process written in Prolog to read this file and then process any Prolog term as done by the parent process. This file can also be passed as argument of the --pl-state option when invoking gplc (section 4.4.3 page 23). More precisely the following elements are saved:

- all operator definitions (section 8.14.10 page 113).
- the value of char_conversion, double_quotes, back_quotes, singleton_warning, suspicious_warning and multifile_warning Prolog flags (section 8.22.1 page 148).

read_pl_state_file(FileName) reads (restores) from FileName all information previously saved by write_pl_state_file/1.

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Type Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>FileName is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>FileName is neither a variable nor an atom</td>
<td>type_error(atom, FileName)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.23 Program state

8.23.1 consult/1, ’./2 - program consult

Templates

    consult(+atom_or_atom_list)
    ’./(+atom, +atom_list)

Description

consult(Files) compiles and loads into memory each file of the list Files. Each file is compiled for byte-code using the GNU Prolog compiler (section 4.4 page 21) then loaded using load/1 (section 8.23.2 page 153). It is possible to specify user as a file name to directly enter the program from the terminal. Files can also be a single file name (i.e. an atom). Refer to the section concerning the consult of a Prolog program for more information (section 4.2.3 page 17).

The final file name of a file is computed using the predicates prolog_file_name/2 (section 8.26.4 page 159) and absolute_file_name/2 (section 8.26.1 page 158).

[ File | Files ], i.e. ’./(File, Files) is equivalent to consult([ File | Files ]).

Since version 1.4.0, with the introduction of shebang support, consult/1 ignores the first line of a Prolog source file which directly begins with #. See (section 4.2.4 page 18) for more information about shebang support and PrologScript.

Errors

| Files is a partial list or a list with an element E      | instantiation_error |
| Files is neither a partial list nor a list nor an atom | type_error(list, Files) |
| an element E of the Files list is neither a variable nor an atom | type_error(atom, E) |
| an element E of the Files list is an atom but not a valid pathname | domain_error(os_path, E) |
| an element E of the Files list is a valid pathname but does not correspond to an existing source | existence_error(source_sink, E) |
| an error occurs executing a directive                  | see call/1 errors (section 7.2.3 page 52) |

Portability

GNU Prolog predicates.

8.23.2 load/1

Templates

    load(+atom_or_atom_list)

Description
load(Files) loads into memory each file of the list Files. Each file must have been previously compiled for byte-code using the GNU Prolog compiler (section 4.4 page 21). Files can be also a single file name (i.e. an atom).

The final file name of a file is computed using the predicates absolute_file_name/2 (section 8.26.1 page 158). If no suffix is given ’.wbc’ is appended to the file name.

**Errors**

<table>
<thead>
<tr>
<th>Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Files is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Files is neither a partial list nor a list nor an atom</td>
<td>type_error(list, Files)</td>
</tr>
<tr>
<td>an element E of the Files list is neither a variable nor an atom</td>
<td>type_error(atom, E)</td>
</tr>
<tr>
<td>an element E of the Files list is an atom but not a valid pathname</td>
<td>domain_error(os_path, E)</td>
</tr>
<tr>
<td>an element E of the Files list is a valid pathname but does not correspond to an existing source</td>
<td>existence_error(source_sink, E)</td>
</tr>
<tr>
<td>an error occurs executing a directive</td>
<td>see call/1 errors (section 7.2.3 page 52)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicate.

8.23.3 listing/1, listing/0

**Templates**

- listing(+predicate_indicator)
- listing(+atom)
- listing

**Description**

listing(Pred) lists the clauses of the consulted predicate whose predicate indicator is Pred. Pred can also be a single atom in which case all predicates whose name is Pred are listed (of any arity). This predicate uses portray_clause/2 (section 8.14.8 page 112) to output the clauses.

listing lists all clauses of all consulted predicates.

**Errors**

<table>
<thead>
<tr>
<th>Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pred is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Pred is neither a variable nor predicate indicator or an atom</td>
<td>type_error(predicate_indicator, Pred)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicate.
8.24 System statistics

8.24.1 statistics/0, statistics/2

Templates

\[
\text{statistics}
\]
\[
\text{statistics}(\text{?atom, ?list})
\]

Description

\text{statistics} displays statistics about memory usage and run times.

\text{statistics(Key, Value)} unifies \text{Value} with the current value of the statistics key \text{Key}. \text{Value} a list of two elements. Times are in milliseconds, sizes of areas in bytes.

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_time</td>
<td>user CPU time</td>
<td>[SinceStart, SinceLast]</td>
</tr>
<tr>
<td>system_time</td>
<td>system CPU time</td>
<td>[SinceStart, SinceLast]</td>
</tr>
<tr>
<td>cpu_time</td>
<td>total CPU time (user + system)</td>
<td>[SinceStart, SinceLast]</td>
</tr>
<tr>
<td>real_time</td>
<td>absolute time</td>
<td>[SinceStart, SinceLast]</td>
</tr>
<tr>
<td>local_stack</td>
<td>local stack sizes (control, environments, choices)</td>
<td>[UsedSize, FreeSize]</td>
</tr>
<tr>
<td>global_stack</td>
<td>global stack sizes (compound terms)</td>
<td>[UsedSize, FreeSize]</td>
</tr>
<tr>
<td>trail_stack</td>
<td>trail stack sizes (variable bindings to undo)</td>
<td>[UsedSize, FreeSize]</td>
</tr>
<tr>
<td>cstr_stack</td>
<td>constraint trail sizes (finite domain constraints)</td>
<td>[UsedSize, FreeSize]</td>
</tr>
<tr>
<td>atoms</td>
<td>atom table</td>
<td>[NumberOfAtoms, FreeNumberOfAtoms]</td>
</tr>
</tbody>
</table>

Note that the key \text{runtime} is recognized as \text{user_time} for compatibility purpose.

Errors

<table>
<thead>
<tr>
<th>Key is neither a variable nor a valid key</th>
<th>domain_error(statistics_key, Key)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value is neither a variable nor a list of two elements</td>
<td>domain_error(statistics_value, Value)</td>
</tr>
<tr>
<td>Value is a list of two elements and an element \text{E} is neither a variable nor an integer</td>
<td>type_error(integer, \text{E})</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.24.2 user_time/1, system_time/1, cpu_time/1, real_time/1

Templates

\[
\text{user_time(?integer)}
\]
\[
\text{system_time(?integer)}
\]
\[
\text{cpu_time(?integer)}
\]
\[
\text{real_time(?integer)}
\]

Description

\text{user_time(Time)} unifies \text{Time} with the user CPU time elapsed since the start of Prolog.
system_time(Time) unifies Time with the system CPU time elapsed since the start of Prolog.

cpu_time(Time) unifies Time with the CPU time (user + system) elapsed since the start of Prolog.

real_time(Time) unifies Time with the absolute time elapsed since the start of Prolog.

Errors

| Time is neither a variable nor an integer | type_error(integer, Time) |

Portability

GNU Prolog predicates.

8.25 Random number generator

8.25.1 set_seed/1, randomize/0

Templates

set_seed(+integer)
randomize

Description

set_seed(Seed) reinitializes the random number generator seed with Seed.

randomize reinitializes the random number generator. This predicates calls set_seed/1 with a random value depending on the absolute time.

Errors

<table>
<thead>
<tr>
<th>Seed is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed is neither a variable nor an integer</td>
<td>type_error(integer, Seed)</td>
</tr>
<tr>
<td>Seed is an integer &lt; 0</td>
<td>domain_error(not_less_than_zero, Seed)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.25.2 get_seed/1

Templates

get_seed(?integer)

Description

get_seed(Seed) unifies Seed with the current random number generator seed.

Errors
8.25 Random number generator

| Seed is neither a variable nor an integer | type_error(integer, Seed) |
| Seed is an integer < 0                   | domain_error(not_less_than_zero, Seed) |

Portability

GNU Prolog predicate.

8.25.3 random/1

Templates

random(-float)

Description

random(Number) unifies Number with a random floating point number such that 0.0 ≤ Number < 1.0.

Errors

| Number is not a variable | uninstantiation_error(Number) |

Portability

GNU Prolog predicate.

8.25.4 random/3

Templates

random(+number, +number, -number)

Description

random(Base, Max, Number) unifies Number with a random number such that Base ≤ Number < Max. If both Base and Max are integers Number will be an integer, otherwise Number will be a floating point number.

Errors

| Base is a variable | instantiation_error |
| Base is neither a variable nor a number | type_error(number, Base) |
| Max is a variable | instantiation_error |
| Max is neither a variable nor a number | type_error(number, Max) |
| Number is not a variable | uninstantiation_error(Number) |

Portability

GNU Prolog predicate.
8.26  File name processing

8.26.1  absolute_file_name/2

Templates

    absolute_file_name(+atom, atom)

Description

absolute_file_name(File1, File2) succeeds if File2 is the absolute pathname associated with the relative file name File1. File1 can contain $VAR_NAME$ sub-strings. When such a sub-string is encountered, it is expanded with the value of the environment variable whose name is VAR_NAME if exists (otherwise no expansion is done). File1 can also begin with a sub-string ~USER_NAME/, this is expanded as the home directory of the user USER_NAME. If USER_NAME does not exist File1 is an invalid pathname. If no USER_NAME is given (i.e. File1 begins with ~/) the ~ character is expanded as the value of the environment variable HOME. If the HOME variable is not defined File1 is an invalid pathname. Relative references to the current directory (/./ sub-string) and to the parent directory (/../ sub-strings) are removed and no longer appear in File2. File1 is also invalid if it contains too many /../ sub-strings (i.e. parent directory relative references). Finally if File1 is user then File2 is also unified with user to allow this predicate to be called on Prolog file names (since user in DEC-10 input/output predicates denotes the current input/output stream).

Under Windows the following applies:

- an alternate recognized form for $VAR_NAME$ is %VAR_NAME%.

- when ~ is expanded, if the HOME variable is not defined, ~ is expanded using HOMEDIR and HOMEPATH (if HOMEPATH is not defined then File1 is an invalid pathname).

Most predicates using a file name implicitly call this predicate to obtain the desired file, e.g. open/4.

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>File1 is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>File1 is neither a variable nor an atom</td>
<td>type_error(atom, File1)</td>
</tr>
<tr>
<td>File2 is neither a variable nor an atom</td>
<td>type_error(atom, File2)</td>
</tr>
<tr>
<td>File1 is an atom but not a valid pathname</td>
<td>domain_error(os_path, File1)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.26.2  is_absolute_file_name/1, is_relative_file_name/1

Templates

    is_absolute_file_name(+atom)
    is_relative_file_name(+atom)

Description

is_absolute_file_name(PathName) succeeds if PathName is an absolute file name.
Conversely, `is_relative_file_name(PathName)` succeeds if `PathName` is not an absolute file name.

See `absolute_file_name/2` for information about the syntax of `PathName` (section 8.26.1, page 158).

The current implementation does not check the validity of `PathName`. If `PathName` starts with a `/` (slash) it is considered as absolute. Under Windows, `PathName` can also start with a `\` (backslash) or a drive specification.

**Errors**

<table>
<thead>
<tr>
<th>PathName is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>PathName is neither a variable nor an atom</td>
<td>type_error(atom, PathName)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.

### 8.26.3 `decompose_file_name/4`

**Templates**


**Description**

`decompose_file_name(File, Directory, Prefix, Suffix)` decomposes the pathname `File` and extracts the `Directory` part (characters before the last `/`), the `Prefix` part (characters after the last `/` and before the last `.`, or until the end if there is no suffix) and the `Suffix` part (characters from the last `. ` to the end of the string).

**Errors**

<table>
<thead>
<tr>
<th>File is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>File is neither a variable nor an atom</td>
<td>type_error(atom, File)</td>
</tr>
<tr>
<td>Directory is neither a variable nor an atom</td>
<td>type_error(atom, Directory)</td>
</tr>
<tr>
<td>Prefix is neither a variable nor an atom</td>
<td>type_error(atom, Prefix)</td>
</tr>
<tr>
<td>Suffix is neither a variable nor an atom</td>
<td>type_error(atom, Suffix)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicate.

### 8.26.4 `prolog_file_name/2`

**Templates**

`prolog_file_name(+atom, ?atom)`

**Description**

`prolog_file_name(File1, File2)` unifies `File2` with the Prolog file name associated with `File1`. More precisely `File2` is computed as follows:

- if `File1` has a suffix or if it is `user` then `File2` is unified with `File1`. 
• else if the file whose name is File1 + '.pl' exists then File2 is unified with this name.
• else if the file whose name is File1 + '.pro' exists then File2 is unified with this name.
• else if the file whose name is File1 + '.prolog' exists then File2 is unified with this name.
• else File2 is unified with the name File1 + '.pl'.

This predicate uses absolute_file_name/2 to check the existence of a file (section 8.26.1, page 158).

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>File1 is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>File1 is neither a variable nor an atom</td>
<td>type_error(atom, File1)</td>
</tr>
<tr>
<td>File2 is neither a variable nor an atom</td>
<td>type_error(atom, File2)</td>
</tr>
<tr>
<td>File1 is an atom but not a valid pathname</td>
<td>domain_error(os_path, File1)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27 Operating system interface

8.27.1 argument_counter/1

Templates

argument_counter(?integer)

Description

argument_counter(Counter) succeeds if Counter is the number of arguments of the command-line. Since the first argument is always the name of the running program, Counter is always ≥ 1. See (section 4.2, page 13) for more information about command-line arguments retrieved under the top-level.

Errors

<table>
<thead>
<tr>
<th>Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counter is neither a variable nor an integer</td>
<td>type_error(integer, Counter)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.2 argument_value/2

Templates

argument_value(+integer, ?atom)

Description

argument_value(N, Arg) succeeds if the Nth argument on the command-line unifies with Arg. The first argument is always the name of the running program and its number is 0. The number of arguments on the command-line can be obtained using argument_counter/1 (section 8.27.1, page 100).
Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N ) is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>( N ) is neither a variable nor an integer</td>
<td>type_error(integer, ( N ))</td>
</tr>
<tr>
<td>( N ) is an integer (&lt; 0)</td>
<td>domain_error(not_less_than_zero, ( N ))</td>
</tr>
<tr>
<td>( \text{Arg} ) is neither a variable nor an atom</td>
<td>type_error(atom, ( \text{Arg} ))</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.3 argument_list/1

Templates

\[
\text{argument_list(?list)}
\]

Description

\( \text{argument_list}(\text{Args}) \) succeeds if \( \text{Args} \) unifies with the list of atoms associated with each argument on the command-line other than the first argument (the name of the running program).

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Args} ) is neither a partial list nor a list</td>
<td>type_error(list, ( \text{Args} ))</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.4 environ/2

Templates

\[
\text{environ(?atom, ?atom)}
\]

Description

\( \text{environ}(\text{Name}, \text{Value}) \) succeeds if \( \text{Name} \) is the name of an environment variable whose value is \( \text{Value} \). This predicate is re-executable on backtracking.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Name} ) is neither a variable nor an atom</td>
<td>type_error(atom, ( \text{Name} ))</td>
</tr>
<tr>
<td>( \text{Value} ) is neither a variable nor an atom</td>
<td>type_error(atom, ( \text{Value} ))</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.27.5  make_directory/1, delete_directory/1, change_directory/1

Templates

make_directory(+atom)
delete_directory(+atom)
change_directory(+atom)

Description

make_directory(PathName) creates the directory whose pathname is PathName.
delete_directory(PathName) removes the directory whose pathname is PathName.
change_directory(PathName) sets the current directory to the directory whose pathname is PathName.

See absolute_file_name/2 for information about the syntax of PathName (section 8.26.1, page 158).

Errors

| PathName is a variable | instantiation_error |
| PathName is neither a variable nor an atom | type_error(atom, PathName) |
| PathName is an atom but not a valid pathname | domain_error(os_path, PathName) |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1, page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicates.

8.27.6  working_directory/1

Templates

working_directory(?atom)

Description

working_directory(PathName) succeeds if PathName is the pathname of the current directory.

Errors

| PathName is neither a variable nor an atom | type_error(atom, PathName) |

Portability

GNU Prolog predicate.

8.27.7  directory_files/2

Templates
directory_files(+atom, ?list)

Description

directory_files(PathName, Files) succeeds if Files is the list of all entries (files, sub-directories,...) in the directory whose pathname is PathName. See absolute_file_name/2 for information about the syntax of PathName (section 8.26.1 page 158).

Errors

<table>
<thead>
<tr>
<th>PathName is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>PathName is neither a variable nor an atom</td>
<td>type_error(atom, PathName)</td>
</tr>
<tr>
<td>PathName is an atom but not a valid pathname</td>
<td>domain_error(os_path, PathName)</td>
</tr>
<tr>
<td>Files is neither a partial list nor a list</td>
<td>type_error(list, Files)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.8 rename_file/2

Templates

rename_file(+atom, +atom)

Description

rename_file(PathName1, PathName2) renames the file or directory whose pathname is PathName1 to PathName2. See absolute_file_name/2 for information about the syntax of PathName1 and PathName2 (section 8.26.1 page 158).

Errors

<table>
<thead>
<tr>
<th>PathName1 is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>PathName1 is neither a variable nor an atom</td>
<td>type_error(atom, PathName1)</td>
</tr>
<tr>
<td>PathName1 is an atom but not a valid pathname</td>
<td>domain_error(os_path, PathName1)</td>
</tr>
<tr>
<td>PathName2 is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>PathName2 is neither a variable nor an atom</td>
<td>type_error(atom, PathName2)</td>
</tr>
<tr>
<td>PathName2 is an atom but not a valid pathname</td>
<td>domain_error(os_path, PathName2)</td>
</tr>
<tr>
<td>an operating system error occurs and value of the os_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.9 delete_file/1, unlink/1

Templates


```prolog
delete_file(PathName)
unlink(PathName)
```

**Description**

`delete_file(PathName)` removes the existing file whose pathname is `PathName`.

`unlink/1` is similar to `delete_file/1` except that it never causes a `system_error` (e.g. if `PathName` does not refer to an existing file).

See `absolute_file_name/2` for information about the syntax of `PathName` (section 8.26.1, page 158).

**Errors**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>PathName</code> is a variable</td>
<td><code>instantiation_error</code></td>
</tr>
<tr>
<td><code>PathName</code> is neither a variable nor an atom</td>
<td><code>type_error(atom, PathName)</code></td>
</tr>
<tr>
<td><code>PathName</code> is an atom but not a valid pathname</td>
<td><code>domain_error(os_path, PathName)</code></td>
</tr>
<tr>
<td>an operating system error occurs and the value of the</td>
<td><code>system_error(atom explaining the error)</code></td>
</tr>
<tr>
<td><code>os_error</code> Prolog flag is <code>error</code></td>
<td></td>
</tr>
<tr>
<td>(section 8.22.1, page 148)</td>
<td></td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.

**8.27.10  file_permission/2, file_exists/1**

**Templates**

- `file_permission(+atom, +atom)`
- `file_permission(+atom, +atom_list)`
- `file_exists(+atom)`

**Description**

`file_permission(PathName, Permission)` succeeds if `PathName` is the pathname of an existing file (or directory) whose permissions include `Permission`.

**File permissions**: `Permission` can be a single permission or a list of permissions. A permission is an atom among:

- `read`: the file or directory can be read.
- `write`: the file or directory can be written.
- `execute`: the file can be executed.
- `search`: the directory can be searched.

If `PathName` does not exist or if its permissions do not include `Permission` this predicate fails.

`file_exists(PathName)` is equivalent to `file_permission(PathName, [])`, i.e. it succeeds if `PathName` is the pathname of an existing file (or directory).

See `absolute_file_name/2` for information about the syntax of `PathName` (section 8.26.1, page 158).
Errors

<table>
<thead>
<tr>
<th>PathName is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>PathName is neither a variable nor an atom</td>
<td>type_error(atom, PathName)</td>
</tr>
<tr>
<td>PathName is an atom but not a valid pathname</td>
<td>domain_error(os_path, PathName)</td>
</tr>
<tr>
<td>Permission is a partial list or a list with an element which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Permission is neither an atom nor partial list or a list</td>
<td>type_error(list, Permission)</td>
</tr>
<tr>
<td>an element E of the Permission list is neither a variable nor an atom</td>
<td>type_error(atom, E)</td>
</tr>
<tr>
<td>an element E of the Permission is an atom but not a valid permission</td>
<td>domain_error(os_file.permission, Permission)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.27.11 file_property/2

Templates

file_property(+atom, ?os_file_property)

Description

file_property(PathName, Property) succeeds if PathName is the pathname of an existing file (or directory) and if Property unifies with one of the properties of the file. This predicate is re-executable on backtracking.

File properties:

- absolute_file_name(File): File is the absolute file name of PathName (section 8.26.1 page 158).
- real_file_name(File): File is the real file name of PathName (follows symbolic links).
- type(Type): Type is the type of PathName. Possible values are: regular, directory, fifo, socket, character_device, block_device or unknown.
- size(Size): Size is the size (in bytes) of PathName.
- permission(Permission): Permission is a permission of PathName (section 8.27.10 page 164).
- last_modification(DT): DT is the last modification date and time (section 8.27.14 page 167).

See absolute_file_name/2 for information about the syntax of PathName (section 8.26.1 page 158).

Errors
### PathName is a variable
- instantiation_error

### PathName is neither a variable nor an atom
- type_error(atom, PathName)

### PathName is an atom but not a valid pathname
- domain_error(os_path, PathName)

### Property is neither a variable nor a file property term
- domain_error(os_file_property, Property)

### Property = absolute_file_name(E), real_file_name(E), type(E) or permission(E) and E is neither a variable nor an atom
- type_error(atom, E)

### Property = last_modification(Date_time) and Date_time is neither a variable nor a compound term
- type_error(compound, Date_time)

### Property = last_modification(Date_time) and Date_time is a compound term but not a structure dt/6
- domain_error(date_time, Date_time)

### Property = size(E) or last_modification(Date_time) and Date_time is a structure dt/6 but an element E is neither a variable nor an integer
- type_error(integer, E)

### an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148)
- system_error(atom explaining the error)

### Portability
GNU Prolog predicate.

### 8.27.12 temporary_name/2

#### Templates
- temporary_name(+atom, ?atom)

#### Description

`temporary_name(Template, PathName)` creates a unique file name `PathName` whose pathname begins by `Template`. `Template` should contain a pathname with six trailing Xs. `PathName` is `Template` with the six Xs replaced with a letter and the process identifier. This predicate is an interface to the C Unix function `mktemp(3)`.

See `absolute_file_name/2` for information about the syntax of `Template` (section 8.26.1 page 158).

#### Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Template is neither a variable nor an atom</td>
<td>type_error(atom, Template)</td>
</tr>
<tr>
<td>Template is an atom but not a valid pathname</td>
<td>domain_error(os_path, Template)</td>
</tr>
<tr>
<td>PathName is neither a variable nor an atom</td>
<td>type_error(atom, PathName)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

### Portability
GNU Prolog predicate.
8.27.13 temporary_file/3

Templates

temporary_file(+atom, +atom, ?atom)

Description

temporary_file(Directory, Prefix, PathName) creates a unique file name PathName whose pathname begins by Directory/Prefix. If Directory is the empty atom ‘’ a standard temporary directory will be used (e.g. /tmp). Prefix can be the empty atom ‘’. This predicate is an interface to the C Unix function tempnam(3).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directory is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Directory is neither a variable nor an atom</td>
<td>type_error(atom, Directory)</td>
</tr>
<tr>
<td>Directory is an atom but not a valid pathname</td>
<td>domain_error(os_path, Directory)</td>
</tr>
<tr>
<td>Prefix is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Prefix is neither a variable nor an atom</td>
<td>type_error(atom, Prefix)</td>
</tr>
<tr>
<td>PathName is neither a variable nor an atom</td>
<td>type_error(atom, PathName)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is</td>
<td>system_error(atom explaining the error)</td>
</tr>
<tr>
<td>error (section 8.22.1 page 148)</td>
<td></td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.14 date_time/1

Templates

date_time(?compound)

Description

date_time(DateTime) unifies DateTime with a compound term containing the current date and time. DateTime is a structure dt(Year, Month, Day, Hour, Minute, Second). Each sub-argument of the term dt/6 is an integer.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>DateTime is neither a variable nor a compound term</td>
<td>type_error(compound, DateTime)</td>
</tr>
<tr>
<td>DateTime is a compound term but not a structure dt/6</td>
<td>domain_error(date_time, DateTime)</td>
</tr>
<tr>
<td>DateTime is a structure dt/6 and an element E is not a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.27.15 host_name/1

Templates

host_name(?atom)

Description

host_name(HostName) unifies HostName with the name of the host machine executing the current GNU Prolog process. If the sockets are available (section 8.28.1, page 170), the name returned will be fully qualified. In that case, host_name/1 will also succeed if HostName is instantiated to the unqualified name (or an alias) of the machine.

Errors

| HostName is neither a variable nor an atom | type_error(atom, HostName) |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1, page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.27.16 os_version/1

Templates

os_version(?atom)

Description

os_version(OSVersion) unifies OSVersions with the operating system version of the machine executing the current GNU Prolog process.

Errors

| OSVersions is neither a variable nor an atom | type_error(atom, OSVersions) |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1, page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.27.17 architecture/1

Templates

architecture(?atom)

Description
architecture(Architecture) unifies Architecture with the name of the machine executing the current GNU Prolog process.

Errors

<table>
<thead>
<tr>
<th>Architecture is neither a variable nor an atom</th>
<th>type_error(atom, Architecture)</th>
</tr>
</thead>
<tbody>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148)</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.18  shell/2, shell/1, shell/0

Templates

shell(+atom, ?integer)  shell(+atom)  shell

Description

shell(Command, Status) invokes a new shell (named by the SHELL environment variable) passing Command for execution and unifies Status with the result of the execution. If Command is the empty atom '' a new interactive shell is executed. The control is returned to Prolog upon termination of the called process.

shell(Command) is equivalent to shell(Command, 0).

shell is equivalent to shell('', 0).

Errors

<table>
<thead>
<tr>
<th>Command is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command is neither a variable nor an atom</td>
<td>type_error(atom, Command)</td>
</tr>
<tr>
<td>Status is neither a variable nor an integer</td>
<td>type_error(integer, Status)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

8.27.19  system/2, system/1

Templates

system(+atom, ?integer)  system(+atom)

Description

system(Command, Status) invokes a new default shell passing Command for execution and unifies Status
with the result of the execution. The control is returned to Prolog upon termination of the shell process. This predicate is an interface to the C Unix function system(3).

system(Command) is equivalent to system(Command, 0).

Errors

| Command is a variable                          | instantiation_error                          |
| Command is neither a variable nor an atom     | type_error(atom, Command)                    |
| Status is neither a variable nor an integer   | type_error(integer, Status)                 |

Portability

GNU Prolog predicates.

8.27.20 spawn/3, spawn/2

Templates

spawn(+atom, +atom_list, ?integer)  
spawn(+atom, +atom_list)

Description

spawn(Command, Arguments, Status) executes Command passing as arguments of the command-line each element of the list Arguments and unifies Status with the result of the execution. The control is returned to Prolog upon termination of the command.

spawn(Command, Arguments) is equivalent to spawn(Command, Arguments, 0).

Errors

| Command is a variable                          | instantiation_error                          |
| Command is neither a variable nor an atom     | type_error(atom, Command)                    |
| Arguments is a partial list or a list with an element which is a variable | instantiation_error |
| Arguments is neither a partial list nor a list | type_error(list, Arguments) |
| an element E of the Arguments list is neither a variable nor an atom | type_error(atom, E) |
| Status is neither a variable nor an integer   | type_error(integer, Status)                 |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicates.

8.27.21 popen/3

Templates

popen(+atom, +io_mode, -stream)
Description

`popen(Command, Mode, Stream)` invokes a new default shell (by creating a pipe) passing Command for execution and associates a stream either to the standard input or the standard output of the created process. If Mode is `read` (resp. `write`) an input (resp. output) stream is created and Stream is unified with the stream-term associated. Writing to the stream writes to the standard input of the command while reading from the stream reads the command’s standard output. The stream must be closed using `close/2` (section 8.10.7, page 82). This predicate is an interface to the C Unix function `popen(3)`.

Errors

<table>
<thead>
<tr>
<th>Command is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command is neither a variable nor an atom</td>
<td><code>type_error(atom, Command)</code></td>
</tr>
<tr>
<td>Mode is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Mode is neither a variable nor an atom</td>
<td><code>type_error(atom, Mode)</code></td>
</tr>
<tr>
<td>Mode is an atom but neither <code>read</code> nor <code>write</code>.</td>
<td><code>domain_error(io_mode, Mode)</code></td>
</tr>
<tr>
<td>Stream is not a variable</td>
<td>uninstantiation_error(Stream)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the <code>os_error</code> Prolog flag is <code>error</code></td>
<td><code>system_error(atom explaining the error)</code></td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.22 exec/5, exec/4

Templates

```
exec(+atom, -stream, -stream, -stream, -integer)
exec(+atom, -stream, -stream, -stream)
```

Description

`exec(Command, StreamIn, StreamOut, StreamErr, Pid)` invokes a new default shell passing Command for execution and associates streams to standard streams of the created process. StreamIn is unified with the stream-term associated with the standard input stream of Command (it is an output stream). StreamOut is unified with the stream-term associated with the standard output stream of Command (it is an input stream). StreamErr is unified with the stream-term associated with the standard error stream of Command (it is an input stream). Pid is unified with the process identifier of the new process. This information is only useful if it is necessary to obtain the status of the execution using `wait/2` (section 8.27.25, page 173). Until a call to `wait/2` is done the process remains in the system processes table (as a zombie process if terminated). For this reason, if the status is not needed it is preferable to use exec/4.

exec/4 is similar to exec/5 but the process is removed from system processes as soon as it is terminated.

Errors
Command is a variable | instantiation_error
---|---
Command is neither a variable nor an atom | type_error(atom, Command)
StreamIn is not a variable | uninstantiation_error(StreamIn)
StreamOut is not a variable | uninstantiation_error(StreamOut)
StreamErr is not a variable | uninstantiation_error(StreamErr)
Pid is not a variable | uninstantiation_error(Pid)
an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148) | system_error(atom explaining the error)

Portability

GNU Prolog predicates.

8.27.23 fork_prolog/1

Templates

fork_prolog(-integer)

Description

fork_prolog(Pid) creates a child process that differs from the parent process only in its PID. In the parent process Pid is unified with the PID of the child while in the child process Pid is unified with 0. In the parent process, the status of the child process can be obtained using wait/2 (section 8.27.25 page 173). Until a call to wait/2 is done the child process remains in the system processes table (as a zombie process if terminated). This predicate is an interface to the C Unix function fork(2).

Errors

| Pid is not a variable | uninstantiation_error(Pid) |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.27.24 create_pipe/2

Templates

create_pipe(-stream, -stream)

Description

create_pipe(StreamIn, StreamOut) creates a pair of streams pointing to a pipe inode. StreamIn is unified with the stream-term associated with the input side of the pipe and StreamOut is unified with the stream-term associated with output side. This predicate is an interface to the C Unix function pipe(2).

Errors
### StreamIn is not a variable

*uninstantiation_error(StreamIn)*

### StreamOut is not a variable

*uninstantiation_error(StreamOut)*

| an operating system error occurs and the value of the *os_error* Prolog flag is error
| (section 8.22.1, page 148) | *system_error(atom explaining the error)* |

### Portability

GNU Prolog predicate.

#### 8.27.25 wait/2

**Templates**

\[
\text{wait}(+\text{integer}, ?\text{integer})
\]

**Description**

\[
\text{wait}(Pid, \text{Status}) \text{ waits for the child process whose identifier is } Pid \text{ to terminate. } \text{Status} \text{ is then unified with the exit status. This predicate is an interface to the C Unix function } \text{waitpid}(2).
\]

**Errors**

<table>
<thead>
<tr>
<th>Pid is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pid is neither a variable nor an integer</td>
<td>type_error(integer, Pid)</td>
</tr>
<tr>
<td>Status is neither a variable nor an integer</td>
<td>type_error(integer, Status)</td>
</tr>
</tbody>
</table>
| an operating system error occurs and the value of the *os_error* Prolog flag is error
| (section 8.22.1, page 148) | *system_error(atom explaining the error)* |

### Portability

GNU Prolog predicate.

#### 8.27.26 prolog_pid/1

**Templates**

\[
\text{prolog_pid}(?\text{integer})
\]

**Description**

\[
\text{prolog_pid}(\text{Pid}) \text{ unifies } \text{Pid} \text{ with the process identifier of the current GNU Prolog process.}
\]

**Errors**

| Pid is neither a variable nor an integer | type_error(integer, Pid) |

### Portability

GNU Prolog predicate.
8.27.27  send_signal/2

Templates

\[
\text{send_signal(+integer, +integer)} \\
\text{send_signal(+integer, +atom)}
\]

Description

\text{send_signal(Pid, Signal)} \text{ sends Signal to the process whose identifier is Pid. Signal can be specified directly as an integer or symbolically as an atom. Allowed atoms depend on the machine (e.g. 'SIGINT', 'SIGQUIT', 'SIGKILL', 'SIGUSR1', 'SIGUSR2', 'SIGALRM',...). This predicate is an interface to the C Unix function kill(2).}

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{Pid} is a variable</td>
<td>\text{instantiation_error}</td>
</tr>
<tr>
<td>\text{Pid is neither a variable nor an integer}</td>
<td>\text{type_error(integer, Pid)}</td>
</tr>
<tr>
<td>\text{Signal is a variable}</td>
<td>\text{instantiation_error}</td>
</tr>
<tr>
<td>\text{Signal is neither a variable nor an integer or an atom}</td>
<td>\text{type_error(integer, Signal)}</td>
</tr>
<tr>
<td>\text{an operating system error occurs and the value of the os_error Prolog flag is error} (section 8.22.1, page 148)</td>
<td>\text{system_error(atom explaining the error)}</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.27.28  sleep/1

Templates

\[
\text{sleep(+number)}
\]

Description

\text{sleep(Seconds)} puts the GNU Prolog process to sleep for \text{Seconds} seconds. \text{Seconds} can be an integer or a floating point number (in which case it can be < 1). This predicate is an interface to the C Unix function usleep(3).

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{Seconds is a variable}</td>
<td>\text{instantiation_error}</td>
</tr>
<tr>
<td>\text{Seconds is neither a variable nor a number}</td>
<td>\text{type_error(number, Seconds)}</td>
</tr>
<tr>
<td>\text{Seconds is a number &lt; 0}</td>
<td>\text{domain_error(not_less_than_zero, Seconds)}</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
8.27 Operating system interface

8.27.29 select/5

Templates

\[ \text{select}(+\text{list}, ?\text{list}, +\text{list}, ?\text{list}, +\text{number}) \]

Description

\( \text{select}(\text{Reads}, \text{ReadyReads}, \text{Writes}, \text{ReadyWrites}, \text{TimeOut}) \) waits for a number of streams (or file descriptors) to change status. \( \text{ReadyReads} \) is unified with the list of elements listed in \( \text{Reads} \) that have characters available for reading. Similarly \( \text{ReadyWrites} \) is unified with the list of elements of \( \text{Writes} \) that are ok for immediate writing. The elements of \( \text{Reads} \) and \( \text{Writes} \) are either stream-terms or aliases or integers considered as file descriptors, e.g. for sockets (section 8.28, page 176). Streams that must be tested with \( \text{select}/5 \) should not be buffered. This can be done at the opening using \( \text{open}/4 \) (section 8.10.6, page 81) or later using \( \text{set\_stream\_buffering}/2 \) (section 8.10.27, page 93). \( \text{TimeOut} \) is an upper bound on the amount of time (in milliseconds) elapsed before \( \text{select}/5 \) returns. If \( \text{TimeOut} \leq 0 \) (no timeout) \( \text{select}/5 \) waits until something is available (either for reading or for writing) and thus can block indefinitely. This predicate is an interface to the C Unix function \( \text{select}(2) \).

Errors

| Reads (or \text{Writes}) is a partial list or a list with an element \( E \) which is a variable | \text{instantiation\_error} |
| Reads is neither a partial list nor a list | \text{type\_error(list, Reads)} |
| Writes is neither a partial list nor a list | \text{type\_error(list, Writes)} |
| \( \text{ReadyReads} \) is neither a partial list nor a list | \text{type\_error(list, ReadyReads)} |
| \( \text{ReadyWrites} \) is neither a partial list nor a list | \text{type\_error(list, ReadyWrites)} |
| an element \( E \) of the \( \text{Reads} \) (or \( \text{Writes} \)) list is neither a stream-term or alias nor an integer | \text{domain\_error(stream\_or\_alias, \( E \))} |
| an element \( E \) of the \( \text{Reads} \) (or \( \text{Writes} \)) list is not a selectable item | \text{domain\_error(selectable\_item, \( E \))} |
| an element \( E \) of the \( \text{Reads} \) (or \( \text{Writes} \)) list is an integer < 0 | \text{domain\_error(not\_less\_than\_zero, \( E \))} |
| an element \( E \) of the \( \text{Reads} \) (or \( \text{Writes} \)) list is a stream-term or alias not associated with an open stream | \text{existence\_error(stream, \( E \))} |
| an element \( E \) of the \( \text{Reads} \) list is associated with an output stream | \text{permission\_error(input, stream, \( E \))} |
| an element \( E \) of the \( \text{Writes} \) list is associated with an input stream | \text{permission\_error(output, stream, \( E \))} |
| \text{TimeOut} is a variable | \text{instantiation\_error} |
| \text{TimeOut} is neither a variable nor a number | \text{type\_error(number, TimeOut)} |
| an operating system error occurs and the value of the \text{os\_error} Prolog flag is error (section 8.22.1, page 148) | \text{system\_error(atom explaining the error)} |

Portability

GNU Prolog predicate.
8.28 Sockets input/output

8.28.1 Introduction

This set of predicates provides a way to manipulate sockets. The predicates are straightforward interfaces to the corresponding BSD-type socket functions. This facility is available if the sockets part of GNU Prolog has been installed. A reader familiar with BSD sockets will understand them immediately otherwise a study of sockets is needed.

The domain is either the atom 'AF_INET' or 'AF_UNIX' corresponding to the same domains in BSD-type sockets.

An address is either of the form 'AF_INET'(HostName, Port) or 'AF_UNIX'(SocketName). HostName is an atom denoting a machine name, Port is a port number and SocketName is an atom denoting a socket.

By default, streams associated with sockets are block buffered. The predicate set_stream_buffering/2 (section 8.10.27, page 93) can be used to change this mode. They are also text streams by default. Use set_stream_type/2 (section 8.10.25, page 92) to change the type if binary streams are needed.

8.28.2 socket/2

Templates

socket(+socket_domain, -integer)

Description

socket(Domain, Socket) creates a socket whose domain is Domain (section 8.28 page 176) and unifies Socket with the descriptor identifying the socket. This predicate is an interface to the C Unix function socket(2).

Errors

| Domain is a variable | instantiation_error |
| Domain is neither a variable nor an atom | type_error(atom, Domain) |
| Domain is an atom but not a valid socket domain | domain_error(socket_domain, Domain) |
| Socket is not a variable | uninstantiation_error(Socket) |
| an operating system error occurs and the value of the os_error Prolog flag is error (section 8.22.1 page 148) | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.28.3 socket_close/1

Templates

socket_close(+integer)

Description
socket_close(Socket) closes the socket whose descriptor is Socket. This predicate should not be used if Socket has given rise to a stream, e.g. by socket_connect/4 (section 8.28.5 page 178). In that case simply use close/2 (section 8.10.7 page 82) on the associated stream.

Errors

| Socket is a variable | instantiation_error |
| Socket is neither a variable nor an integer | type_error(integer, Socket) |
| an operating system error occurs and the value of the os_error Prolog flag is error | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.28.4 socket_bind/2

Templates

socket_bind(+integer, +socket_address)

Description

socket_bind(Socket, Address) binds the socket whose descriptor is Socket to the address specified by Address (section 8.28 page 176). If Address if of the form ‘AF_INET’(HostName, Port) and if HostName is uninstantiated then it is unified with the current machine name. If Port is uninstantiated, it is unified to a port number picked by the operating system. This predicate is an interface to the C Unix function bind(2).

Errors

| Socket is a variable | instantiation_error |
| Socket is neither a variable nor an integer | type_error(integer, Socket) |
| Address is a variable | instantiation_error |
| Address is neither a variable nor a valid address | domain_error(socket_address, Address) |
| Address = ‘AF_UNIX’(E) and E is a variable | instantiation_error |
| Address = ‘AF_UNIX’(E) or ‘AF_INET’(E, _) and E is neither a variable nor an atom | type_error(atom, E) |
| Address = ‘AF_UNIX’(E) and E is an atom but not a valid pathname | domain_error(os_path, E) |
| Address = ‘AF_INET’(_, E) and E is neither a variable nor an integer | type_error(integer, E) |
| an operating system error occurs and the value of the os_error Prolog flag is error | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.
8.28.5 socket_connect/4

Templates

\[
\text{socket_connect(+integer, +socket_address, -stream, -stream)}
\]

Description

\[
\text{socket_connect(Socket, Address, StreamIn, StreamOut)}
\]
connects the socket whose descriptor is Socket to the address specified by Address (section 8.28 page 176). StreamIn is unified with a stream-term associated with the input of the connection (it is an input stream). Reading from this stream gets data from the socket. StreamOut is unified with a stream-term associated with the output of the connection (it is an output stream). Writing to this stream sends data to the socket. The use of select/5 can be useful (section 8.27.29 page 175). This predicate is an interface to the C Unix function connect(2).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Socket is neither a variable nor an integer</td>
<td>type_error(integer, Socket)</td>
</tr>
<tr>
<td>Address is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Address is neither a variable nor a valid address</td>
<td>domain_error(socket_address, Address)</td>
</tr>
<tr>
<td>Address = 'AF_UNIX'(E) or 'AF_INET'(E, <em>) or Address = 'AF_INET'(</em>, E) and E is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Address = 'AF_UNIX'(E) or 'AF_INET'(E, _) and E is neither a variable nor an atom</td>
<td>type_error(atom, E)</td>
</tr>
<tr>
<td>Address = 'AF_UNIX'(E) and E is an atom but not a valid pathname</td>
<td>domain_error(os_path, E)</td>
</tr>
<tr>
<td>Address = 'AF_INET'(_, E) and E is neither a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
<tr>
<td>StreamIn is not a variable</td>
<td>uninstanitation_error(StreamIn)</td>
</tr>
<tr>
<td>StreamOut is not a variable</td>
<td>uninstanitation_error(StreamOut)</td>
</tr>
<tr>
<td>an operating system error occurs and the value of the os_error Prolog flag is error</td>
<td>system_error(atom explaining the error)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.28.6 socket_listen/2

Templates

\[
\text{socket_listen(+integer, +integer)}
\]

Description

\[
\text{socket_listen(Socket, Length)}
\]
defines the socket whose descriptor is Socket to have a maximum backlog queue of Length pending connections. This predicate is an interface to the C Unix function listen(2).

Errors
8.28 Sockets input/output

<table>
<thead>
<tr>
<th>Socket is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket is neither a variable nor an integer</td>
<td>type_error(integer, Socket)</td>
</tr>
<tr>
<td>Length is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Length is neither a variable nor an integer</td>
<td>type_error(integer, Length)</td>
</tr>
</tbody>
</table>

an operating system error occurs and the value of the os_error Prolog flag is error

| section [8.22.1 page 148] | system_error(atom explaining the error) |

Portability

GNU Prolog predicate.

8.28.7 socket_accept/4, socket_accept/3

Templates

socket_accept(+integer, -atom, -stream, -stream)
socket_accept(+integer, -stream, -stream)

Description

socket_accept(Socket, Client, StreamIn, StreamOut) extracts the first connection to the socket whose descriptor is Socket. If the domain is 'AF_INET', Client is unified with an atom whose name is the Internet host address in numbers-and-dots notation of the connecting machine. StreamIn is unified with a stream-term associated with the input of the connection (it is an input stream). Reading from this stream gets data from the socket. StreamOut is unified with a stream-term associated with the output of the connection (it is an output stream). Writing to this stream sends data to the socket. The use of select/5 can be useful (section [8.27.29 page 175]). This predicate is an interface to the C Unix function accept(2).

socket_accept(Socket, StreamIn, StreamOut) is equivalent to socket_accept(Socket, _, StreamIn, StreamOut).

Errors

<table>
<thead>
<tr>
<th>Socket is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket is neither a variable nor an integer</td>
<td>type_error(integer, Socket)</td>
</tr>
<tr>
<td>Client is not a variable</td>
<td>uninstantiation_error(Client)</td>
</tr>
<tr>
<td>StreamIn is not a variable</td>
<td>uninstantiation_error(StreamIn)</td>
</tr>
<tr>
<td>StreamOut is not a variable</td>
<td>uninstantiation_error(StreamOut)</td>
</tr>
</tbody>
</table>

an operating system error occurs and the value of the os_error Prolog flag is error

| section [8.22.1 page 148] | system_error(atom explaining the error) |

Portability

GNU Prolog predicates.

8.28.8 hostname_address/2

Templates
hostname_address(+atom, ?atom)
hostname_address(?atom, +atom)

Description

hostname_address(HostName, HostAddress) succeeds if the Internet host address in numbers-and-dots notation of HostName is HostAddress. Hostname can be given as a fully qualified name, or an unqualified name or an alias of the machine. The predicate will fail if the machine name or address cannot be resolved.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HostName and HostAddress are variables</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>HostName is neither a variable nor an atom</td>
<td>type_error(atom, HostName)</td>
</tr>
<tr>
<td>HostAddress is neither a variable nor an atom</td>
<td>type_error(atom, HostAddress)</td>
</tr>
<tr>
<td>Address is neither a variable nor a valid address</td>
<td>domain_error(socket_address, Address)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.29 Linedit management

The following predicates are only available if the linedit part of GNU Prolog has been installed.

8.29.1 get_linedit_prompt/1

Templates

get_linedit_prompt(?atom)

Description

get_linedit_prompt(Prompt) succeeds if Prompt is the current linedit prompt, e.g. the top-level prompt is ’| ?-’. By default all other reads have an empty prompt.

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompt is neither a variable nor an atom</td>
<td>type_error(atom, Pred)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

8.29.2 set_linedit_prompt/1

Templates

set_linedit_prompt(+atom)

Description
8.29 Linedit management

set_linedit_prompt(Prompt) sets the current linedit prompt to Prompt. This prompt will be displayed for reads from a terminal (except for top-level reads).

Errors

| Prompt is a variable                  | instantiation_error          |
| Prompt is neither a variable nor an atom | type_error(atom, Pred)       |

Portability

GNU Prolog predicate.

8.29.3 add_linedit_completion/1

Templates

add_linedit_completion(+atom)

Description

add_linedit_completion(Word) adds Word in the list of completion words maintained by linedit (section 4.2.6 page 18). Only words containing letters, digits and the underscore character are added (if Word does not respect this restriction the predicate fails).

Errors

| Word is a variable                  | instantiation_error          |
| Word is neither a variable nor an atom | type_error(atom, Word)       |

Portability

GNU Prolog predicate.

8.29.4 find_linedit_completion/2

Templates

find_linedit_completion(+atom, ?atom)

Description

find_linedit_completion(Prefix, Word) succeeds if Word is a word beginning by Prefix and belongs to the list of completion words maintained by linedit (section 4.2.6 page 18). This predicate is re-executable on backtracking.

Errors

| Prefix is a variable                  | instantiation_error          |
| Prefix is neither a variable nor an atom | type_error(atom, Prefix)     |
| Word is neither a variable nor an atom | type_error(atom, Word)       |

Portability

GNU Prolog predicate.
9 Finite domain solver and built-in predicates

9.1 Introduction

The finite domain (FD) constraint solver extends Prolog with constraints over FD. This facility is available if the FD part of GNU Prolog has been installed. The solver is an instance of the Constraint Logic Programming scheme introduced by Jaffar and Lassez in 1987 [7]. Constraints on FD are solved using propagation techniques, in particular arc-consistency (AC). The interested reader can refer to “Constraint Satisfaction in Logic Programming” of P. Van Hentenryck (1989) [8]. The solver is based on the clp(FD) solver [4]. The GNU Prolog FD solver offers arithmetic constraints, boolean constraints, reified constraints and symbolic constraints on a new kind of variables: Finite Domain variables.

9.1.1 Finite Domain variables

A new type of data is introduced: FD variables which can only take values in their domains. The initial domain of an FD variable is 0..fd_max_integer where fd_max_integer represents the greatest value that any FD variable can take. The predicate fd_max_integer/1 returns this value which may be different from the max_integer Prolog flag (section 8.22.1, page 148). The domain of an FD variable X is reduced step by step by constraints in a monotonic way: when a value has been removed from the domain of X it will never reappear in the domain of X. An FD variable is fully compatible with both Prolog integers and Prolog variables. Namely, when an FD variable is expected by an FD constraint it is possible to pass a Prolog integer (considered as an FD variable whose domain is a singleton) or a Prolog variable (immediately bound to an initial range 0..fd_max_integer). This avoids the need for specific type declaration. Although it is not necessary to declare the initial domain of an FD variable (since it will be bound 0..fd_max_integer when appearing for the first time in a constraint) it is advantageous to do so and thus reduce as soon as possible the size of its domain: particularly because GNU Prolog, for efficiency reasons, does not check for overflows. For instance, without any preliminary domain definitions for X, Y and Z, the non-linear constraint X*Y#=Z will fail due to an overflow when computing the upper bound of the domain of Z: fd_max_integer × fd_max_integer. This overflow causes a negative result for the upper bound and the constraint then fails.

There are two internal representations for an FD variable:

- **interval representation**: only the min and the max of the variable are maintained. In this representation it is possible to store values included in 0..fd_max_integer.

- **sparse representation**: an additional bit-vector is used to store the set of possible values for the variable (i.e. the domain). In this representation it is possible to store values included in 0..vector_max. By default vector_max is set to 127. This value can be redefined via an environment variable VECTORMAX or via the built-in predicate fd_set_vector_max/1 (section 9.2.3, page 185). The predicate fd_vector_max/1 returns the current value of vector_max (section 9.2.1, page 184).

The initial representation for an FD variable X is always an interval representation and is switched to a sparse representation when a “hole” appears in the domain (e.g. due to an inequality constraint). Once a variable uses a sparse representation it will not switch back to an interval representation even if there are no longer holes in its domain. When this switching occurs some values in the domain of X can be lost since vector_max is less than fd_max_integer. We say that “X is extra-constrained” since X is constrained by the solver to the domain 0..vector_max (via an imaginary constraint X #=< vector_max). An extra_cstr is associated with each FD variable to indicate that values have been lost due to the switch to a sparse representation. This flag is updated on every operations. The domain of an extra-constrained FD variable is output followed by the @ symbol. When a constraint fails on a extra-constrained variable
9.2 FD variable parameters

9.2.1 \texttt{fd} \texttt{max} \texttt{integer}/1

Templates

\texttt{fd} \texttt{max} \texttt{integer}(\texttt{?integer})

Description

\texttt{fd} \texttt{max} \texttt{integer}(N) succeeds if \( N \) is the current value of \texttt{fd} \texttt{max} \texttt{integer} (section 9.1 page 183).

Errors

\begin{Verbatim}
N \text{ is neither a variable nor an integer} \quad \texttt{type\_error(integer, N)}
\end{Verbatim}

Portability

GNU Prolog predicate.
9.3 Initial value constraints

9.2.2 fd_vector_max/1

Templates

fd_vector_max(?integer)

Description

fd_vector_max(N) succeeds if N is the current value of vector_max (section 9.1 page 183).

Errors

| N is neither a variable nor an integer | type_error(integer, N) |

Portability

GNU Prolog predicate.

9.2.3 fd_set_vector_max/1

Templates

fd_set_vector_max(+integer)

Description

fd_set_vector_max(N) initializes vector_max based on the value N (section 9.1 page 183). More precisely, on 32 bit machines, vector_max is set to the smallest value of (32*k)-1 which is ≥ N.

Errors

| N is a variable | instantiation_error |
| N is neither a variable nor an integer | type_error(integer, N) |
| N is an integer < 0 | domain_error(not_less_than_zero, N) |

Portability

GNU Prolog predicate.

9.3 Initial value constraints

9.3.1 fd_domain/3, fd_domain_bool/1

Templates

fd_domain(+fd_variable_list_or_fd_variable, +integer, +integer)
fd_domain(?fd_variable, +integer, +integer)
fd_domain(bool(+fd_variable_list))
fd_domain_bool(+fd_variable)

Description
fd_domain(Vars, Lower, Upper) constraints each element X of Vars to take a value in Lower..Upper. This predicate is generally used to set the initial domain of variables to an interval. Vars can be also a single FD variable (or a single Prolog variable).

fd_domain_bool(Vars) is equivalent to fd_domain(Vars, 0, 1) and is used to declare boolean FD variables.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vars is not a variable but is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Vars is neither a variable nor an FD variable nor an integer nor a list</td>
<td>type_error(list, Vars)</td>
</tr>
<tr>
<td>an element E of the Vars list is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, E)</td>
</tr>
<tr>
<td>Lower is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Lower is neither a variable nor an integer</td>
<td>type_error(integer, Lower)</td>
</tr>
<tr>
<td>Upper is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Upper is neither a variable nor an integer</td>
<td>type_error(integer, Upper)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

9.3.2 fd_domain/2

Templates

fd_domain(+fd_variable_list, +integer_list)
fd_domain(?fd_variable, +integer_list)

Description

fd_domain(Vars, Values) constraints each element X of the list Vars to take a value in the list Values. This predicate is generally used to set the initial domain of variables to a set of values. The domain of each variable of Vars uses a sparse representation. Vars can be also a single FD variable (or a single Prolog variable).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vars is not a variable but is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Vars is neither a variable nor an FD variable nor an integer nor a list</td>
<td>type_error(list, Vars)</td>
</tr>
<tr>
<td>an element E of the Vars list is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, E)</td>
</tr>
<tr>
<td>Values is a partial list or a list with an element E which is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Values is neither a partial list nor a list</td>
<td>type_error(list, Values)</td>
</tr>
<tr>
<td>an element E of the Values list is neither a variable nor an integer</td>
<td>type_error(integer, E)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
9.4 Type testing

9.4.1 fd_var/1, non_fd_var/1, generic_var/1, non_generic_var/1

Templates

<table>
<thead>
<tr>
<th>fd_var(?term)</th>
<th>generic_var(?term)</th>
</tr>
</thead>
<tbody>
<tr>
<td>non_fd_var(?term)</td>
<td>non_generic_var(?term)</td>
</tr>
</tbody>
</table>

Description

fd_var(Term) succeeds if Term is currently an FD variable.

non_fd_var(Term) succeeds if Term is currently not an FD variable (opposite of fd_var/1).

generic_var(Term) succeeds if Term is either a Prolog variable or an FD variable.

non_generic_var(Term) succeeds if Term is neither a Prolog variable nor an FD variable (opposite of generic_var/1).

Errors

None.

Portability

GNU Prolog predicate.

9.5 FD variable information

These predicates allow the user to get some information about FD variables. They are not constraints, they only return the current state of a variable.

9.5.1 fd_min/2, fd_max/2, fd_size/2, fd_dom/2

Templates

<table>
<thead>
<tr>
<th>fd_min(+fd_variable, ?integer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>fd_max(+fd_variable, ?integer)</td>
</tr>
<tr>
<td>fd_size(+fd_variable, ?integer)</td>
</tr>
<tr>
<td>fd_dom(+fd_variable, ?integer_list)</td>
</tr>
</tbody>
</table>

Description

fd_min(X, N) succeeds if N is the minimal value of the current domain of X.

fd_max(X, N) succeeds if N is the maximal value of the current domain of X.

fd_size(X, N) succeeds if N is the number of elements of the current domain of X.

fd_dom(X, Values) succeeds if Values is the list of values of the current domain of X.
Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X$ is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>$X$ is neither an FD variable nor an integer</td>
<td>type_error(fd_variable, $X$)</td>
</tr>
<tr>
<td>$N$ is neither a variable nor an integer</td>
<td>type_error(integer, $N$)</td>
</tr>
<tr>
<td>An element $E$ of the $\text{Vars}$ list is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, $E$)</td>
</tr>
<tr>
<td>$\text{Values}$ is neither a partial list nor a list</td>
<td>type_error(list, $\text{Values}$)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

9.5.2 $\text{fd}$ has extra $\text{cstr}/1$, $\text{fd}$ has vector/1, $\text{fd}$ use vector/1

Templates

$\text{fd}$ has extra $\text{cstr}(+\text{fd_variable})$

$\text{fd}$ has vector(+fd_variable)

$\text{fd}$ use vector(+fd_variable)

Description

$\text{fd}$ has extra $\text{cstr}(X)$ succeeds if the extra $\text{cstr}$ of $X$ is currently on (section 9.1 page 183).

$\text{fd}$ has vector($X$) succeeds if the current domain of $X$ uses a sparse representation (section 9.1 page 183).

$\text{fd}$ use vector($X$) enforces a sparse representation for the domain of $X$ (section 9.1 page 183).

Errors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X$ is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>$X$ is neither an FD variable nor an integer</td>
<td>type_error(fd_variable, $X$)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.

9.6 Arithmetic constraints

9.6.1 FD arithmetic expressions

An FD arithmetic expression is a Prolog term built from integers, variables (Prolog or FD variables), and functors (or operators) that represent arithmetic functions. The following table details the components of an FD arithmetic expression:
### 9.6 Arithmetic constraints

<table>
<thead>
<tr>
<th>FD Expression</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolog variable</td>
<td>domain $0..\text{fd}_\text{max}_\text{integer}$</td>
</tr>
<tr>
<td>FD variable $X$</td>
<td>domain of $X$</td>
</tr>
<tr>
<td>integer number $N$</td>
<td>domain $N..N$</td>
</tr>
<tr>
<td>$+ E$</td>
<td>same as $E$</td>
</tr>
<tr>
<td>$- E$</td>
<td>opposite of $E$</td>
</tr>
<tr>
<td>$E1 + E2$</td>
<td>sum of $E1$ and $E2$</td>
</tr>
<tr>
<td>$E1 - E2$</td>
<td>subtraction of $E2$ from $E1$</td>
</tr>
<tr>
<td>$E1 * E2$</td>
<td>multiplication of $E1$ by $E2$</td>
</tr>
<tr>
<td>$E1 / E2$</td>
<td>integer division of $E1$ by $E2$ (only succeeds if the remainder is 0)</td>
</tr>
<tr>
<td>$E1 ** E2$</td>
<td>$E1$ raised to the power of $E2$ ($E1$ or $E2$ must be an integer)</td>
</tr>
<tr>
<td>$\text{min}(E1,E2)$</td>
<td>minimum of $E1$ and $E2$</td>
</tr>
<tr>
<td>$\text{max}(E1,E2)$</td>
<td>maximum of $E1$ and $E2$</td>
</tr>
<tr>
<td>$\text{dist}(E1,E2)$</td>
<td>distance, i.e. $</td>
</tr>
<tr>
<td>$E1 \div E2$</td>
<td>quotient of the integer division of $E1$ by $E2$</td>
</tr>
<tr>
<td>$E1 \mod E2$</td>
<td>remainder of the integer division of $E1$ by $E2$</td>
</tr>
<tr>
<td>$\text{quot_rem}(E1,E2,R)$</td>
<td>quotient of the integer division of $E1$ by $E2$ ($R$ is the remainder of the integer division of $E1$ by $E2$)</td>
</tr>
</tbody>
</table>

FD expressions are not restricted to be linear. However non-linear constraints usually yield less constraint propagation than linear constraints.

+, -, *, /, //, rem and ** are predefined infix operators. + and - are predefined prefix operators (section 8.14.10, page 113).

#### Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>a sub-expression is of the form $- ** E$ and $E$ is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>a sub-expression $E$ is neither a variable nor an integer nor an FD arithmetic functor</td>
<td>type_error(fd_evaluable, $E$)</td>
</tr>
<tr>
<td>an expression is too complex</td>
<td>resource_error(too_big_fd_constraint)</td>
</tr>
</tbody>
</table>

#### 9.6.2 Partial AC: $(=)/2$ - constraint equal, $(\neq)/2$ - constraint not equal, $(<)/2$ - constraint less than, $(\leq)/2$ - constraint less than or equal, $(>)/2$ - constraint greater than, $(\geq)/2$ - constraint greater than or equal

#### Templates

- $=(?fd\_evaluable, ?fd\_evaluable)$
- $\neq(?fd\_evaluable, ?fd\_evaluable)$
- $<(?fd\_evaluable, ?fd\_evaluable)$
- $\leq(?fd\_evaluable, ?fd\_evaluable)$
- $>(?fd\_evaluable, ?fd\_evaluable)$
- $\geq(?fd\_evaluable, ?fd\_evaluable)$

#### Description

$FdExpr1 = FdExpr2$ constrains $FdExpr1$ to be equal to $FdExpr2$.

$FdExpr1 \neq FdExpr2$ constrains $FdExpr1$ to be different from $FdExpr2$.

$FdExpr1 < FdExpr2$ constrains $FdExpr1$ to be less than $FdExpr2$. 
FdExpr₁ #=< FdExpr₂ constrains FdExpr₁ to be less than or equal to FdExpr₂.

FdExpr₁ #> FdExpr₂ constrains FdExpr₁ to be greater than FdExpr₂.

FdExpr₁ #>= FdExpr₂ constrains FdExpr₁ to be greater than or equal to FdExpr₂.

FdExpr₁ and FdExpr₂ are arithmetic FD expressions (section 9.6.1, page 188).

#=, #\=, #<, #=<, #> and #>= are predefined infix operators (section 8.14.10, page 113).

These predicates post arithmetic constraints that are managed by the solver using a partial arc-consistency algorithm to reduce the domain of involved variables. In this scheme only the bounds of the domain of variables are updated. This leads to less propagation than full arc-consistency techniques (section 9.6.3, page 190) but is generally more efficient for arithmetic. These arithmetic constraints can be reified (section 9.7, page 191).

Errors

Refer to the syntax of arithmetic FD expressions for possible errors (section 9.6.1, page 188).

Portability

GNU Prolog predicates.

9.6.3 Full AC: (#=#)/2 - constraint equal, (#\=#)/2 - constraint not equal,
(#<#)/2 - constraint less than, (#=<#)/2 - constraint less than or equal,
(#>#)/2 - constraint greater than, (#>=#)/2 - constraint greater than or equal

Templates

###(?fd_evaluable, ?fd_evaluable)
\-###(?fd_evaluable, ?fd_evaluable)
#<#(?fd_evaluable, ?fd_evaluable)
#=<#(?fd_evaluable, ?fd_evaluable)
#>#(?fd_evaluable, ?fd_evaluable)
#>=#(?fd_evaluable, ?fd_evaluable)

Description

FdExpr₁ #=# FdExpr₂ constrains FdExpr₁ to be equal to FdExpr₂.

FdExpr₁ #\=# FdExpr₂ constrains FdExpr₁ to be different from FdExpr₂.

FdExpr₁ #<# FdExpr₂ constrains FdExpr₁ to be less than FdExpr₂.

FdExpr₁ #=<# FdExpr₂ constrains FdExpr₁ to be less than or equal to FdExpr₂.

FdExpr₁ #># FdExpr₂ constrains FdExpr₁ to be greater than FdExpr₂.

FdExpr₁ #>=# FdExpr₂ constrains FdExpr₁ to be greater than or equal to FdExpr₂.

FdExpr₁ and FdExpr₂ are arithmetic FD expressions (section 9.6.1, page 188).

#=, #\=, #<, #=<, #> and #>= are predefined infix operators (section 8.14.10, page 113).
These predicates post arithmetic constraints that are managed by the solver using a full arc-consistency algorithm to reduce the domain of involved variables. In this scheme the full domain of variables is updated. This leads to more propagation than partial arc-consistency techniques (section 9.6.1 page 188) but is generally less efficient for arithmetic. These arithmetic constraints can be reified (section 9.7.1 page 191).

Errors

Refer to the syntax of arithmetic FD expressions for possible errors (section 9.6.1 page 188).

Portability

GNU Prolog predicates.

9.6.4 fd_prime/1, fd_not_prime/1

Templates

fd_prime(?fd_variable)
fd_not_prime(?fd_variable)

Description

fd_prime(X) constraints X to be a prime number between 0..vector_max. This constraint enforces a sparse representation for the domain of X (section 9.1 page 183).

fd_not_prime(X) constraints X to be a non prime number between 0..vector_max. This constraint enforces a sparse representation for the domain of X (section 9.1 page 183).

Errors

X is neither an FD variable nor an integer  type_error(fd_variable, X)

Portability

GNU Prolog predicates.

9.7 Boolean and reified constraints

9.7.1 Boolean FD expressions

An boolean FD expression is a Prolog term built from integers (0 for false, 1 for true), variables (Prolog or FD variables), partial AC arithmetic constraints (section 9.6.2 page 189), full AC arithmetic constraints (section 9.6.3 page 190) and functors (or operators) that represent boolean functions. When a sub-expression of a boolean expression is an arithmetic constraint c, it is reified. Namely, as soon as the solver detects that c is true (i.e. *entailed*) the sub-expression has the value 1. Similarly when the solver detects that c is false (i.e. *disentailed*) the sub-expression evaluates as 0. While neither the entailment nor the disentailment can be detected the sub-expression is evaluated as a domain 0..1. The following table details the components of an FD boolean expression:
9.7.2 **fd_reified_in/4**

**Templates**

\[
\text{fd_reified_in}(?fd\text{\_variable}, +integer, +integer, ?fd\text{\_variable})
\]

**Description**

\[
\text{fd_reified_in}(X, \text{Lower}, \text{Upper}, B) \text{\ captures the truth value of the constraint } X \in [\text{Lower..Upper}] \text{ in the boolean variable } B.
\]

**Errors**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>X is neither a variable nor an FD variable nor an integer</td>
<td>\text{type_error(fd_variable, X)}</td>
</tr>
<tr>
<td>B is neither a variable nor an FD variable nor an integer</td>
<td>\text{type_error(fd_variable, B)}</td>
</tr>
<tr>
<td>\text{Lower} is a variable</td>
<td>\text{instantiation_error}</td>
</tr>
<tr>
<td>\text{Lower} is neither a variable nor an integer</td>
<td>\text{type_error(integer, Lower)}</td>
</tr>
<tr>
<td>\text{Upper} is a variable</td>
<td>\text{instantiation_error}</td>
</tr>
<tr>
<td>\text{Upper} is neither a variable nor an integer</td>
<td>\text{type_error(integer, Upper)}</td>
</tr>
</tbody>
</table>
9.7.3  (\#)/1 - constraint NOT, (\#=)/2 - constraint equivalent, 
(\#<>)/2 - constraint different, (\#\#)/2 - constraint XOR, 
(\#==>/2 - constraint imply, (\#\==>/2 - constraint not imply, 
(\#\)/2 - constraint AND, (\#\\)/2 - constraint NAND, 
(\#\)/2 - constraint OR, (\#\\)/2 - constraint NOR

Templates

\#(?fd_bool_evaluable) 
\#<>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#<=>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#(\#)(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#==(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#<=>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#\>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#\<=>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#\\>(?fd_bool_evaluable, ?fd_bool_evaluable) 
\#\\>(?fd_bool_evaluable, ?fd_bool_evaluable)

Description

\#\ FdBoolExpr1 constraints FdBoolExpr1 to be false.

FdBoolExpr1 \#<> FdBoolExpr2 constrains FdBoolExpr1 to be equivalent to FdBoolExpr2.

FdBoolExpr1 \#<> FdBoolExpr2 constrains FdBoolExpr1 to be equivalent to not FdBoolExpr2.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 XOR FdBoolExpr2 to be true

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 to imply FdBoolExpr2.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 to not imply FdBoolExpr2.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 AND FdBoolExpr2 to be true.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 AND FdBoolExpr2 to be false.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 OR FdBoolExpr2 to be true.

FdBoolExpr1 \#\ FdBoolExpr2 constrains FdBoolExpr1 OR FdBoolExpr2 to be false.

FdBoolExpr1 and FdBoolExpr2 are boolean FD expressions (section 9.7.1 page 191).

Note that \#<=> (not equivalent) and \#\ (exclusive or) are synonymous.

These predicates post boolean constraints that are managed by the FD solver using a partial arc consistency algorithm to reduce the domain of involved variables. The (dis)entailment of reified constraints is detected using either the bounds (for partial AC arithmetic constraints) or the full domain (for full AC arithmetic constraints).

\#<=>, \#<>\, \#, \#\<=>, \#\#, \#/\, \#/\ and \#/\ are predefined infix operators. \#/ is a predefined prefix operator (section 8.14.10 page 113).

Errors
Refer to the syntax of boolean FD expressions for possible errors (section 9.7.1, page 191).

Portability

GNU Prolog predicates.

9.7.4  \texttt{fd_cardinality/2, fd_cardinality/3, fd_at_least_one/1, fd_at_most_one/1, fd_only_one/1}

Templates

\begin{verbatim}
 fd_cardinality(+fd_bool_evaluable_list, ?fd_variable)
 fd_cardinality(+integer, ?fd_variable, +integer)
 fd_at_least_one(+fd_bool_evaluable_list)
 fd_at_most_one(+fd_bool_evaluable_list)
 fd_only_one(+fd_bool_evaluable_list)
\end{verbatim}

Description

\texttt{fd_cardinality(List, Count)} unifies \texttt{Count} with the number of constraints that are true in \texttt{List}. This is equivalent to post the constraint \(B_1 + B_2 + \ldots + B_n \# = \text{Count}\) where each variable \(B_i\) is a new variable defined by the constraint \(B_i \#<=> \text{C}_i\) where \(\text{C}_i\) is the \(i\)th constraint of \texttt{List}. Each \(\text{C}_i\) must be a boolean FD expression (section 9.7.1, page 191).

\texttt{fd_cardinality(Lower, List, Upper)} is equivalent to \texttt{fd_cardinality(List, Count)}, \texttt{Lower \#=< Count, Count \#=< Upper}

\texttt{fd_at_least_one(List)} is equivalent to \texttt{fd_cardinality(List, Count)}, \texttt{Count \#>= 1}.

\texttt{fd_at_most_one(List)} is equivalent to \texttt{fd_cardinality(List, Count)}, \texttt{Count \#=< 1}.

\texttt{fd_only_one(List)} is equivalent to \texttt{fd_cardinality(List, 1)}.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>List is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>List is neither a partial list nor a list</td>
<td>type_error(list, List)</td>
</tr>
<tr>
<td>Count is neither an FD variable nor an integer</td>
<td>type_error(fd_variable, Count)</td>
</tr>
<tr>
<td>Lower is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Lower is neither a variable nor an integer</td>
<td>type_error(integer, Lower)</td>
</tr>
<tr>
<td>Upper is a variable</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>Upper is neither a variable nor an integer</td>
<td>type_error(integer, Upper)</td>
</tr>
<tr>
<td>an element (E) of the \texttt{List} list is an invalid boolean expression</td>
<td>an FD boolean constraint (section 9.7.1, page 191)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicates.
9.8 Symbolic constraints

9.8.1 \texttt{fd_all_different/1}

Templates

\[ \texttt{fd} \texttt{all} \texttt{different} (+\texttt{fd_variable_list}) \]

Description

\texttt{fd_all_different(List)} constrains all variables in \texttt{List} to take distinct values. This is equivalent to posting an inequality constraint for each pair of variables. This constraint is triggered when a variable becomes ground, removing its value from the domain of the other variables.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{List} is a partial list</td>
<td>\texttt{instantiation_error}</td>
</tr>
<tr>
<td>\texttt{List} is neither a partial list nor a list</td>
<td>\texttt{type_error(list, List)}</td>
</tr>
<tr>
<td>an element \texttt{E} of the \texttt{List} list is neither a variable nor an integer nor an FD variable</td>
<td>\texttt{type_error(fd_variable, E)}</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

9.8.2 \texttt{fd_element/3}

Templates

\[ \texttt{fd} \texttt{element}(\texttt{?fd\_variable}, +\texttt{integer\_list}, \texttt{?fd\_variable}) \]

Description

\texttt{fd_element(I, List, X)} constrains \texttt{X} to be equal to the \texttt{I}th integer (from 1) of \texttt{List}.

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{I} is neither a variable nor an FD variable nor an integer</td>
<td>\texttt{type_error(fd_variable, I)}</td>
</tr>
<tr>
<td>\texttt{X} is neither a variable nor an FD variable nor an integer</td>
<td>\texttt{type_error(fd_variable, X)}</td>
</tr>
<tr>
<td>\texttt{List} is a partial list or a list with an element \texttt{E} which is a variable</td>
<td>\texttt{instantiation_error}</td>
</tr>
<tr>
<td>\texttt{List} is neither a partial list nor a list</td>
<td>\texttt{type_error(list, List)}</td>
</tr>
<tr>
<td>an element \texttt{E} of the \texttt{List} list is neither a variable nor an integer</td>
<td>\texttt{type_error(integer, E)}</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.
9.8.3 fd_element_var/3

Templates

\texttt{fd-element-var(?fd-variable, +fd-variable-list, ?fd-variable)}

Description

(fd-element-var(I, List, X)) constraints X to be equal to the Ith variable (from 1) of List. This constraint is similar to \texttt{fd-element/3} (section 9.8.2, page 195) but List can also contain FD variables (rather than just integers).

Errors

<table>
<thead>
<tr>
<th>Error Description</th>
<th>Error Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>I is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, I)</td>
</tr>
<tr>
<td>X is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, X)</td>
</tr>
<tr>
<td>List is a partial list</td>
<td>instantiation_error</td>
</tr>
<tr>
<td>List is neither a partial list nor a list</td>
<td>type_error(list, List)</td>
</tr>
<tr>
<td>an element E of the List list is neither a variable nor an integer nor an FD variable</td>
<td>type_error(fd_variable, E)</td>
</tr>
</tbody>
</table>

Portability

GNU Prolog predicate.

9.8.4 fd_atmost/3, fd_atleast/3, fd_exactly/3

Templates

\texttt{fd-atmost(+integer, +fd-variable-list, +integer)}
\texttt{fd-atleast(+integer, +fd-variable-list, +integer)}
\texttt{fd-exactly(+integer, +fd-variable-list, +integer)}

Description

(fd-atmost(N, List, V)) posts the constraint that at most N variables of List are equal to the value V.
(fd-atleast(N, List, V)) posts the constraint that at least N variables of List are equal to the value V.
(fd-exactly(N, List, V)) posts the constraint that at exactly N variables of List are equal to the value V.

These constraints are special cases of \texttt{fd-cardinality/2} (section 9.7.4, page 194) but their implementation is more efficient.

Errors


N is a variable | instantiation_error
N is neither a variable nor an integer | type_error(integer, N)
V is a variable | instantiation_error
V is neither a variable nor an integer | type_error(integer, V)
List is a partial list | instantiation_error
List is neither a partial list nor a list | type_error(list, List)
an element E of the List list is neither a variable nor an FD variable nor an integer | type_error(fd_variable, E)

Portability
GNU Prolog predicates.

9.8.5 fd_relation/2, fd_relationc/2

Templates

\[
\text{fd_relation}(+\text{integer list list}, \ ?\text{fd variable list}) \\
\text{fd_relationc}(+\text{integer list list}, \ ?\text{fd variable list})
\]

Description

\text{fd_relation}(\text{Relation}, \text{Vars}) \text{ constraints the tuple of variables } \text{Vars} \text{ to be equal to one tuple of the list } \text{Relation}. \text{ A tuple is represented by a list.}

Example: definition of the boolean AND relation so that \text{X AND Y }\leftrightarrow \text{ Z:}

\[
\text{and}(X, Y, Z):- \\
\quad \text{fd_relation([\,[0,0,0],[0,1,0],[1,0,0],[1,1,1]], [X,Y,Z])}.
\]

\text{fd_relationc}(\text{Columns}, \text{Vars}) \text{ is similar to } \text{fd_relation/2} \text{ except that the relation is not given as the list of tuples but as the list of the columns of the relation. A column is represented by a list.}

Example:

\[
\text{and}(X, Y, Z):- \\
\quad \text{fd_relationc([\,[0,0,1,1],[0,1,0,1],[0,0,0,1]], [X,Y,Z])}.
\]

Errors

| Relation is a partial list or a list with a sub-term E which is a variable | instantiation_error |
| Relation is neither a partial list nor a list | type_error(list, Relation) |
| an element E of the Relation list is neither a variable nor an integer | type_error(integer, E) |
| Vars is a partial list | instantiation_error |
| Vars is neither a partial list nor a list | type_error(list, Vars) |
| an element E of the Vars list is neither a variable nor an integer nor an FD variable | type_error(fd_variable, E) |

Portability

GNU Prolog predicates.
9.9 Labeling constraints

9.9.1 fd_labeling/2, fd_labeling/1, fd_labelingff/1

Templates

fd_labeling(+fd_variable_list, +fd_labeling_option_list)
fd_labeling(+fd_variable, +fd_labeling_option_list)
fd_labeling(+fd_variable_list)
fd_labeling(+fd_variable)
fd_labelingff(+fd_variable_list)
fd_labelingff(+fd_variable)

Description

fd_labeling(Vars, Options) assigns a value to each variable X of the list Vars according to the list of labeling options given by Options. Vars can be also a single FD variable. This predicate is re-executable on backtracking.

FD labeling options: Options is a list of labeling options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- **variable method(V)**: specifies the heuristics to select the variable to enumerate:
  - **standard**: no heuristics, the leftmost variable is selected.
  - **first_fail** (or **ff**): selects the variable with the smallest number of elements in its domain. If several variables have the same number of elements the leftmost variable is selected.
  - **most_constrained**: like first_fail but when several variables have the same number of elements selects the variable that appears in most constraints.
  - **smallest**: selects the variable that has the smallest value in its domain. If there is more than one such variable selects the variable that appears in most constraints.
  - **largest**: selects the variable that has the greatest value in its domain. If there is more than one such variable selects the variable that appears in most constraints.
  - **max_regret**: selects the variable that has the greatest difference between the smallest value and the next value of its domain. If there is more than one such variable selects the variable that appears in most constraints.
  - **random**: selects randomly a variable. Each variable is chosen only once.

The default value is **standard**.

- **reorder(true/false)**: specifies if the variable heuristics should dynamically reorder the list of variable (true) or not (false). Dynamic reordering is generally more efficient but in some cases a static ordering is faster. The default value is **true**.

- **value_method(V)**: specifies the heuristics to select the value to assign to the chosen variable:
  - **min**: enumerates the values from the smallest to the greatest (default).
  - **max**: enumerates the values from the greatest to the smallest.
  - **middle**: enumerates the values from the middle to the bounds.
  - **bounds**: enumerates the values from the bounds to the middle.
  - **random**: enumerates the values randomly. Each value is tried only once.
  - **bisect**: recursively creates a choice between X #=< M and X #> M, where M is the midpoint of the domain of the variable. Values are thus tried from the smallest to the greatest. This is also known as domain splitting.
The default value is \( \text{min} \).

- \texttt{backtracks(B)}: unifies \( B \) with the number of backtracks during the enumeration.

\texttt{fd_labeling(Vars)} is equivalent to \texttt{fd_labeling(Vars, [])}.

\texttt{fd_labelingff(Vars)} is equivalent to \texttt{fd_labeling(Vars, [variable_method(ff)])}.

**Errors**

| Vars is a partial list or a list with an element \( E \) which is a variable | instantiation_error |
| Vars is neither a partial list nor a list nor an integer nor an FD variable | type_error(list, Vars) |
| an element \( E \) of the Vars list is neither a variable nor an integer nor an FD variable | type_error(fd_variable, E) |
| Options is a partial list or a list with an element \( E \) which is a variable | instantiation_error |
| Options is neither a partial list nor a list | type_error(list, Options) |
| an element \( E \) of the Options list is neither a variable nor a labeling option | domain_error(fd_labeling_option, E) |

**Portability**

GNU Prolog predicates.

### 9.10 Optimization constraints

#### 9.10.1 \texttt{fd_minimize/2, fd_maximize/2}

**Templates**

\texttt{fd_minimize(+callable_term, ?fd_variable)}  
\texttt{fd_maximize(+callable_term, ?fd_variable)}

**Description**

\texttt{fd_minimize(Goal, X)} repeatedly calls \texttt{Goal} to find a value that minimizes the variable \( X \). \texttt{Goal} is a Prolog goal that should instantiate \( X \), a common case being the use of \texttt{fd_labeling/2} (section 9.9.1 page 198). This predicate uses a branch-and-bound algorithm with restart: each time \texttt{call(Goal)} succeeds the computation restarts with a new constraint \( X \neq V \) where \( V \) is the value of \( X \) at the end of the last call of \texttt{Goal}. When a failure occurs (either because there are no remaining choice-points for \texttt{Goal} or because the added constraint is inconsistent with the rest of the store) the last solution is recomputed since it is optimal.

\texttt{fd_maximize(Goal, X)} is similar to \texttt{fd_minimize/2} but \( X \) is maximized.

**Errors**
<table>
<thead>
<tr>
<th>Goal is a variable</th>
<th>instantiation_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is neither a variable nor a callable term</td>
<td>type_error(callable, Goal)</td>
</tr>
<tr>
<td>The predicate indicator Pred of Goal does not correspond to an existing procedure and the value of the unknown Prolog flag is error (section 8.22.1 page 148)</td>
<td>existence_error(procedure, Pred)</td>
</tr>
<tr>
<td>X is neither a variable nor an FD variable nor an integer</td>
<td>type_error(fd_variable, X)</td>
</tr>
</tbody>
</table>

**Portability**

GNU Prolog predicates.
10 Interfacing Prolog and C

10.1 Introduction

The foreign code interface allows the use to link Prolog and C in both directions.

A Prolog predicate can call a C function passing different kinds of arguments (input, output or input/output). The interface performs implicit Prolog ↔ C data conversions for simple types (for instance a Prolog integer is automatically converted into a C integer) and provides a set of API (Application Programming Interface) functions to convert more complex types (lists or structures). The interface also performs automatic error detection depending on the actual type of the passed argument. An important feature is the ability to write non-deterministic code in C.

It is also possible to call (or callback) a Prolog predicate from a C function and to manage Prolog non-determinism: the C code can ask for next solutions, remove all remaining solutions or terminate and keep alternatives for the calling Prolog predicate).

10.2 Including and using gprolog.h

The C code should include gprolog.h which provides a set of C definitions (types, macros, prototypes) associated to the API. Include this file as follows:

```
#include <gprolog.h>
```

If the installation has been correctly done nothing else is needed. If the C compiler/preprocessor cannot locate gprolog.h pass the C compiler option required to specify an additional include directory (e.g. -Iinclude_dir) to gplc as follows (section 4.4.3, page 23):

```
% gplc -C -Iinclude_dir ...
```

The file gprolog.h declares the following C types:

- **PlBool** as an integer and the constants **PL_FALSE** (i.e. 0) and **PL_TRUE** (i.e. 1).

- **PlLong** as an integer able to store a pointer (equivalent to intptr_t). This type appeared in GNU Prolog 1.4.0 in replacement of long to support Windows 64 bits (where the long type is only 32 bits). This type is used to handle integer types.

- **PlULong** same as PlLong but unsigned (same as uintptr_t).

- **PlTerm** same as intptr_t. This type is used to store general Prolog terms.

**New in GNU Prolog 1.3.1 and backward compatibility issues:** in GNU Prolog 1.3.1 the API has been modified to protect namespace. The name of public functions, macros, variables and types are now prefixed with Pl_, PL_ or pl_. All these prefixes should be avoided by the foreign C-code to prevent name clashes. To ensure a backward compatibility, the names used by the old API are available thanks to a set of #define. However, this deprecated API should not be used by recent code. It is also possible to prevent the definition of the compatibility macros using:

```
#define __GPROLOG_FOREIGN_STRICT__
#include <gprolog.h>
```

In addition, gprolog.h defines a set of macros:

- **__GNU_PROLOG__** (as the major version).
• **_GPROLOG__, _GPROLOG_MINOR__, and _GPROLOG_PATCHLEVEL_.** Their values are the major version, minor version, and patch level of GNU Prolog, as integer constants. For example, GNU Prolog 1.3.2 will define **_GPROLOG_** to 1, **_GPROLOG_MINOR_** to 3, and **_GPROLOG_PATCHLEVEL_** to 2.

If you need to write code which depends on a specific version, you must be more careful. Recall these macros appeared in GNU Prolog 1.3.1 (undefined before), each time the minor version is increased, the patch level is reset to zero; each time the major version is increased (which happens rarely), the minor version and patch level are reset.

• **_GPROLOG_VERSION_.** the version as an integer defined as follows: \( \text{major} \times 10000 + \text{minor} \times 100 + \text{patchlevel} \). For example: version 1.3.2 will result in the value 10302.

• **PL_PROLOG_DIALECT:** a C constant string (generally "gprolog"). Appeared in 1.3.2.

• **PL_PROLOG_NAME:** a C constant string (generally "GNU Prolog").

• **PL_PROLOG_VERSION:** a C constant string associated to the version (e.g. "1.4.0").

• **PL_PROLOG_DATE:** a C constant string associated with the date of this version (e.g. "Mar 29 2011").

• **PL_PROLOG_COPYRIGHT:** a C constant string associated with the copyright of this version (e.g. "Copyright (C) 1999-2021 Daniel Diaz").

Note the above **PL_PROLOG...** macros are also accessible via Prolog flags thanks to the built-in predicate `current_prolog_flag/2` (section 8.22.2 page 151).

### 10.3 Calling C from Prolog

#### 10.3.1 Introduction

This interface can then be used to write both simple and complex C routines. A simple routine uses either input or output arguments which type is simple. In that case the user does not need any knowledge of Prolog data structures since all Prolog ↔ C data conversions are implicitly achieved. To manipulate complex terms (lists, structures) a set of functions is provided. Finally it is also possible to write non-deterministic C code.

#### 10.3.2 `foreign/2` directive

`foreign/2` directive (section 7.1.15 page 50) declares a C function interface. The general form is `foreign(Template, Options)` which defines an interface predicate whose prototype is `Template` according to the options given by `Options`. `Template` is a callable term specifying the type/mode of each argument of the associated Prolog predicate.

**Foreign options:** `Options` is a list of foreign options. If this list contains contradictory options, the rightmost option is the one which applies. Possible options are:

- **fct_name(F):** `F` is an atom representing the name of the C function to call. By default the name of the C function is the same as the principal functor of `Template`. In any case, the atom associated with the name of the function must conforms to the syntax of C identifiers.

- **return(boolean/none/jump):** specifies the value returned by the C function:
  - `boolean`: the type of the function is `PlBool` (returns `PL_TRUE` on success, `PL_FALSE` otherwise).
  - `none`: the type of the function is `void` (no returned value).
  - `jump`: the type of the function is `void(*)()` (returns the address of a Prolog code to execute).
The default value is _boolean_.

- **_bip_name(Name, Arity)_**: initializes the error context with _Name_ and _Arity_. If an error occurs this information is used to indicate from which predicate the error occurred (section 6.3.1, page 39). It is also possible to prevent the initialization of the error context using _bip_name(_none_). By default _Name_ and _Arity_ are set to the functor and arity of _Template_.

- **_choice_size(N)_**: this option specifies that the function implements a non-deterministic code. _N_ is an integer specifying the size needed by the non-deterministic C function. This facility is explained later (section 10.3.7, page 205). By default a foreign function is deterministic.

_foreign(_Template_) is equivalent to _foreign(_Template_, [])_.

**Foreign modes and types**: each argument of _Template_ specifies the foreign mode and type of the corresponding argument. This information is used to check the type of effective arguments at run-time and to perform Prolog ↔ C data conversions. Each argument of _Template_ is formed with a mode symbol followed by a type name. Possible foreign modes are:

- **+**: input argument.
- **-**: output argument.
- **?:** input/output argument.

Possible foreign types are:

<table>
<thead>
<tr>
<th>Foreign type</th>
<th>Prolog type</th>
<th>C type</th>
<th>Description of the C type</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>integer</td>
<td><em>PlLong</em></td>
<td>value of the integer</td>
</tr>
<tr>
<td>positive</td>
<td>positive integer</td>
<td><em>PlLong</em></td>
<td>value of the integer</td>
</tr>
<tr>
<td>float</td>
<td>floating point number</td>
<td><em>double</em></td>
<td>value of the floating point number</td>
</tr>
<tr>
<td>number</td>
<td>number</td>
<td><em>double</em></td>
<td>value of the number</td>
</tr>
<tr>
<td>atom</td>
<td>atom</td>
<td><em>PlLong</em></td>
<td>internal key of the atom</td>
</tr>
<tr>
<td>boolean</td>
<td>boolean</td>
<td><em>PlLong</em></td>
<td>value of the boolean (0=_false, 1=_true)</td>
</tr>
<tr>
<td>char</td>
<td>character</td>
<td><em>PlLong</em></td>
<td>value of (the code of) the character</td>
</tr>
<tr>
<td>code</td>
<td>character code</td>
<td><em>PlLong</em></td>
<td>value of the character-code</td>
</tr>
<tr>
<td>byte</td>
<td>byte</td>
<td><em>PlLong</em></td>
<td>value of the byte</td>
</tr>
<tr>
<td>in_char</td>
<td>in-character</td>
<td><em>PlLong</em></td>
<td>value of the character or -1 for end-of-file</td>
</tr>
<tr>
<td>in_code</td>
<td>in-character code</td>
<td><em>PlLong</em></td>
<td>value of the character-code or -1 for end-of-file</td>
</tr>
<tr>
<td>in_byte</td>
<td>in-byte</td>
<td><em>PlLong</em></td>
<td>value of the byte or -1 for the end-of-file</td>
</tr>
<tr>
<td>string</td>
<td>atom</td>
<td>_char*</td>
<td>C string containing the name of the atom</td>
</tr>
<tr>
<td>chars</td>
<td>character list</td>
<td>_char*</td>
<td>C string containing the characters of the list</td>
</tr>
<tr>
<td>codes</td>
<td>character-code list</td>
<td>_char*</td>
<td>C string containing the characters of the list</td>
</tr>
<tr>
<td>term</td>
<td>Prolog term</td>
<td><em>PlTerm</em></td>
<td>generic Prolog term</td>
</tr>
</tbody>
</table>

**Simple foreign type**: a simple type is any foreign type listed in the above tabled except _term_. A simple foreign type is an atomic term (character and character-code lists are in fact lists of constants). Each simple foreign type is converted to/from a C type to simplify the writing of the C function.

**Complex foreign type**: type foreign type _term_ refers to any Prolog term (e.g. lists, structures...). When such an type is specified the argument is passed to the C function as a _PlTerm_ (GNU Prolog C type equivalent to a _PlLong_). Several functions are provided to manipulate _PlTerm_ variables (section 10.4, page 210). Since the original term is passed to the function it is possible to read its value or to unify it. So the meaning of the mode symbol is less significant. For this reason it is possible to omit the mode symbol. In that case _term_ is equivalent to +_term_.

10.3.3 The C function

The type returned by the C function depends on the value of the return foreign option (section \[10.3.2\], page \[202\]). If it is boolean then the C function is of type PlBool and shall return PL_TRUE in case of success and PL_FALSE otherwise. If the return option is none the C function is of type void. Finally if it is jump, the function shall return the address of a Prolog predicate and, at the exit of the function, the control is given to that predicate.

The type of the arguments of the C function depends on the mode and type declaration specified in Template for the corresponding argument as explained in the following sections.

10.3.4 Input arguments

An input argument is tested at run-time to check if its type conforms to the foreign type and then it is passed to the C function. The type of the associated C argument is given by the above table (section \[10.3.2\], page \[202\]). For instance, the effective argument Arg associated with +positive foreign declaration is submitted to the following process:

- if Arg is a variable an instantiation_error is raised.
- if Arg is neither a variable nor an integer a type_error(integer, Arg) is raised.
- if Arg is an integer < 0 a domain_error(not_less_than_zero, Arg) is raised.
- otherwise the value of Arg is passed to the C function as an integer (PlLong).

When +string is specified the string passed to the function is the internal string of the corresponding atom and should not be modified.

When +term is specified the term passed to the function is the original Prolog term. It can be read and/or unified. It is also the case when term is specified without any mode symbol.

10.3.5 Output arguments

An output argument is tested at run-time to check if its type conforms to the foreign type and it is unified with the value set by the C function. The type of the associated C argument is a pointer to the type given by the above table (section \[10.3.2\], page \[202\]). For instance, the effective argument Arg associated with -positive foreign declaration is handled as follows:

- if Arg is neither a variable nor an integer a type_error(integer, Arg) is raised.
- if Arg is an integer < 0 a domain_error(not_less_than_zero, Arg) is raised.
- otherwise a pointer to an integer (PlLong *) is passed to the C function. If the function returns PL_TRUE the integer stored at this location is unified with Arg.

When -term is specified, the function must construct a term into the its corresponding argument (which is of type PlTerm *). At the exit of the function this term will be unified with the actual predicate argument.
10.3.6 Input/output arguments

Basically an input/output argument is treated as in input argument if it is not a variable, as an output argument otherwise. The type of the associated C argument is a pointer to a `PlFIOArg` (GNU Prolog C type) defined as follows:

```c
typedef struct {
    PlBool is_var;
    PlBool unify;
    union {
        PlLong l;
        char *s;
        double d;
    }value;
} PlFIOArg;
```

The field `is_var` is set to `PL_TRUE` if the argument is a variable and `PL_FALSE` otherwise. This value can be tested by the C function to determine which treatment to perform. The field `unify` controls whether the effective argument must be unified at the exit of the C function. Initially `unify` is set to the same value as `is_var` (i.e. a variable argument will be unified while a non-variable argument will not) but it can be modified by the C function. The field `value` stores the value of the argument. It is declared as a C union since there are several kinds of value types. The field `s` is used for C strings, `d` for C doubles and `l` otherwise (int, `PlLong`, `PlTerm`). If `is_var` is `PL_FALSE` then `value` contains the input value of the argument with the same conventions as for input arguments (section 10.3.4, page 204). At the exit of the function, if unify is `PL_TRUE` `value` must contain the value to unify with the same conventions as for output arguments (section 10.3.5, page 204).

For instance, the effective argument `Arg` associated with `?positive` foreign declaration is handled as follows:

- If `Arg` is a variable `is_var` and `unify` are set to `PL_TRUE` else to `PL_FALSE` and its value is copied in `value.l`.
- If `Arg` is neither a variable nor an integer a `type_error(integer, Arg)` is raised.
- If `Arg` is an integer < 0 a `domain_error(not_less_than_zero, Arg)` is raised.
- Otherwise a pointer to the `PlFIOArg` (`PlFIOArg *`) is passed to the C function. If the function returns `PL_TRUE` and if `unify` is `PL_TRUE` the value stored in `value.l` is unified with `Arg`.

10.3.7 Writing non-deterministic C code

The interface allows the user to write non-deterministic C code. When a C function is non-deterministic, a choice-point is created for this function. When a failure occurs, if all more recent non-deterministic code are finished, the function is re-invoked. It is then important to inform Prolog when there is no more solution (i.e. no more choice) for a non-deterministic code. So, when no more choices remains the function must remove the choice-point. The interface increments a counter each time the function is re-invoked. At the first call this counter is equal to 0. This information allows the function to detect its first call. When writing non-deterministic code, it is often useful to record data between consecutive re-invocations of the function. The interface maintains a buffer to record such an information. The size of this buffer is given by `choice_size(N)` when using `foreign/2` (section 10.3.2, page 202). This size is the number of (consecutive) `PlLong`s needed by the C function. Inside the function it is possible to call the following functions/macros:
int Pl_Get_Choice_Counter(void)
TYPE Pl_Get_Choice_Buffer (TYPE)
void Pl_No_More_Choice (void)

The macro `Pl_Get_Choice_Counter()` returns the value of the invocation counter (0 at the first call).

The macro `Pl_Get_Choice_Buffer(TYPE)` returns a pointer to the buffer (casted to `TYPE`).

The function `Pl_No_More_Choice()` deletes the choice point associated with the function.

10.3.8 Example: input and output arguments

All examples presented here can be found in the ExamplesC sub-directory of the distribution, in the files `examp.pl` (Prolog part) and `examp.c.c` (C part).

Let us define a predicate `first_occurrence(A, C, P)` which unifies `P` with the position (from 0) of the first occurrence of the character `C` in the atom `A`. The predicate must fail if `C` does not appear in `A`.

In the prolog file `examp.pl`:

```prolog
:- foreign(first_occurrence(+string, +char, -positive)).
```

In the C file `examp.c.c`:

```c
#include <string.h>
#include <gprolog.h>

PlBool first_occurrence(char *str, PlLong c, PlLong *pos)
{
    char *p;
    p = strchr(str, c);
    if (p == NULL) /* C does not appear in A */
        return PL_FALSE; /* fail */
    *pos = p - str; /* set the output argument */
    return PL_TRUE; /* succeed */
}
```

The compilation produces an executable called `examp`:

```
% gplc examp.pl examp.c.c
```

Examples of use:

```
| ?- first_occurrence(prolog, p, X).
X = 0
| ?- first_occurrence(prolog, k, X).
no
| ?- first_occurrence(prolog, A, X).
{exception: error(instantiation_error,first_occurrence/3)}
```
10.3.9 Example: non-deterministic code

We here define a predicate occurrence(A, C, P) which unifies P with the position (from 0) of one occurrence of the character C in the atom A. The predicate will fail if C does not appear in A. The predicate is re-executable on backtracking. The information that must be recorded between two invocations of the function is the next starting position in A to search for C.

In the prolog file examp.pl:

:- foreign(occurrence(+string, +char, -positive), [choice_size(1)]).

In the C file examp.c.c:

```c
#include <string.h>
#include <gprolog.h>

PlBool occurrence(char *str, PlLong c, PlLong *pos)
{
    char **info_pos;
    char *p;

    info_pos = Pl_Get_Choice_Buffer(char **); /* recover the buffer */
    if (Pl_Get_Choice_Counter() == 0) /* first invocation ? */
        *info_pos = str;

    p = strchr(*info_pos, c);
    if (p == NULL) /* c does not appear */
    {
        Pl_No_More_Choice(); /* remove choice-point */
        return PL_FALSE; /* fail */
    }
    *pos = p - str; /* set the output argument */
    *info_pos = p + 1; /* update next starting pos */
    return PL_TRUE; /* succeed */
}
```

The compilation produces an executable called examp:

```
% gplc examp.pl examp.c.c
```

Examples of use:
?- occurrence(prolog, o, X).
X = 2 ?
  (here the user presses ; to compute another solution)
X = 4 ?
  (here the user presses ; to compute another solution)
no
  (no more solution)

?- occurrence(prolog, k, X).
no

In the first example when the second (the last) occurrence is found (X=4) the choice-point remains and the failure is detected only when another solution is requested (by pressing ;). It is possible to improve this behavior by deleting the choice-point when there is no more occurrence. To do this it is necessary to do one search ahead. The information stored is the position of the next occurrence. Let us define such a behavior for the predicate occurrence2/3.

In the prolog file examp.pl:

:- foreign(occurrence2(+string, +char, -positive), [choice_size(1)]).

In the C file examp.c.c:

```c
#include <string.h>
#include <gprolog.h>

PlBool occurrence2(char *str, PlLong c, PlLong *pos)
{
  char **info_pos;
  char *p;

  info_pos = Pl_Get_Choice_Buffer(char **); /* recover the buffer */

  if (Pl_Get_Choice_Counter() == 0) /* first invocation ? */
  {
    p = strchr(str, c);
    if (p == NULL) /* C does not appear at all */
    {
      Pl_No_More_Choice(); /* remove choice-point */
      return PL_FALSE; /* fail */
    }
    *info_pos = p;
  }
  /* info_pos = an occurrence */
  *pos = *info_pos - str; /* set the output argument */

  p = strchr(*info_pos + 1, c);
  if (p == NULL) /* no more occurrence */
    Pl_No_More_Choice(); /* remove choice-point */
  else
    *info_pos = p; /* else update next solution */

  return PL_TRUE; /* succeed */
}
```
10.3 Calling C from Prolog

Examples of use:

| ?- occurrence2(prolog, l, X).  
X = 3                (here the user is not prompted since there is no more alternative)  
| ?- occurrence2(prolog, o, X).  
X = 2 ?           (here the user presses ; to compute another solution)  
X = 4                (here the user is not prompted since there is no more alternative)

10.3.10 Example: input/output arguments

We here define a predicate `char_ascii(Char, Code)` which converts in both directions the character `Char` and its character-code `Code`. This predicate is then similar to `char_code/2` (section 8.19.4 page 130).

In the prolog file `examp.pl`:

```prolog
:- foreign(char_ascii(?char, ?code)).
```

In the C file `examp.c.c`:

```c
#include <gprolog.h>

PlBool char_ascii(PlFIOArg *c, PlFIOArg *ascii) {
    if (!c->is_var) /* Char is not a variable */
    {
        ascii->unify = PL_TRUE; /* enforce unif. of Code */
        ascii->value.l = c->value.l; /* set Code */
        return PL_TRUE; /* succeed */
    }
    if (ascii->is_var) /* Code is also a variable */
        Pl_Err_Instantiation(); /* emit instantiation_error */
    c->value.l = ascii->value.l; /* set Char */
    return PL_TRUE; /* succeed */
}
```

If `Char` is instantiated it is necessary to enforce the unification of `Code` since it could be instantiated. Recall that by default if an input/output argument is instantiated it will not be unified at the exit of the function (section 10.3.6 page 205). If both `Char` and `Code` are variables the function raises an `instantiation_error`. The way to raise Prolog errors is described later (section 10.5 page 217).

The compilation produces an executable called `examp`:

```bash
% gplc examp.pl examp.c.c
```

Examples of use:

| ?- char_ascii(a, X).  
X = 97
| ?- char_ascii(X, 65).
X = 'A'
| ?- char_ascii(a, 12).
no
| ?- char_ascii(X, X).
{exception: error(instantiation_error,char_ascii/2)}
| ?- char_ascii(1, 12).
{exception: error(type_error(character,1),char_ascii/2)}

10.4 Manipulating Prolog terms

10.4.1 Introduction

In the following we present a set of functions to manipulate Prolog terms. For simple foreign terms the functions manipulate simple C types (section 10.3.2, page 202).

Functions managing lists handle an array of 2 elements (of type P1Term) containing the terms corresponding to the head and the tail of the list. For the empty list NULL is passed as the array. These functions require to flatten a list in each sub-list. To simplify the management of proper lists (i.e. lists terminated by []) a set of functions is provided that handle the number of elements of the list (an integer) and an array whose elements (of type P1Term) are the elements of the list. The caller of these functions must provide the array.

Functions managing compound terms handle a functor (the principal functor of the term), an arity \( N \geq 0 \) and an array of \( N \) elements (of type P1Term) containing the sub-terms of the compound term. Since a list is a special case of compound term (functor = '.' and arity=2) it is possible to use any function managing compound terms to deal with a list but the error detection is not the same. Indeed many functions check if the Prolog argument is correct. The name of a read or unify function checking the Prolog arguments is of the form \( Name() \). For each of these functions there is a also check-free version called \( Name() \). We then only present the name of checking functions.

10.4.2 Managing Prolog atoms

Each atom has a unique internal key (an integer) which corresponds to its index in the GNU Prolog atom table. It is possible to obtain the information about an atom and to create new atoms using:

```c
char *P1_Atom_Name (int atom) (int atom)
int P1_Atom_Length (int atom) (int atom)
P1Bool P1_Atom_Needs_Quote (int atom) (int atom)
P1Bool P1_Atom_Needs_Scan (int atom) (int atom)
P1Bool P1_Is_Valid_Atom (int atom) (int atom)
int P1_Create_Atom (const char *str) (int atom)
int P1_Create_Allocate_Atom(const char *str) (const char *str)
int P1_Find_Atom (const char *str) (const char *str)
int P1_Atom_Char (char c) (char c)
```
The function \( \text{PlAtomName}(\text{atom}) \) returns the internal string of \( \text{atom} \) (this string should not be modified). The function \( \text{PlAtomLength}(\text{atom}) \) returns the length (of the name) of \( \text{atom} \).

The function \( \text{Pl Atom Needs Scan}(\text{atom}) \) indicates if the canonical form of \( \text{atom} \) needs to be quoted as done by \text{writeq/2} \quad (\text{section 8.14.6, page 108}). In that case \( \text{PlAtomNeedsScan}(\text{atom}) \) indicates if this simply comes down to write quotes around the name of \( \text{atom} \) or if it necessary to scan each character of the name because there are some non-printable characters (or included quote characters). The function \( \text{PlIsValidAtom}(\text{atom}) \) is true only if \( \text{atom} \) is the internal key of an existing atom.

The function \( \text{PlCreateAtom}(\text{str}) \) adds a new atom whose name is the content of \( \text{str} \) to the system and returns its internal key. If the atom already exists its key is simply returned. The string \( \text{str} \) passed to the function should not be modified later. The function \( \text{PlCreateAllocateAtom}(\text{str}) \) is provided when this condition cannot be ensured. It simply makes a dynamic copy of \( \text{str} \) (using \text{strdup(3)}).

The function \( \text{PlFindAtom}(\text{str}) \) returns the internal key of the atom whose name is \( \text{str} \) or \(-1\) if it does not exist.

All atoms corresponding to a single character already exist and their key can be obtained via the function \( \text{PlAtomChar} \). For instance \( \text{PlAtomChar}('.' \) \) is the atom associated with \( '.' \) (this atom is the functor of lists). The other functions return the internal key of frequently used atoms: \( [\], \text{false}, \text{true} \) and \text{end_of_file}.

10.4.3 Reading Prolog terms

The name of all functions presented here are of the form \( \text{PlRdNameCheck()} \). They all check the validity of the Prolog term to read emitting appropriate errors if necessary. Each function has a check-free version called \( \text{PlRdName()} \).

**Simple foreign types**: for each simple foreign type (section \[10.3.2, page 202\] there is a read function (used by the interface when an input argument is provided):

\[
\begin{align*}
\text{PlLong} & \quad \text{PlRdIntegerCheck(PlTerm term)} \\
\text{PlLong} & \quad \text{PlRdPositiveCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdCIntCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdCIntPositiveCheck(PlTerm term)} \\
\text{double} & \quad \text{PlRdFloatCheck(PlTerm term)} \\
\text{double} & \quad \text{PlRdNumberCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdAtomCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdBooleanCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdCharCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdInCharCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdCodeCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdInCodeCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdByteCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdInByteCheck(PlTerm term)} \\
\text{char} & \quad \text{PlRdStringCheck(PlTerm term)} \\
\text{char} & \quad \text{PlRdCharsCheck(PlTerm term)} \\
\text{char} & \quad \text{PlRdCodesCheck(PlTerm term)} \\
\text{int} & \quad \text{PlRdCharsStrCheck(PlTerm term, char *str)}
\end{align*}
\]
int Pl_Rd_Codes_Str_Check (PlTerm term, char *str)

The function Pl_Rd_C_Int_Check() is similar to Pl_Rd_Integer_Check() but returns a C int instead of a PlLong. If the Prolog integer does not fit into a C int, a representation_error is raised (this can occur on 64-bits machine with int on 32-bits). Similarly for Pl_Rd_C_Int_Positive_Check().

All functions returning a C string (char *) use a same buffer. The function Pl_Rd_Char_S_Str_Check() is similar to Pl_Rd_Char_S_Check() but accepts as argument a string to store the result and returns the length of that string (which is also the length of the Prolog list). Similarly for Pl_Rd_Codes_Str_Check().

**Complex terms**: the following functions return the sub-arguments (terms) of complex terms as an array of PlTerm except Pl_Rd_Proper_List_Check() which returns the size of the list read (and initializes the array element). Refer to the introduction of this section for more information about the arguments of complex functions (section 10.4.1, page 210).

```
int Pl_Rd_Proper_List_Check(PlTerm term, PlTerm *arg)
PlTerm *Pl_Rd_List_Check (PlTerm term)
PlTerm *Pl_Rd_Compound_Check (PlTerm term, int *functor, int *arity)
PlTerm *Pl_Rd_Callable_Check (PlTerm term, int *functor, int *arity)
```

### 10.4.4 Unifying Prolog terms

The name of all functions presented here are of the form Pl_Un_Name_Check(). They all check the validity of the Prolog term to unify emitting appropriate errors if necessary. Each function has a check-free version called Pl_Un_Name().

**Simple foreign types**: for each simple foreign type (section 10.3.2, page 202) there is an unify function (used by the interface when an output argument is provided):

```
PlBool Pl_Un_Integer_Check (PlLong n, PlTerm term)
PlBool Pl_Un_Positive_Check(PlLong n, PlTerm term)
PlBool Pl_Un_Float_Check (double n, PlTerm term)
PlBool Pl_Un_Number_Check (double n, PlTerm term)
PlBool Pl_Un_Atom_Check (int atom, PlTerm term)
PlBool Pl_Un_Boolean_Check (int b, PlTerm term)
PlBool Pl_Un_Char_Check (int c, PlTerm term)
PlBool Pl_Un_In_Char_Check (int c, PlTerm term)
PlBool Pl_Un_Code_Check (int c, PlTerm term)
PlBool Pl_Un_In_Code_Check (int c, PlTerm term)
PlBool Pl_Un_Number_Check (int n, PlTerm term)
PlBool Pl_Un_In_Number_Check (int n, PlTerm term)
PlBool Pl_Un_Code_Check (const char *str, PlTerm term)
PlBool Pl_Un_In_Code_Check (const char *str, PlTerm term)
```

The function Pl_Un_Number_Check(n, term) unifies term with an integer if n is an integer, with a floating point number otherwise. The function Pl_Un_String_Check(str, term) creates the atom corresponding to str and then unifies term with it (same as Pl_Un_Atom_Check(Pl_Create_Allocate_Atom(str), term)).

The following functions perform a general unification (between 2 terms). The second one performs a occurs-check test (while the first one does not).

```
PlBool Pl_Unif(PlTerm term1, PlTerm term2)
PlBool Pl_Unif_With_Occurs_Check(PlTerm term1, PlTerm term2)
```
Complex terms: the following functions accept the sub-arguments (terms) of complex terms as an array of PLTerm. Refer to the introduction of this section for more information about the arguments of complex functions (section 10.4.1, page 210).

\[
\begin{align*}
&\text{PlBool } \text{Pl_Un_Proper_List_Check}(\text{int size, PLTerm } \ast \text{arg, PLTerm term}) \\
&\text{PlBool } \text{Pl_Un_List_Check} (\text{PLTerm } \ast \text{arg, PLTerm term}) \\
&\text{PlBool } \text{Pl_Un_Compound_Check} (\text{int functor, int arity, PLTerm } \ast \text{arg, PLTerm term}) \\
&\text{PlBool } \text{Pl_Un_Callable_Check} (\text{int functor, int arity, PLTerm } \ast \text{arg, PLTerm term})
\end{align*}
\]

All these functions check the type of the term to unify and return the result of the unification. Generally if an unification fails the C function returns PL\_FALSE to enforce a failure. However if there are several arguments to unify and if an unification fails then the C function returns PL\_FALSE and the type of other arguments has not been checked. Normally all error cases are tested before doing any work to be sure that the predicate fails/succeeds only if no error condition is satisfied. So a good method is to check the validity of all arguments to unify and later to do the unification (using check-free functions). Obviously if there is only one to unify it is more efficient to use a unify function checking the argument. For the other cases the interface provides a set of functions to check the type of a term.

Simple foreign types: for each simple foreign type (section 10.3.2, page 202) there is check-for-unification function (used by the interface when an output argument is provided):

\[
\begin{align*}
&\text{void } \text{Pl_Check_For_Un_Integer}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Positive}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Float}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Number}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Atom}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Boolean}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Char}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_In_Char}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Code}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_In_Code}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Byte}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_In_Byte}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_String}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Chars}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Codes}(\text{PLTerm term})
\end{align*}
\]

Complex terms: the following functions check the validity of complex terms:

\[
\begin{align*}
&\text{void } \text{Pl_Check_For_Un_List}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Compound}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Callable}(\text{PLTerm term}) \\
&\text{void } \text{Pl_Check_For_Un_Variable}(\text{PLTerm term})
\end{align*}
\]

The function Pl\_Check\_For\_Un\_List(term) checks if term can be unified with a list. This test is done for the entire list (not only for the functor/arity of term but also recursively on the tail of the list). The function Pl\_Check\_For\_Un\_Variable(term) ensures that term is not currently instantiated. These functions can be defined using functions to test the type of a Prolog term (section 10.4.6, page 214) and functions to raise Prolog errors (section 10.5, page 217). For instance Pl\_Check\_For\_Un\_List(term) is defined as follows:

\[
\begin{align*}
&\text{void } \text{Pl_Check_For_Un_List}(\text{PLTerm term}) \\
&\{ \\
&\quad \text{if } (!\text{Pl_Builtin_List_Or_Partial_List}(\text{term})) \\
&\quad \text{Pl_Err_Type(type_list, term);}
&\}
\end{align*}
\]
10.4.5 Creating Prolog terms

These functions are provided to create Prolog terms. Each function returns a PlTerm containing the created term.

**Simple foreign types**: for each simple foreign type (section 10.3.2 page 202) there is a creation function:

- `PlTerm Pl_Mk_Integer (PlLong n)`
- `PlTerm Pl_Mk_Positive(PlLong n)`
- `PlTerm Pl_Mk_Float (double n)`
- `PlTerm Pl_Mk_Number (double n)`
- `PlTerm Pl_Mk_Atom (int atom)`
- `PlTerm Pl_Mk_Boolean (int b)`
- `PlTerm Pl_Mk_Char (int c)`
- `PlTerm Pl_Mk_In_Char (int c)`
- `PlTerm Pl_Mk_Code (int c)`
- `PlTerm Pl_Mk_In_Code (int c)`
- `PlTerm Pl_Mk_Byte (int b)`
- `PlTerm Pl_Mk_In_Byte (int b)`
- `PlTerm Pl_Mk_String (const char *str)`
- `PlTerm Pl_Mk_Chars (const char *str)`
- `PlTerm Pl_Mk_Codes (const char *str)`

The function `Pl_Mk_Number(n, term)` initializes `term` with an integer if `n` is an integer, with a floating point number otherwise. The function `Pl_Mk_String(str)` first creates an atom corresponding to `str` and then returns that Prolog atom (i.e. equivalent to `Pl_Mk_Atom(Pl_Create_Allocate_Atom(str))`).

**Complex terms**: the following functions accept the sub-arguments (terms) of complex terms as an array of PlTerm. Refer to the introduction of this section for more information about the arguments of complex functions (section 10.4.1 page 210).

- `PlTerm Pl_Mk_Proper_List(int size, const PlTerm *arg)`
- `PlTerm Pl_Mk_List (PlTerm *arg)`
- `PlTerm Pl_Mk_Compound (int functor, int arity, const PlTerm *arg)`
- `PlTerm Pl_Mk_Callable (int functor, int arity, const PlTerm *arg)`

10.4.6 Testing the type of Prolog terms

The following functions test the type of a Prolog term. Each function corresponds to a type testing built-in predicate (section 8.1.1 page 55).

- `PlBool Pl_Builtin_Var (PlTerm term)`
- `PlBool Pl_Builtin_Non_Var (PlTerm term)`
- `PlBool Pl_Builtin_Atom (PlTerm term)`
- `PlBool Pl_Builtin_Integer (PlTerm term)`
- `PlBool Pl_Builtin_Float (PlTerm term)`
- `PlBool Pl_Builtin_Number (PlTerm term)`
- `PlBool Pl_Builtin_Atomic (PlTerm term)`
- `PlBool Pl_Builtin_Compound (PlTerm term)`
- `PlBool Pl_Builtin_Callable (PlTerm term)`
- `PlBool Pl_Builtin_List (PlTerm term)`
- `PlBool Pl_Builtin_Partial_List (PlTerm term)`
- `PlBool Pl_Builtin_List_Or_Partial_List(PlTerm term)`
- `PlBool Pl_Builtin_Fd_Var (PlTerm term)`
10.4 Manipulating Prolog terms

PlBool Pl_Builtin_NonFd_Var (PlTerm term)
PlBool Pl_Builtin_Generic_Var (PlTerm term)
PlBool Pl_Builtin_Non_Generic_Var (PlTerm term)
int Pl_Type_Of_Term (PlTerm term)
PlLong Pl_List_Length (PlTerm list)

The function Pl_Type_Of_Term(term) returns the type of term, the following constants can be used to test this type (e.g. in a switch instruction):

- PL_PLV: Prolog variable.
- PL_FDV: finite domain variable.
- PL_INT: integer.
- PL_FLT: floating point number.
- PL_ATM: atom.
- PL_LST: list.
- PL_STC: structure

The tag PL_LST means a term whose principal functor is '.' and whose arity is 2 (recall that the empty list is the atom []). The tag PL_STC means any other compound term.

The function Pl_List_Length(list) returns the number of elements of the list (0 for the empty list). If list is not a list this function returns -1.

10.4.7 Comparing Prolog terms

The following functions compares Prolog terms. Each function corresponds to a comparison built-in predicate (section 8.3.2, page 57).

PlBool Pl_Builtin_Term_Eq (PlTerm term1, PlTerm term2)
PlBool Pl_Builtin_Term_Neq (PlTerm term1, PlTerm term2)
PlBool Pl_Builtin_Term_Lt (PlTerm term1, PlTerm term2)
PlBool Pl_Builtin_Term_Lte (PlTerm term1, PlTerm term2)
PlBool Pl_Builtin_Term_Gt (PlTerm term1, PlTerm term2)
PlBool Pl_Builtin_Term_Gte (PlTerm term1, PlTerm term2)

All these functions are based on a general comparison function returning a negative integer if term1 is less than term2, 0 if they are equal and a positive integer otherwise:

PlLong Term_Compare (PlTerm term1, PlTerm term2)

Finally, the following function gives an access to the compare/3 built-in (section 8.3.3, page 58) unifying cmp with the atom <, = or > depending on the result of the comparison of term1 and term2.

PlBool Pl_Builtin_Compare (PlTerm cmp, PlTerm term1, PlTerm term2)

10.4.8 Term processing

The following functions give access to the built-in predicates: functor/3 (section 8.4.1, page 59), arg/3 (section 8.4.2, page 59) and (=/..)/2 (section 8.4.3, page 60).
PlBool Pl_Builtin_Functor(PlTerm term, PlTerm functor, PlTerm arity)

PlBool Pl_Builtin_Arg(PlTerm arg_no, PlTerm term, PlTerm sub_term)

PlBool Pl_Builtin_Univ(PlTerm term, PlTerm list)

The following functions make a copy of a Prolog term:

void Pl_Copy_Term (PlTerm *dst_term, const PlTerm *src_term)
void Pl_Copy_Contiguous_Term(PlTerm *dst_term, const PlTerm *src_term)
int Pl_Term_Size (PlTerm term)

The function Pl_Copy_Term(dst_term, src_term) makes a copy of the term located at src_term and stores it from the address given by dst_term. The result is a contiguous term. If it can be ensured that the source term is a contiguous term (i.e. result of a previous copy) the function Pl_Copy_Contiguous_Term() can be used instead (it is faster). In any case, sufficient space should be available for the copy (i.e. from dst_term). The function Pl_Term_Size(term) returns the number of PlTerm needed by term.

The following function is an utility to display a term to the console, similarly to the built-in predicate write/1 (section 8.14.6, page 108).

void Pl_Write(PlTerm term)

This Pl_Write function can be used for debugging purpose. However, it is more flexible to receive the content of the write/1 as a C string. This can be achieved by the following functions (using respectively write/1, writeq/1, write_canonical/1 and display/1 (section 8.14.6, page 108) to obtain a textual representation of the term). These functions return a dynamically allocated C string (using malloc(3)) which can be freed by the user when no longer needed.

char *Pl_Write_To_String(PlTerm term)
char *Pl_Writeq_To_String(PlTerm term)
char *Pl_Write_Canonical_To_String(PlTerm term)
char *Pl_Display_To_String(PlTerm term)

Finally the following function performs the opposite conversion: given a C string it returns the associated Prolog term. It uses read_term/2 (section 8.14.1 page 104) with the option end_of_term(eof) (thus the C string does not need to terminate by a dot).

PlTerm Pl_Read_From_String(const char *str)

10.4.9 Comparing and evaluating arithmetic expressions

The following functions compare arithmetic expressions. Each function corresponds to a comparison built-in predicate (section 8.6.3 page 69).

PlBool Pl_Builtin_Eq (PlTerm expr1, PlTerm expr2)
PlBool Pl_Builtin_Neq(PlTerm expr1, PlTerm expr2)
PlBool Pl_Builtin_Lt (PlTerm expr1, PlTerm expr2)
PlBool Pl_Builtin_Lte(PlTerm expr1, PlTerm expr2)
PlBool Pl_Builtin_Gt (PlTerm expr1, PlTerm expr2)
PlBool Pl_Builtin_Gte(PlTerm expr1, PlTerm expr2)

The following function evaluates the expression expr and stores its result as a Prolog number (integer or floating point number) in result:

void Pl_Math_Evaluate(PlTerm expr, PlTerm *result)

This function can be followed by a read function (section 10.4.3 page 211) to obtain the result.
10.5 Raising Prolog errors

The following functions allows a C function to raise a Prolog error. Refer to the section concerning Prolog errors for more information about the effect of raising an error (section 6.3, page 39).

10.5.1 Managing the error context

When one of the following error function is invoked it refers to the implicit error context (section 6.3.1, page 39). This context indicates the name and the arity of the concerned predicate. When using a foreign/2 declaration this context is set by default to the name and arity of the associated Prolog predicate. This can be controlled using the bip_name option (section 10.3.2, page 202). In any case, the following functions can also be used to modify this context:

```c
void Pl_Set_C_Bip_Name (const char *functor, int arity);
void Pl_Unset_C_Bip_Name(void);
```

The function `Pl_Set_C_Bip_Name(functor, arity)` initializes the context of the error with `functor` and `arity` (if `arity<0` only `functor` is significant). The function `Pl_Unset_C_Bip_Name()` removes such an initialization (the context is then reset to the last `Functor/Arity` set by a call to `set_bip_name/2` (section 8.22.3, page 151). This is useful when writing a C routine to define a context for errors occurring in this routine and, before exiting to restore the previous context.

10.5.2 Instantiation error

The following function raises an instantiation error (section 6.3.2, page 39):

```c
void Pl_Err_Instantiation(void);
```

10.5.3 Uninstantiation error

The following function raises an uninstantiation error (section 6.3.3, page 40):

```c
void Pl_Err_Uninstantiation( PlTerm culprit);
```

10.5.4 Type error

The following function raises a type error (section 6.3.4, page 40):

```c
void Pl_Err_Type(int atom_type, PlTerm culprit);
```

`atom_type` is (the internal key of) the atom associated with the expected type. For each type name `T` there is a corresponding predefined atom stored in a global variable whose name is of the form `pl_type_T`. `culprit` is the argument which caused the error.

**Example:** `x` is an atom while an integer was expected: `Pl_Err_Type(pl_type_integer, x)`.

10.5.5 Domain error

The following function raises a domain error (section 6.3.5, page 40):
void Pl_Err_Domain(int atom_domain, PlTerm culprit)

atom_domain is (the internal key of) the atom associated with the expected domain. For each domain name $D$ there is a corresponding predefined atom stored in a global variable whose name is of the form domain_$D$. culprit is the argument which caused the error.

Example: $x$ is $< 0$ but should be $\geq 0$: Pl_Err_Domain(pl_domain_not_less_than_zero, $x$).

10.5.6 Existence error

The following function raises an existence error (section 6.3.6 page 41):

void Pl_Err_Existence(int atom_object, PlTerm culprit)

atom_object is (the internal key of) the atom associated with the type of the object. For each object name $O$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_existence_$O$. culprit is the argument which caused the error.

Example: $x$ does not refer to an existing source: Pl_Err_Existence(pl_existence_source_sink, $x$).

10.5.7 Permission error

The following function raises a permission error (section 6.3.7 page 41):

void Pl_Err_Permission(int atom_operation, int atom_permission, PlTerm culprit)

atom_operation is (the internal key of) the atom associated with the operation which caused the error. For each operation name $O$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_permission_operation_$O$. atom_permission is (the internal key of) the atom associated with the tried permission. For each permission name $P$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_permission_type_$P$. culprit is the argument which caused the error.

Example: reading from an output stream $x$: Pl_Err_Permission(pl_permission_operation_input, pl_permission_type_stream, $x$).

10.5.8 Representation error

The following function raises a representation error (section 6.3.8 page 41):

void Pl_Err_Representation(int atom_limit)

atom_limit is (the internal key of) the atom associated with the reached limit. For each limit name $L$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_representation_$L$.

Example: an arity too big occurs: Pl_Err_Representation(pl_representation_max arity).

10.5.9 Evaluation error

The following function raises an evaluation error (section 6.3.9 page 42):
10.5 Raising Prolog errors

void Pl_Err_Evaluation(int atom_error)

atom_error is (the internal key of) the atom associated with the error. For each evaluation error name $E$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_evaluation_$E$.

**Example:** a division by zero occurs: Pl_Err_Evaluation(pl_evaluation_zero_divisor).

### 10.5.10 Resource error

The following function raises a resource error (section 6.3.10 page 42):

```c
void Pl_Err_Resource(int atom_resource)
```

atom_resource is (the internal key of) the atom associated with the resource. For each resource error name $R$ there is a corresponding predefined atom stored in a global variable whose name is of the form pl_resource_$R$.

**Example:** too many open streams: Pl_Err_Resource(pl_resource_too_many_open_streams).

### 10.5.11 Syntax error

The following function raises a syntax error (section 6.3.11 page 42):

```c
void Pl_Err_Syntax(int atom_error)
```

atom_error is (the internal key of) the atom associated with the error. There is no predefined syntax error atoms.

**Example:** a `/` is expected: Pl_Err_Syntax(Pl_Create_Atom("/ expected")).

The following function emits a syntax error according to the value of the syntax_error Prolog flag (section 8.22.1 page 148). This function can then return (if the value of the flag is either `warning` or `fail`). In that case the calling function should fail (e.g. returning PL_FALSE). This function accepts a file name (the empty string C "" can be passed), a line and column number and an error message string. Using this function makes it possible to further call the built-in predicate syntax_error_info/4 (section 8.14.4 page 107):

```c
void Pl_Emit_Syntax_Error(char *file_name, int line, int column, char *message)
```

**Example:** a `/` is expected: Pl_Emit_Syntax_Error("data", 10, 30, "/ expected").

### 10.5.12 System error

The following function raises a system error (4.3.11, page *):

```c
void Pl_Err_System(int atom_error)
```

atom_error is (the internal key of) the atom associated with the error. There is no predefined system error atoms.

**Example:** an invalid pathname is given: Pl_Err_System(Pl_Create_Atom("invalid path name")).
The following function emits a system error associated with an operating system error according to the value of the os_error Prolog flag (section 8.22.1, page 148). This function can then return (if the value of the flag is either warning or fail). In that case the calling function should fail (e.g. returning PL_FALSE).

The following function uses the value of the errno C library variable (basically it calls Pl_Err_System with the result of strerror(errno)).

```c
void Pl_Os_Error(void)
```

**Example:** if a call to the C Unix function chdir(2) returns -1 then call Os_Error().

### 10.6 Calling Prolog from C

#### 10.6.1 Introduction

The following functions allows a C function to call a Prolog predicate:

```c
void Pl_Query_Begin (PlBool recoverable)
int Pl_Query_Call (int functor, int arity, PlTerm *arg)
int Pl_Query_Start (int functor, int arity, PlTerm *arg, PlBool recoverable)
int Pl_Query_Next_Solution(void)
void Pl_Query_End (int op)
PlTerm Pl_Get_Exception (void)
void Pl_Exec_Continuation (int functor, int arity, PlTerm *arg)
void Pl_Throw (PlTerm ball)
```

The invocation of a Prolog predicate should be done as follows:

- open a query using `Pl_Query_Begin()`
- compute the first solution using `Pl_Query_Call()`
- eventually compute next solutions using `Pl_Query_Next_Solution()`
- close the query using `Pl_Query_End()`

The function `Pl_Query_Begin(recoverable)` is used to initialize a query. The argument recoverable shall be set to PL_TRUE if the user wants to recover, at the end of the query, the memory space consumed by the query (in that case an additional choice-point is created). All terms created in the heap, e.g. using `Pl_Mk...` family functions (section 10.4.5, page 214), after the invocation of `Pl_Query_Begin()` can be recovered when calling `Pl_Query_End(PL_TRUE)` (see below).

The function `Pl_Query_Call(functor, arity, arg)` calls a predicate passing arguments. It is then used to compute the first solution. The arguments functor, arity and arg are similar to those of the functions handling complex terms (section 10.4.1, page 210). This function returns:

- **PL_FAILURE** (a constant equal to PL_FALSE, i.e. 0) if the query fails.
- **PL_SUCCESS** (a constant equal to PL_TRUE, i.e. 1) in case of success. In that case the argument array arg can be used to obtain the unification performed by the query.
- **PL_EXCEPTION** (a constant equal to 2). In that case function `Pl_Get_Exception()` can be used to obtained the exceptional term raised by `throw/1` (section 7.2.4, page 53).
The function \texttt{Pl\_Query\_Start(functor, arity, arg, recoverable)} is a shorthand equivalent to a call to \texttt{Pl\_Query\_Begin(recoverable)} followed by a call to \texttt{Pl\_Query\_Call(functor, arity, arg)}.

The function \texttt{Pl\_Query\_Next\_Solution()} is used to compute a new solution. It must be only used if the result of the previous solution was \texttt{PL\_SUCCESS}. This function returns the same kind of values as \texttt{Pl\_Query\_Call()} (see above).

The function \texttt{Pl\_Query\_End(op)} is used to finish a query. This function mainly manages the remaining alternatives of the query. However, even if the query has no alternatives this function must be used to correctly finish the query. The value of \texttt{op} is:

- \texttt{PL\_RECOVER}: to recover the memory space consumed by the query. After that the state of Prolog stacks is exactly the same as before opening the query. To use this option the query must have been initialized specifying \texttt{PL\_TRUE} for \texttt{recoverable} (see above).
- \texttt{PL\_CUT}: to cut remaining alternatives. The effect of this option is similar to a cut after the query.
- \texttt{PL\_KEEP\_FOR\_PROLOG}: to keep the alternatives for Prolog. This is useful when the query was invoked in a foreign C function. In that case, when the predicate corresponding to the C foreign function is invoked a query is executed and the remaining alternatives are then available as alternatives of that predicate.

Note that several queries can be nested since a stack of queries is maintained. For instance, it is possible to call a query and before terminating it to call another query. In that case the first execution of \texttt{Pl\_Query\_End()} will finish the second query (i.e. the inner) and the next execution of \texttt{Pl\_Query\_End()} will finish the first query.

The function \texttt{Pl\_Exec\_Continuation(functor, arity, arg)} replaces the current calculus by the execution of the specified predicate. The arguments \texttt{functor}, \texttt{arity} and \texttt{arg} are similar to those of the functions handling complex terms (section 10.4.1, page 210).

Finally the function \texttt{Pl\_Throw(ball)} throws an exception. See the \texttt{throw/1} control construct for more information on exceptions (section 7.2.4, page 53). Note that \texttt{Pl\_Throw(ball)} is logically equivalent (but faster) to \texttt{Pl\_Exec\_Continuation(Pl\_Find\_Atom("throw"), 1, &ball)}.

### 10.6.2 Example: my\_call/1 - a call/1 clone

We here define a predicate \texttt{my\_call(Goal)} which acts like \texttt{call(Goal)} except that we do not handle exceptions (if an exception occurs the goal simply fails):

In the prolog file \texttt{examp.pl}:

```prolog
:- foreign(my\_call(term)).
```

In the C file \texttt{examp\_c.c}:

```c
#include <string.h>
#include <gprolog.h>

Pl\_Bool
my\_call(Pl\_Term goal)
{
    Pl\_Term *arg;
    int functor, arity;
```
int result;

arg = Pl_Rd_Callable_Check(goal, &functor, &arity);
Pl_Query_Begin(PL_FALSE);
result = Pl_Query_Call(functor, arity, arg);
Pl_Query_End(PL_KEEP_FOR_PROLOG);
return (result == PL_SUCCESS);
}

The compilation produces an executable called `examp`:

% gplc examp.pl examp.c.c

Examples of use:

<table>
<thead>
<tr>
<th>?- my_call(write(hello)).</th>
</tr>
</thead>
<tbody>
<tr>
<td>hello</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>?- my_call(for(X,1,3)).</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = 1 ?</td>
</tr>
<tr>
<td>(here the user presses ; to compute another solution)</td>
</tr>
</tbody>
</table>

| X = 2 ?                  |
| (here the user presses ; to compute another solution) |

| X = 3                    |
| (here the user is not prompted since there is no more alternative) |

| ?- my_call(1).           |
| {exception: error(type_error(callable,1),my_call/1)} |

| ?- my_call(call(1)).     |
| no                       |

When `my_call(1)` is called an error is raised due to the use of `Pl_Rd_Callable_Check()`. However the error raised by `my_call(call(1))` is ignored and `PL_FALSE` (i.e. a failure) is returned by the foreign function.

To really simulate the behavior of `call/1` when an exception is recovered it should be re-raised to be captured by an earlier handler. The idea is then to execute a `throw/1` as the continuation. This is what it is done by the following code:

```c
#include <string.h>
#include <gprolog.h>

PlBool
my_call(PlTerm goal)
{
    PlTerm *args;
    int functor, arity;
    int result;

    args = Pl_Rd_Callable_Check(goal, &functor, &arity);
    Pl_Query_Begin(PL_FALSE);
    result = Pl_Query_Call(functor, arity, args);
    Pl_Query_End(PL_KEEP_FOR_PROLOG);
    if (result == PL_EXCEPTION)
    {
```
The following code propagates the error raised by \texttt{call/1}.

\begin{verbatim}
| ?- my_call(call(1)).
{exception: error(type_error(callingable,1),my_call/1)}
\end{verbatim}

Finally note that a simpler way to define \texttt{my_call/1} is to use \texttt{Pl\_Exec\_Continuation()} as follows:

\begin{verbatim}
#include <string.h>
#include <gprolog.h>

PlBool
my_call(PlTerm goal)
{
    PlTerm *args;
    int functor, arity;

    args = Pl\_Rd\_Callable\_Check(goal, &functor, &arity);
    Pl\_Exec\_Continuation(functor, arity, args);
    return PL\_TRUE;
}
\end{verbatim}

\subsection*{Example: recovering the list of all operators}

We here define a predicate \texttt{all_op(List)} which unifies \texttt{List} with the list of all currently defined operators as would be done by: \texttt{findall(X, current_op(_,_,X),List)}.

In the prolog file \texttt{examp.pl}:

\begin{verbatim}
:- foreign(all_op(term)).
\end{verbatim}

In the C file \texttt{examp.c.c}:

\begin{verbatim}
#include <string.h>
#include <gprolog.h>

PlBool
all_op(PlTerm list)
{
    PlTerm op[1024];
    PlTerm args[3];
    int n = 0;
    int result;

    Pl\_Query\_Begin(PL\_TRUE);
    args[0] = Pl\_Mk\_Variable();
    args[1] = Pl\_Mk\_Variable();
    args[2] = Pl\_Mk\_Variable();
    result = Pl\_Query\_Call(Find\_Atom("current\_op"), 3, args);
\end{verbatim}
while (result)
{
    op[n++] = Pl_Mk_Atom(Pl_Rd_Atom(args[2])); /* arg[2]: the name of the op */
    result = Pl_Query_Next_Solution();
}
Pl_Query_End(PL_RECOVER);

return Pl_Un_Proper_List_Check(n, op, list);
}

Note that we know here that there is no source for exception. In that case the result of Pl_Query_Call and Pl_Query_Next_Solution can be considered as a boolean.

The compilation produces an executable called examp:

% gplc examp.pl examp.c.c

Example of use:

| ?- all_op(L).
| L = [:-,-,\=,\=,\#,\#,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&,\&
Here is the definition of the default GNU Prolog `main()` function:

```c
static int
Main_Wrapper(int argc, char *argv[])
{
    int nb_user_directive;
    PlBool top_level;

    nb_user_directive = Pl_Start_Prolog(argc, argv);

    top_level = Pl_Try_Execute_Top_Level();

    Pl_Stop_Prolog();

    if (top_level || nb_user_directive)
        return 0;

    fprintf(stderr,
            "Warning: no initial goal executed
            " use a directive :- initialization(Goal)
            " or remove the link option --no-top-level"
            " (or --min-bips or --min-size)\n         ");

    return 1;
}

int
main(int argc, char *argv[])
{
    return Main_Wrapper(argc, argv);
}
```

Note that under some circumstances it is necessary to encapsulate the code of `main()` inside an intermediate function called by `main()`. Indeed, some C compilers (e.g. gcc) treats `main()` particularly, producing an incompatible code w.r.t GNU Prolog. So it is a good idea to always use a wrapper function as shown above.

10.7.1 Example: asking for ancestors

In this example we use the following Prolog code (in a file called `new_main.pl`):

```prolog
parent(bob, mary).
parent(jane, mary).
parent(mary, peter).
parent(paul, peter).
parent(peter, john).

anc(X, Y):-
    parent(X, Y).

anc(X, Z) :-
    parent(X, Y),
    anc(Y, Z).
```
The following file (called `new_main.c.c`) defines a `main()` function read the name of a person and displaying all successors of that person. This is equivalent to the Prolog query: `anc(Result, Name).

```c
static int
Main_Wrapper(int argc, char *argv[])
{
    int func;
    PlTerm arg[10];
    char str[100];
    char *sol[100];
    int i, nb_sol = 0;
    PlBool res;

    Pl_Start_Prolog(argc, argv);

    func = Pl_Find_Atom("anc");
    for (;;)
    {
        printf("Enter a name (or 'end' to finish): ");
        fflush(stdout);
        scanf("%s", str);
        if (strcmp(str, "end") == 0)
            break;
        Pl_Query_Begin(PL_TRUE);
        arg[0] = Pl_Mk_Variable();
        arg[1] = Pl_Mk_String(str);
        nb_sol = 0;
        res = Pl_Query_Call(func, 2, arg);
        while (res)
        {
            sol[nb_sol++] = Pl_Rd_String(arg[0]);
            res = Pl_Query_Next_Solution();
        }
        Pl_Query_End(PL_RECOVER);
        for (i = 0; i < nb_sol; i++)
            printf(" solution: %s\n", sol[i]);
        printf("%d solution(s)\n", nb_sol);
    }
    Pl_Stop_Prolog();
    return 0;
}

int
main(int argc, char *argv[])
{
    return Main_Wrapper(argc, argv);
}
```

The compilation produces an executable called `new_main`:

```
gplc new_main.pl new_main_c.c
```
Examples of use:

Enter a name (or 'end' to finish): john
  solution: peter
  solution: bob
  solution: jane
  solution: mary
  solution: paul
  5 solution(s)

Enter a name (or 'end' to finish): mary
  solution: bob
  solution: jane
  2 solution(s)

Enter a name (or 'end' to finish): end
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