SWI-Prolog 5.0
Reference Manual

*Updated for version 5.0.2, March 2002*

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SWI-Prolog is a Prolog implementation based on a subset of the WAM (Warren Abstract Machine). SWI-Prolog was developed as an open Prolog environment, providing a powerful and bi-directional interface to C in an era this was unknown to other Prolog implementations. This environment is required to deal with XPCE, an object-oriented GUI system developed at SWI. XPCE is used at SWI for the development of knowledge-intensive graphical applications.

As SWI-Prolog became more popular, a large user-community provided requirements that guided its development. Compatibility, portability, scalability, stability and providing a powerful development environment have been the most important requirements. Edinburgh, Quintus, SICStus and the ISO-standard guide the development of the SWI-Prolog primitives.

This document gives an overview of the features, system limits and built-in predicates.

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1.1 SWI-Prolog

SWI-Prolog has been designed and implemented to get a Prolog implementation which can be used for experiments with logic programming and the relation to other programming paradigms. The intention was to build a Prolog environment which offers enough power and flexibility to write substantial applications, but is straightforward enough to be modified for experiments with debugging, optimisation or the introduction of non-standard data types. Performance optimisation is limited due to the main objectives: portability (SWI-Prolog is entirely written in C and Prolog) and modifiability.

SWI-Prolog is based on a very restricted form of the WAM (Warren Abstract Machine) described in [Bowen & Byrd, 1983] which defines only 7 instructions. Prolog can easily be compiled into this language and the abstract machine code is easily decompiled back into Prolog. As it is also possible to wire a standard 4-port debugger in the WAM interpreter there is no need for a distinction between compiled and interpreted code. Besides simplifying the design of the Prolog system itself this approach has advantages for program development: the compiler is simple and fast, the user does not have to decide in advance whether debugging is required and the system only runs slightly slower when in debug mode. The price we have to pay is some performance degradation (taking out the debugger from the WAM interpreter improves performance by about 20%) and somewhat additional memory usage to help the decompiler and debugger.

SWI-Prolog extends the minimal set of instructions described in [Bowen & Byrd, 1983] to improve performance. While extending this set care has been taken to maintain the advantages of decompilation and tracing of compiled code. The extensions include specialised instructions for unification, predicate invocation, some frequently used built-in predicates, arithmetic, and control (;/2, |/2), if-then (->/2) and negation-by-failure (/+/1).

1.1.1 Other books about Prolog

This manual does not describe the full syntax and semantics of Prolog, nor how one should write a program in Prolog. These subjects have been described extensively in the literature. See [Bratko, 1986], [Sterling & Shapiro, 1986], and [Clocksin & Melish, 1987]. For more advanced Prolog material see [O’Keefe, 1990]. Syntax and standard operator declarations confirm to the ‘Edinburgh standard’. Most built in predicates are compatible with those described in [Clocksin & Melish, 1987]. SWI-Prolog also offers a number of primitive predicates compatible with Quintus Prolog¹ [Qui, 1997] and BIM_Prolog² [BIM, 1989].

ISO compliant predicates are based on “Prolog: The Standard”, [Deransart et al., 1996], validated using [Hodgson, 1998].

¹Quintus is a trademark of Quintus Computer Systems Inc., USA
²BIM is a trademark of BIM sa/nv., Belgium
1.2 Status

This manual describes version 5.0 of SWI-Prolog. SWI-Prolog has been used now for many years. The application range includes Prolog course material, meta-interpreters, simulation of parallel Prolog, learning systems, natural language processing and two large workbenches for knowledge engineering. Although we experienced rather obvious and critical bugs can remain unnoticed for a remarkable long period, we assume the basic Prolog system is fairly stable. Bugs can be expected in infrequently used built-in predicates.

Some bugs are known to the author. They are described as footnotes in this manual.

1.3 Compliance to the ISO standard

SWI-Prolog 3.3.0 implements all predicates described in “Prolog: The Standard” [Deransart et al., 1996].

Exceptions and warning are still weak. Some SWI-Prolog predicates silently fail on conditions where the ISO specification requires an exception (functor/3 for example). Many predicates print warnings rather than raising an exception. All predicates where exceptions may be caused due to a correct program operating in an imperfect world (I/O, arithmetic, resource overflows) should behave according to the ISO standard. In other words: SWI-Prolog should be able to execute any program conforming to [Deransart et al., 1996] that does not rely on exceptions generated by errors in the program.

1.4 Should you be using SWI-Prolog?

There are a number of reasons why you better choose a commercial Prolog system, or another academic product:

- **SWI-Prolog is not supported**
  Although I usually fix bugs shortly after a bug report arrives, I cannot promise anything. Now that the sources are provided, you can always dig into them yourself.

- **Memory requirements and performance are your first concerns**
  A number of commercial compilers are more keen on memory and performance than SWI-Prolog. I do not wish to sacrifice some of the nice features of the system, nor its portability to compete on raw performance.

- **You need features not offered by SWI-Prolog**
  In this case you may wish to give me suggestions for extensions. If you have great plans, please contact me (you might have to implement them yourself however).

On the other hand, SWI-Prolog offers some nice facilities:

- **Nice environment**
  This includes ‘Do What I Mean’, automatic completion of atom names, history mechanism and a tracer that operates on single key-strokes. Interfaces to some standard editors are provided (and can be extended), as well as a facility to maintain programs (see make/0).
CHAPTER 1. INTRODUCTION

- **Very fast compiler**
  Even very large applications can be loaded in seconds on most machines. If this is not enough, there is a Quick Load Format that is slightly more compact and loading is almost always I/O bound.

- **Transparent compiled code**
  SWI-Prolog compiled code can be treated just as interpreted code: you can list it, trace it, etc. This implies you do not have to decide beforehand whether a module should be loaded for debugging or not. Also, performance is much better than the performance of most interpreters.

- **Profiling**
  SWI-Prolog offers tools for performance analysis, which can be very useful to optimise programs. Unless you are very familiar with Prolog and Prolog performance considerations this might be more helpful than a better compiler without these facilities.

- **Flexibility**
  SWI-Prolog can easily be integrated with C, supporting non-determinism in Prolog calling C as well as C calling Prolog (see section 6). It can also be embedded in external programs (see section 6.7). System predicates can be redefined locally to provide compatibility with other Prolog systems.

- **Integration with XPCE**
  SWI-Prolog offers a tight integration to the Object Oriented Package for User Interface Development, called XPCE [Anjewierden & Wielemaker, 1989]. XPCE allows you to implement graphical user interfaces that are source-code compatible over Unix/X11 and Win32 (Windows 95 and NT).

1.5 The XPCE GUI system for Prolog

The XPCE GUI system for dynamically typed languages has been with SWI-Prolog for a long time. It is developed by Anjo Anjewierden and Jan Wielemaker from the department of SWI, University of Amsterdam. It aims at a high-productive development environment for graphical applications based on Prolog.

Object oriented technology has proven to be a suitable model for implementing GUIs, which typically deal with things Prolog is not very good at: event-driven control and global state. With XPCE, we designed a system that has similar characteristics that make Prolog such a powerful tool: dynamic typing, meta-programming and dynamic modification of the running system.

XPCE is an object-system written in the C-language. It provides for the implementation of methods in multiple languages. New XPCE classes may be defined from Prolog using a simple, natural syntax. The body of the method is executed by Prolog itself, providing a natural interface between the two systems. Below is a very simple class definition.

```prolog
:- pce_begin_class(prolog_lister, frame,
   "List Prolog predicates").

initialise(Self) :->
   "As the C++ constructor":
   send(Self, send_super, initialise, 'Prolog Lister'),
```
1.6 Release Notes

Collected release-notes. This section only contains some highlights. Smaller changes to especially older releases have been removed. For a complete log, see the file ChangeLog from the distribution.

1.6.1 Version 1.8 Release Notes

Version 1.8 offers a stack-shifter to provide dynamically expanding stacks on machines that do not offer operating-system support for implementing dynamic stacks.

1.6.2 Version 1.9 Release Notes

Version 1.9 offers better portability including an MS-Windows 3.1 version. Changes to the Prolog system include:

Availability. XPCE runs on most Unix\textsuperscript{tm} platforms, Windows 95, 98 and Windows NT. It has been connected to SWI-Prolog, SICStus\textsuperscript{tm} and Quintus\textsuperscript{tm} Prolog as well as some Lisp dialects and C++. The Quintus version is commercially distributed and supported as ProWindows-3\textsuperscript{tm}.

Info. Further information is available from http://www.swi.psy.uva.nl/projects/xpce/ or by E-mail to xpce-request@swi.psy.uva.nl. There are demo versions for Windows 95, 98, NT and i386/Linux available from the XPCE download page.

Its 165 built-in classes deal with the meta-environment, data-representation and—of course—graphics. The graphics classes concentrate on direct-manipulation of diagrammatic representations.

send(Self, append, new(D, dialog)),
send(D, append,
text_item(predicate, message(Self, list, @arg1))),
send(new(view), below, D).

list(Self, From:name) :-
"List predicates from specification":
( catch(term_to_atom(Term, From), _, fail)
  ->
  get(Self, member, view, V),
pce_open(V, write, Fd),
set_output(Fd),
listing(Term),
close(Fd)
; send(Self, report, error, 'Syntax error')
).

:- pce_end_class.

test :- send(new(prolog_lister), open).

1.6. RELEASE NOTES 11
• **Redefinition of system predicates**
  Redefinition of system predicates was allowed silently in older versions. Version 1.9 only allows it if the new definition is headed by a `:- redefine_system_predicate/1` directive.

• **‘Answer’ reuse**
  The toplevel maintains a table of bindings returned by toplevel goals and allows for reuse of these bindings by prefixing the variables with the $ sign. See section 2.8.

• **Better source code administration**
  Allows for proper updating of multfile predicates and finding the sources of individual clauses.

### 1.6.3 Version 2.0 Release Notes

New features offered:

• **32-bit Virtual Machine**
  Removes various limits and improves performance.

• **Inline foreign functions**
  ‘Simple’ foreign predicates no longer build a Prolog stack-frame, but are directly called from the VM. Notably provides a speedup for the test predicates such as `var/1`, etc.

• **Various compatibility improvements**

• **Stream based I/O library**
  All SWI-Prolog’s I/O is now handled by the stream-package defined in the foreign include file `SWI-Stream.h`. Physical I/O of Prolog streams may be redefined through the foreign language interface, facilitating much simpler integration in window environments.

### 1.6.4 Version 2.5 Release Notes

Version 2.5 is an intermediate release on the path from 2.1 to 3.0. All changes are to the foreign-language interface, both to user- and system-predicates implemented in the C-language. The aim is twofold. First of all to make garbage-collection and stack-expansion (stack-shifts) possible while foreign code is active without the C-programmer having to worry about locking and unlocking C-variables pointing to Prolog terms. The new approach is closely compatible to the Quintus and SIC-Stus Prolog foreign interface using the `+term` argument specification (see their respective manuals). This allows for writing foreign interfaces that are easily portable over these three Prolog platforms.

Apart from various bug fixes listed in the Changelog file, these are the main changes since 2.1.0:

• **ISO compatibility**
  Many ISO compatibility features have been added: `open/4`, arithmetic functions, syntax, etc.

• **Win32**
  Many fixes for the Win32 (NT, ’95 and win32s) platforms. Notably many problems related to pathnames and a problem in the garbage collector.

• **Performance**
  Many changes to the clause indexing system: added hash-tables, lazy computation of the index information, etc.
• **Portable saved-states**
  The predicate `qsave_program/[1,2]` allows for the creating of machine independent saved-states that load very quickly.

### 1.6.5 Version 2.6 Release Notes

Version 2.6 provides a stable implementation of the features added in the 2.5.x releases, but at the same time implements a number of new features that may have impact on the system stability.

• **32-bit integer and double float arithmetic**
  The biggest change is the support for full 32-bit signed integers and raw machine-format double precision floats. The internal data representation as well as the arithmetic instruction set and interface to the arithmetic functions has been changed for this.

• **Embedding for Win32 applications**
  The Win32 version has been reorganised. The Prolog kernel is now implemented as Win32 DLL that may be embedded in C-applications. Two front ends are provided, one for window-based operation and one to run as a Win32 console application.

• **Creating stand-alone executables**
  Version 2.6.0 can create stand-alone executables by attaching the saved-state to the emulator. See `qsave_program/2`.

### 1.6.6 Version 2.7 Release Notes

Version 2.7 reorganises the entire data-representation of the Prolog data itself. The aim is to remove most of the assumption on the machine’s memory layout to improve portability in general and enable embedding on systems where the memory layout may depend on invocation or on how the executable is linked. The latter is notably a problem on the Win32 platforms. Porting to 64-bit architectures is feasible now.

Furthermore, 2.7 lifts the limits on arity of predicates and number of variables in a clause considerably and allow for further expansion at minimal cost.

### 1.6.7 Version 2.8 Release Notes

With version 2.8, we declare the data-representation changes of 2.7.x stable. Version 2.8 exploits the changes of 2.7 to support 64-bit processors like the DEC Alpha. As of version 2.8.5, the representation of recorded terms has changed, and terms on the heap are now represented in a compiled format. SWI-Prolog no longer limits the use of `malloc()` or uses assumptions on the addresses returned by this function.

### 1.6.8 Version 2.9 Release Notes

Version 2.9 is the next step towards version 3.0, improving ISO compliance and introducing ISO compliant exception handling. New are `catch/3`, `throw/1`, `abolish/1`, `write_term/[2,3]`, `write_canonical/[1,2]` and the C-functions `PL_exception()` and `PL_throw()`. The predicates `display/[1,2]` and `displayq/[1,2]` have been moved to `library(backcomp)`, so old code referring to them will autoload them.
The interface to `pl_open_query()` has changed. The `debug` argument is replaced by a bitwise or’d `flags` argument. The values `FALSE` and `TRUE` have their familiar meaning, making old code using these constants compatible. Non-zero values other than `TRUE` (1) will be interpreted different.

### 1.6.9 Version 3.0 Release Notes

Complete redesign of the saved-state mechanism, providing the possibility of ‘program resources’. See `resource/3`, `open_resource/3`, and `qsave_program/[1,2]`.

### 1.6.10 Version 3.1 Release Notes

Improvements on exception-handling. Allows relating software interrupts (signals) to exceptions, handling signals in Prolog and C (see `on_signal/3` and `pl_signal()`). Prolog stack overflows now raise the `resource_error` exception and thus can be handled in Prolog using `catch/3`.

### 1.6.11 Version 3.3 Release Notes

Version 3.3 is a major release, changing many things internally and externally. The highlights are a complete redesign of the high-level I/O system, which is now based on explicit streams rather then current input/output. The old Edinburgh predicates (see `see/1`, `tell/1`, etc.) are now defined on top of this layer instead of the other way around. This fixes various internal problems and removes Prolog limits on the number of streams.

Much progress has been made to improve ISO compliance: handling strings as lists of one-character atoms is now supported (next to character codes as integers). Many more exceptions have been added and printing of exceptions and messages is rationalised using Quintus and SICStus Prolog compatible `print_message/2`, `message_hook/3` and `print_message_lines/3`. All predicates described in [Deransart et al., 1996] are now implemented.

As of version 3.3, SWI-Prolog adheres the ISO logical update view for dynamic predicates. See section 4.13.1 for details.

SWI-Prolog 3.3 includes garbage collection on atoms, removing the last serious memory leak especially in text-manipulation applications. See section 6.6.2. In addition, both the user-level and foreign interface supports atoms holding 0-bytes.

Finally, an alpha version of a multi-threaded SWI-Prolog for Linux is added. This version is still much slower than the single-threaded version due to frequent access to ‘thread-local-data’ as well as some too detailed mutex locks. The basic thread API is ready for serious use and testing however. See section 4.39.

### Incompatible changes

A number of incompatible changes result from this upgrade. They are all easily fixed however.

- `/0, call/1
  The cut now behaves according to the ISO standard. This implies it works in compound goals passed to `call/1` and is local to the `condition` part of if-then-else as well as the argument of `/+/1`.

- `atom_chars/2
  This predicate is now ISO compliant and thus generates a list of one-character atoms. The
1.6. RELEASE NOTES

behave of the old predicate is available in the —also ISO compliant— atom_codes/2 predicate. Safest repair is a replacement of all atom_chars into atom_codes. If you do not want to change any source-code, you might want to use

user:goal_expansion(atom_chars(A,B), atom_codes(A,B)).

- number_chars/2
  Same applies for number_chars/2 and number_codes/2.

- feature/2, set_feature/2
  These are replaced by the ISO compliant current_prolog_flag/2 and set_prolog_flag/2. The library library(backcomp) provides definitions for feature/2 and set_feature/2, so no source has to be updated.

- Accessing command-line arguments
  This used to be provided by the undocumented '$argv'/1 and Quintus compatible library unix/1. Now there is also documented current_prolog_flag(argv, Argv).

- dup_stream/2
  Has been deleted. New stream-aliases can deal with most of the problems for which dup_stream/2 was designed and dup/2 from the clib package can with most others.

- op/3
  Operators are now local to modules. This implies any modification of the operator-table does not influence other modules. This is consistent with the proposed ISO behaviour and a necessity to have any usable handling of operators in a multi-threaded environment.

- set_prolog_flag(character_escapes, Bool)
  This prolog flag is now an interface to changing attributes on the current source-module, effectively making this flag module-local as well. This is required for consistent handling of sources written with ISO (obligatory) character-escape sequences together with old Edinburgh code.

- current_stream/3 and stream_position
  These predicates have been moved to library(quintus).

1.6.12 Version 3.4 Release Notes

The 3.4 release is a consolidation release. It consolidates the improvements and standard conformance of the 3.3 releases. This version is closely compatible with the 3.3 version except for one important change:

- Argument order in select/3
  The list-processing predicate select/3 somehow got into a very early version of SWI-Prolog with the wrong argument order. This has been fixed in 3.4.0. The correct order is select(?Elem, ?List, ?Rest).

As select/3 has no error conditions, runtime checking cannot be done. To simplify debugging, the library module library(checkselect) will print references to select/3 in your source code and install a version of select that enters the debugger if select is called and the second argument is not a list.

This library can be loaded explicitly or by calling check_old_select/0.
1.6.13 Version 4.0 Release Notes

As of version 4.0 the standard distribution of SWI-Prolog is bundled with a number of its popular extension packages, among which the now open source XPCE GUI toolkit (see section 1.5). No significant changes have been made to the basic SWI-Prolog engine.

Some useful tricks in the integrated environment:

- Register the GUI tracer
  Using a call to guitracer/0, hooks are installed that replace the normal command-line driven tracer with a graphical frontend.

- Register PceEmacs for editing files
  From your initialisation file, you can load library(emacs/swi_prolog) that cause edit/1 to use the built-in PceEmacs editor.

1.7 Acknowledgements

Some small parts of the Prolog code of SWI-Prolog are modified versions of the corresponding Edinburgh C-Prolog code: grammar rule compilation and writeln/2. Also some of the C-code originates from C-Prolog: finding the path of the currently running executable and the code underlying absolute_file_name/2. Ideas on programming style and techniques originate from C-Prolog and Richard O’Keefe’s thief editor. An important source of inspiration are the programming techniques introduced by Anjo Anjewierden in PCE version 1 and 2.

I also would like to thank those who had the fade of using the early versions of this system, suggested extensions or reported bugs. Among them are Anjo Anjewierden, Huub Knops, Bob Wielinga, Wouter Jansweijer, Luc Peerdeman, Eric Nombden, Frank van Harmelen, Bert Rengel.

Martin Jansche (jansche@novell1.gs.uni-heidelberg.de) has been so kind to reorganise the sources for version 2.1.3 of this manual.

Horst von Brand has been so kind to fix many typos in the 2.7.14 manual. Thanks!
Overview

2.1 Getting started quickly

2.1.1 Starting SWI-Prolog

Starting SWI-Prolog on Unix

By default, SWI-Prolog is installed as ‘pl’, though some administrators call it ‘swipl’ or ‘swi-prolog’. The command-line arguments of SWI-Prolog itself and its utility programs are documented using standard Unix man pages. SWI-Prolog is normally operated as an interactive application simply by starting the program:

```
machine% pl
Welcome to SWI-Prolog (Version 5.0.0)
Copyright (c) 1990-2002 University of Amsterdam.
SWI-Prolog comes with ABSOLUTELY NO WARRANTY. This is free software, and you are welcome to redistribute it under certain conditions. Please visit http://www.swi-prolog.org for details.

For help, use ?- help(Topic). or ?- apropos(Word).
```

1 ?-

After starting Prolog, one normally loads a program into it using `consult/1`, which—for historical reasons—may be abbreviated by putting the name of the program file between square brackets. The following goal loads the file `likes.pl` containing clauses for the predicates `likes/2`:

```
?- [likes].
% likes compiled, 0.00 sec, 596 bytes.
```

Yes

?-

After this point, Unix and Windows users unite, so if you are using Unix please continue at section 2.1.2.

Starting SWI-Prolog on Windows

After SWI-Prolog has been installed on a Windows system, the following important new things are available to the user:
• A folder (called directory in the remainder of this document) called pl containing the executables, libraries, etc. of the system. No files are installed outside this directory.

• A program plwin.exe, providing a window for interaction with Prolog. The program plcon.exe is a version of SWI-Prolog that runs in a DOS-box.

• The file-extension .pl is associated with the program plwin.exe. Opening a .pl file will cause plwin.exe to start, change directory to the directory in which the file-to-open resides and load this file.

The normal way to start with the likes.pl file mentioned in section 2.1.1 is by simply double-clicking this file in the Windows explorer.

2.1.2 Executing a query

After loading a program, one can ask Prolog queries about the program. The query below asks Prolog to prove whether ‘john’ likes someone and who is liked by ‘john’. The system responds with \( X = ⟨\text{value}⟩ \) if it can prove the goal for a certain \( X \). The user can type the semi-colon (;) if (s)he wants another solution, or RETURN if (s)he is satisfied, after which Prolog will say Yes. If Prolog answers No, it indicates it cannot find any more answers to the query. Finally, Prolog can answer using an error message to indicate the query or program contains an error.

\[
\text{?- likes(john, X).}
\]

\[
X = \text{mary}
\]

2.2 The user’s initialisation file

After the necessary system initialisation the system consults (see consult/1) the user’s startup file. The base-name of this file follows conventions of the operating system. On MS-Windows, it is the file pl.ini and on Unix systems .plrc. The file is searched using the file_search_path/2 clauses for user_profile. The table below shows the default value for this search-path.

<table>
<thead>
<tr>
<th>Unix</th>
<th>Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>local home</td>
<td>.  %HOME% or %HOMEDRIVE%%HOMEPATH%</td>
</tr>
<tr>
<td>global</td>
<td>SWI-Home directory or %WINDIR% or %SYSTEMROOT%</td>
</tr>
</tbody>
</table>

After the first startup file is found it is loaded and Prolog stops looking for further startup files. The name of the startup file can be changed with the ‘-f file’ option. If File denotes an absolute path, this file is loaded, otherwise the file is searched for using the same conventions as for the default startup file. Finally, if file is none, no file is loaded.
2.3 Initialisation files and goals

Using commandline arguments (see section 2.4), SWI-Prolog can be forced to load files and execute queries for initialisation purposes or non-interactive operation. The most commonly used options are 
\(-f\) file or \(-s\) file to make Prolog load a file, \(-g\) goal to define an initialisation goal and \(-t\) goal to define the toplevel goal. The following is a typical example for starting an application directly from the commandline.

```
machine% pl -f load.pl -g go -t halt
```

It tells SWI-Prolog to load load.pl, start the application using the entry-point go/0 and —instead of entering the interactive toplevel— exit after completing go/0. The \(-q\) may be used to suppress all informational messages.

In MS-Windows, the same can be achieved using a short-cut with appropriately defined commandline arguments. A typically seen alternative is to write a file run.pl with content as illustrated below. Double-clicking run.pl will start the application.

```
:- [load]. % load program
:- go. % run it
:- halt. % and exit
```

Section 2.10.2 discusses further scripting options and chapter 7 discusses the generation of runtime executables. Runtime executables are a mean to deliver executables that do not require the Prolog system.

2.4 Command line options

The full set of command line options is given below:

\textbf{-help}

When given as the only option, it summarises the most important options.

\textbf{-v}

When given as the only option, it summarises the version and the architecture identifier.

\textbf{-arch}

When given as the only option, it prints the architecture identifier (see current_prolog_flag(arch, Arch)) and exits. See also \texttt{-dump-runtime-variables}.

\textbf{-dump-runtime-variables}

When given as the only option, it prints a sequence of variable settings that can be used in shell-scripts to deal with Prolog parameters. This feature is also used by \texttt{plld} (see section 6.7). Below is a typical example of using this feature.

```
eval `pl -dump-runtime-variables`
cc -I$PLBASE/include -L$PLBASE/runtime/$PLARCH ...
```
-q
Set the prolog-flag verbose to silent, supressing informational and banner messages.

-L size[km]
Give local stack limit (2 Mbytes default). Note that there is no space between the size option and its argument. By default, the argument is interpreted in Kbytes. Postfixing the argument with m causes the argument to be interpreted in Mbytes. The following example specifies 32 Mbytes local stack.

% pl -L32m

A maximum is useful to stop buggy programs from claiming all memory resources. -L0 sets the limit to the highest possible value. See section 2.16.

-G size[km]
Give global stack limit (4 Mbytes default). See -L for more details.

-T size[km]
Give trail stack limit (4 Mbytes default). This limit is relatively high because trail-stack overflows are not often caused by program bugs. See -L for more details.

-A size[km]
Give argument stack limit (1 Mbytes default). The argument stack limits the maximum nesting of terms that can be compiled and executed. SWI-Prolog does ‘last-argument optimisation’ to avoid many deeply nested structure using this stack. Enlarging this limit is only necessary in extreme cases. See -L for more details.

-c file . . .
Compile files into an ‘intermediate code file’. See section 2.10.

-o output
Used in combination with -c or -b to determine output file for compilation.

-O
Optimised compilation. See current_prolog_flag/2.

-s file
Use file as a script-file. The script file is loaded after the initialisation file specified with the -f file option. Unlike -f file, using

-s d
does not stop Prolog from loaded the personal initialisation file.

-f file
Use file as initialisation file instead of the default .plrc (Unix) or pl.ini (Windows). ‘-f none’ stops SWI-Prolog from searching for a startup file. This option can be used as an alternative to -s file that stops Prolog from loading the personal initialisation file. See also section 2.2.
2.4. COMMAND LINE OPTIONS

-F script
Selects a startup-script from the SWI-Prolog home directory. The script-file is named <script>.rc. The default script name is deduced from the executable, taking the leading alphanumerical characters (letters, digits and underscore) from the program-name. -F none stops looking for a script. Intended for simple management of slightly different versions. One could for example write a script iso.rc and then select ISO compatibility mode using pl -F iso or make a link from iso-pl to pl.

-g goal
Goal is executed just before entering the top level. Default is a predicate which prints the welcome message. The welcome message can thus be suppressed by giving -g true. goal can be a complex term. In this case quotes are normally needed to protect it from being expanded by the Unix shell.

-t goal
Use goal as interactive toplevel instead of the default goal prolog/0. goal can be a complex term. If the toplevel goal succeeds SWI-Prolog exits with status 0. If it fails the exit status is 1. This flag also determines the goal started by break/0 and abort/0. If you want to stop the user from entering interactive mode start the application with ‘-g goal’ and give ‘halt’ as toplevel.

-tty
Unix only. Switches controlling the terminal for allowing single-character commands to the tracer and get_single_char/1. By default manipulating the terminal is enabled unless the system detects it is not connected to a terminal or it is running as a GNU-Emacs inferior process. This flag is sometimes required for smooth interaction with other applications.

-x bootfile
Boot from bootfile instead of the system’s default boot file. A bootfile is a file resulting from a Prolog compilation using the -b or -c option or a program saved using qsave_program/[1,2].

-p alias=path1[:path2 ...]
Define a path alias for file_search_path. alias is the name of the alias, path1 ... is a : separated list of values for the alias. A value is either a term of the form alias(value) or pathname. The computed aliases are added to file_search_path/2 using asserta/1, so they precede predefined values for the alias. See file_search_path/2 for details on using this file-location mechanism.

-- Stops scanning for more arguments, so you can pass arguments for your application after this one. See current_prolog_flag/2 using the flag argv for obtaining the commandline arguments.

The following options are for system maintenance. They are given for reference only.

-b initfile ... -c file ...
Boot compilation. initfile ... are compiled by the C-written bootstrap compiler, file ... by the normal Prolog compiler. System maintenance only.
-d level
   Set debug level to level. Only has effect if the system is compiled with the \texttt{-DDEBUG} flag. System maintenance only.

2.5 GNU Emacs Interface

The default Prolog mode for GNU-Emacs can be activated by adding the following rules to your Emacs initialisation file:

\begin{verbatim}
(setq auto-mode-alist
  (append
   '(("\.pl" . prolog-mode)
      auto-mode-alist))
(setq prolog-program-name "pl")
(setq prolog-consult-string "[user].\n")
;if you want this. Indentation is either poor or I don’t use
;it as intended.
;(setq prolog-indent-width 8)
\end{verbatim}


2.6 Online Help

Online help provides a fast lookup and browsing facility to this manual. The online manual can show predicate definitions as well as entire sections of the manual.

The online help is displayed from the file library('MANUAL'). The file library(helpidx) provides an index into this file. library('MANUAL') is created from the \LaTeX \textsc{e} sources with a modified version of dvitty, using overstrike for printing bold text and underlining for rendering italic text. XPCE is shipped with library(swi_help), presenting the information from the online help in a hyper-text window. The prolog-flag write\_help\_with\_overstrike controls whether or not help/1 writes its output using overstrike to realise bold and underlined output or not. If this prolog-flag is not set it is initialised by the help library to \texttt{true} if the TERM variable equals \texttt{xterm} and \texttt{false} otherwise. If this default does not satisfy you, add the following line to your personal startup file (see section 2.2):

\begin{verbatim}
:- set_prolog_flag(write_help_with_overstrike, true).
\end{verbatim}

help
   Equivalent to help\(\text{(help/1)}\).

help(+What)
   Show specified part of the manual. What is one of:
2.7. QUERY SUBSTITUTIONS

\[
\begin{align*}
\langle \text{Name} \rangle/\langle \text{Arity} \rangle & : \text{Give help on specified predicate} \\
\langle \text{Name} \rangle & : \text{Give help on named predicate with any arity or C interface function with that name} \\
\langle \text{Section} \rangle & : \text{Display specified section. Section numbers are dash-separated numbers: 2-3 refers to section 2.3 of the manual. Section numbers are obtained using \text{apropos/1}.}
\end{align*}
\]

Examples:

?- help(assert). \quad \text{Give help on predicate assert}
?- help(3-4). \quad \text{Display section 3.4 of the manual}
?- help('PL_retry'). \quad \text{Give help on interface function PL_retry()}

See also \text{apropos/1}, and the SWI-Prolog home page at http://www.swi.psy.uva.nl/projects/SWI-Prolog/, which provides a FAQ, an HTML version of manual for online browsing and HTML and PDF versions for downloading.

\text{apropos(+Pattern)}

Display all predicates, functions and sections that have \text{Pattern} in their name or summary description. Lowercase letters in \text{Pattern} also match a corresponding uppercase letter. Example:

?- apropos(file). \quad \text{Display predicates, functions and sections that have ‘file’ (or ‘File’, etc.) in their summary description.}

\text{explain(+ToExplain)}

Give an explanation on the given ‘object’. The argument may be any Prolog data object. If the argument is an atom, a term of the form \text{Name/Arity} or a term of the form \text{Module:Name/Arity}, explain will try to explain the predicate as well as possible references to it.

\text{explain(+ToExplain, -Explanation)}

Unify \text{Explanation} with an explanation for \text{ToExplain}. Backtracking yields further explanations.

2.7 Query Substitutions

SWI-Prolog offers a query substitution mechanism similar to that of Unix csh (csh(1)), called ‘history’. The availability of this feature is controlled by \text{set_prolog_flag/2}, using the \text{history} prolog-flag. By default, history is available if the prolog-flag \text{readline} is false. To enable this feature, remembering the last 50 commands, put the following into your startup file (see section 2.2:

\[
\begin{align*}
:~ & : ~ \text{set_prolog_flag(history, 50).}
\end{align*}
\]

The history system allows the user to compose new queries from those typed before and remembered by the system. It also allows to correct queries and syntax errors. SWI-Prolog does not offer the Unix csh capabilities to include arguments. This is omitted as it is unclear how the first, second, etc. argument should be defined.\footnote{One could choose words, defining words as a sequence of alpha-numeric characters and the word separators as anything else, but one could also choose Prolog arguments}

The available history commands are shown in table 2.1.
1 ?- maplist(plus(1), "hello", X).

X = [105, 102, 109, 109, 112]

Yes
2 ?- format('˜s˜n', [\$X]).

Yes
3 ?-

Table 2.1: History commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>!.</td>
<td>Repeat last query</td>
</tr>
<tr>
<td>!nr.</td>
<td>Repeat query numbered ⟨nr⟩</td>
</tr>
<tr>
<td>!str.</td>
<td>Repeat last query starting with ⟨str⟩</td>
</tr>
<tr>
<td>!?str.</td>
<td>Repeat last query holding ⟨str⟩</td>
</tr>
<tr>
<td>^old^new.</td>
<td>Substitute ⟨old⟩ into ⟨new⟩ in last query</td>
</tr>
<tr>
<td>!nr^old^new.</td>
<td>Substitute in query numbered ⟨nr⟩</td>
</tr>
<tr>
<td>!str^old^new.</td>
<td>Substitute in query starting with ⟨str⟩</td>
</tr>
<tr>
<td>!?str^old^new.</td>
<td>Substitute in query holding ⟨str⟩</td>
</tr>
<tr>
<td>h.</td>
<td>Show history list</td>
</tr>
<tr>
<td>!h.</td>
<td>Show this list</td>
</tr>
</tbody>
</table>

Figure 2.1: Reusing toplevel bindings

2.7.1 Limitations of the History System

History expansion is executed after raw-reading. This is the first stage of read_term/2 and friends, reading the term into a string while deleting comment and canonising blank. This makes it hard to use it for correcting syntax errors. Command-line editing as provided using the GNU-readline library is more suitable for this. History expansion is first of all useful for executing or combining commands from long ago.

2.8 Reuse of toplevel bindings

Bindings resulting from the successful execution of a toplevel goal are asserted in a database. These values may be reused in further toplevel queries as $Var. Only the latest binding is available. Example:

Note that variables may be set by executing =/2:

6 ?- X = statistics.

X = statistics

Yes
7 ?- $X.
2.9. OVERVIEW OF THE DEBUGGER

28.00 seconds cpu time for 183,128 inferences
4,016 atoms, 1,904 functors, 2,042 predicates, 52 modules
55,915 byte codes; 11,239 external references

<table>
<thead>
<tr>
<th></th>
<th>Limit</th>
<th>Allocated</th>
<th>In use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local stack</td>
<td>2,048,000</td>
<td>8,192</td>
<td>404 Bytes</td>
</tr>
<tr>
<td>Global stack</td>
<td>4,096,000</td>
<td>16,384</td>
<td>968 Bytes</td>
</tr>
<tr>
<td>Trail stack</td>
<td>4,096,000</td>
<td>8,192</td>
<td>432 Bytes</td>
</tr>
</tbody>
</table>

Yes
8 ?-

2.9 Overview of the Debugger

SWI-Prolog has a 6-port tracer, extending the standard 4-port tracer [Clocksin & Melish, 1987] with two additional ports. The optional unify port allows the user to inspect the result after unification of the head. The exception port shows exceptions raised by throw/1 or one of the built-in predicates. See section 4.9.

The standard ports are called call, exit, redo, fail and unify. The tracer is started by the trace/0 command, when a spy point is reached and the system is in debugging mode (see spy/1 and debug/0) or when an exception is raised.

The interactive toplevel goal trace/0 means “trace the next query”. The tracer shows the port, displaying the port name, the current depth of the recursion and the goal. The goal is printed using the Prolog predicate write_term/2. The style is defined by the prolog-flag debugger_print_options and can be modified using this flag or using the w, p and d commands of the tracer.

On leashed ports (set with the predicate leash/1, default are call, exit, redo and fail) the user is prompted for an action. All actions are single character commands which are executed without waiting for a return, unless the command line option –tty is active. Tracer options:

+ (Spy)
  Set a spy point (see spy/1) on the current predicate.

- (No spy)
  Remove the spy point (see nospy/1) from the current predicate.

/ (Find)
  Search for a port. After the ‘/’, the user can enter a line to specify the port to search for. This line consists of a set of letters indicating the port type, followed by an optional term, that should unify with the goal run by the port. If no term is specified it is taken as a variable, searching for any port of the specified type. If an atom is given, any goal whose functor has a name equal to that atom matches. Examples:
1 \texttt{?- visible(+all), leash(-exit).}

Yes

2 \texttt{?- trace, min([3, 2], X).}

Call: \texttt{(3) min([3, 2], G235) ? creep}

Unify: \texttt{(3) min([3, 2], G235)}

Call: \texttt{(4) min([2], G244) ? creep}

Unify: \texttt{(4) min([2], 2)}

Exit: \texttt{(4) min([2], 2)}

Call: \texttt{(4) min(3, 2, G235) ? creep}

Unify: \texttt{(4) min(3, 2, G235)}

Call: \texttt{(5) 3 < 2 ? creep}

Fail: \texttt{(5) 3 < 2 ? creep}

Redo: \texttt{(4) min(3, 2, G235) ? creep}

Exit: \texttt{(4) min(3, 2, 2)}

Exit: \texttt{(3) min([3, 2], 2)}

Yes

[trace] 3 ?-

Figure 2.2: Example trace

\texttt{/f} \hspace{2cm} \texttt{fe solve} \hspace{2cm} \texttt{Search for any fail port}

\texttt{/fe solve} \hspace{2cm} \texttt{Search for a fail or exit port of any goal with name solve}

\texttt{/c solve(a, _)} \hspace{2cm} \texttt{Search for a call to solve/2 whose first argument}
\hspace{2cm} \texttt{is a variable or the atom a}

\texttt{/a member(_, _)} \hspace{2cm} \texttt{Search for any port on member/2. This is equivalent to setting a spy point}
\hspace{2cm} \texttt{on member/2.}

. \texttt{(Repeat find)}
\hspace{1cm} \texttt{Repeat the last find command (see "/").}

A \texttt{(Alternatives)}
\hspace{1cm} \texttt{Show all goals that have alternatives.}

C \texttt{(Context)}
\hspace{1cm} \texttt{Toggle ‘Show Context’. If \texttt{on} the context module of the goal is displayed between square}
\hspace{1cm} \texttt{brackets (see section 5). Default is \texttt{off}.}

L \texttt{(Listing)}
\hspace{1cm} \texttt{List the current predicate with listing/1.}

a \texttt{(Abort)}
\hspace{1cm} \texttt{Abort Prolog execution (see abort/0).}

b \texttt{(Break)}
\hspace{1cm} \texttt{Enter a Prolog break environment (see break/0).}
2.9. OVERVIEW OF THE DEBUGGER

- **c (Creep)**
  Continue execution, stop at next port. (Also return, space).

- **d (Display)**
  Set the `max_depth(\text{Depth})` option of `debugger_print_options`, limiting the depth to which terms are printed. See also the `w` and `p` options.

- **e (Exit)**
  Terminate Prolog (see `halt/0`).

- **f (Fail)**
  Force failure of the current goal.

- **g (Goals)**
  Show the list of parent goals (the execution stack). Note that due to tail recursion optimization a number of parent goals might not exist any more.

- **h (Help)**
  Show available options (also `?`).

- **i (Ignore)**
  Ignore the current goal, pretending it succeeded.

- **l (Leap)**
  Continue execution, stop at next spy point.

- **n (No debug)**
  Continue execution in ‘no debug’ mode.

- **p (Print)**
  Set the prolog-flag `debugger_print_options` to `[\text{quoted(true)}, \text{portrait(true)}, \text{max_depth(10)}]`. This is the default.

- **r (Retry)**
  Undo all actions (except for database and i/o actions) back to the call port of the current goal and resume execution at the call port.

- **s (Skip)**
  Continue execution, stop at the next port of this goal (thus skipping all calls to children of this goal).

- **u (Up)**
  Continue execution, stop at the next port of the parent goal (thus skipping this goal and all calls to children of this goal). This option is useful to stop tracing a failure driven loop.

- **w (Write)**
  Set the prolog-flag `debugger_print_options` to `[\text{quoted(true)}]`, bypassing `portrait/1`, etc.

The ideal 4 port model as described in many Prolog books [Clocksin & Melish, 1987] is not visible in many Prolog implementations because code optimisation removes part of the choice- and
exit-points. Backtrack points are not shown if either the goal succeeded deterministically or its alternatives were removed using the cut. When running in debug mode (debug/0) choice points are only destroyed when removed by the cut. In debug mode, tail recursion optimisation is switched off.\(^2\)

Reference information to all predicates available for manipulating the debugger is in section 4.42.

2.10 Compilation

2.10.1 During program development

During program development, programs are normally loaded using consult/1, or the list abbreviation. It is common practice to organise a project as a collection of source-files and a load-file, a Prolog file containing only use_module/[1,2] or ensure_loaded/1 directives, possibly with a definition of the entry-point of the program, the predicate that is normally used to start the program. This file is often called load.pl. If the entry-point is called go, a typical session starts as:

\[
\%
\]

% pl
<banner>

1 ?- [load].
<compilation messages>

Yes
2 ?- go.
<program interaction>

When using Windows, the user may open load.pl from the Windows explorer, which will cause plwin.exe to be started in the directory holding load.pl. Prolog loads load.pl before entering the toplevel.

2.10.2 For running the result

There are various options if you want to make your program ready for real usage. The best choice depends on whether the program is to be used only on machines holding the SWI-Prolog development system, the size of the program and the operating system (Unix vs. Windows).

Using PrologScript

New in version 4.0.5 is the possibility to use a Prolog source file directly as a Unix script-file. the same mechanism is useful to specify additional parameters for running a Prolog file on Windows.

If the first letter of a Prolog file is #, the first line is treated as comment.\(^3\) To create a Prolog script, make the first line start like this:

\[
#! /path/to/pl (options) -s
\]

---

\(^2\)This implies the system can run out of local stack in debug mode, while no problems arise when running in non-debug mode.

\(^3\)The #-sign can be the legal start of a normal Prolog clause. In the unlikely case this is required, leave the first line blank or add a header-comment.
2.10. COMPILATION

Prolog recognises this starting sequence and causes the interpreter to receive the following argument-list:

```
/path/to/pl ⟨options⟩ -s ⟨script⟩ -- ⟨ScriptArguments⟩
```

Instead of -s, the user may use -f to stop Prolog from looking for a personal initialisation file. Here is a simple script doing expression evaluation:

```
#!/usr/bin/pl -q -t main -f

eval :-
    current_prolog_flag(argv, Argv),
    append(_, [-- |Args], Argv),
    concat_atom(Args, ' ', SingleArg),
    term_to_atom(Term, SingleArg),
    Val is Term,
    format('˜w˜n', [Val]).

main :-
    catch(eval, E, (print_message(error, E), fail)),
    halt.
main :-
    halt(1).
```

And here are two example runs:

```
% eval 1+2
3
% eval foo
ERROR: Arithmetic: ‘foo/0’ is not a function
```

**The Windows version** supports the #! construct too, but here it serves a rather different role. The Windows shell already allows the user to start Prolog source-files directly through the Windows file-type association. Windows however makes it rather complicated to provide additional parameters, such as the required stack-size for an individual Prolog file. The #! line provides for this, providing a more flexible approach then changing the global defaults. The following starts Prolog with unlimited stack-size on the given source-file:

```
#!/usr/bin/pl -L0 -T0 -G0 -s
```

```
....
```

Note the use of /usr/bin/pl, which specifies the interpreter. This argument is ignored in the Windows version, but required to ensure best cross-platform compatibility.
Creating a shell-script

With the introduction of PrologScript (see section 2.10.2), using shell-scripts as explained in this section has become redundant for most applications.

Especially on Unix systems and not-too-large applications, writing a shell-script that simply loads your application and calls the entry-point is often a good choice. A skeleton for the script is given below, followed by the Prolog code to obtain the program arguments.

```bash
#!/bin/sh
base=<absolute-path-to-source>
PL=pl
exec $PL -f none -g "load_files([\'$base/load\'],[silent(true)])" \
   -t go -- $*

go :-
current_prolog_flag(argv, Arguments),
append(_SytremArgs, [--|Args], Arguments), !,
go(Arg).
go(Args) :-
...
```

On Windows systems, similar behaviour can be achieved by creating a shortcut to Prolog, passing the proper options or writing a .bat file.

Creating a saved-state

For larger programs, as well as for programs that are required to run on systems that do not have the SWI-Prolog development system installed, creating a saved state is the best solution. A saved state is created using qsave_program/[1,2] or using the linker plld(1). A saved state is a file containing machine-independent intermediate code in a format dedicated for fast loading. Optionally, the emulator may be integrated in the saved state, creating a single-file, but machine-dependent, executable. This process is described in chapter 7.

Compilation using the -c commandline option

This mechanism loads a series of Prolog source files and then creates a saved-state as qsave_program/2 does. The command syntax is:

```
% pl [option ...] [-o output] -c file ...
```

The options argument are options to qsave_program/2 written in the format below. The option-names and their values are described with qsave_program/2.

```
--option-name=option-value
```
For example, to create a stand-alone executable that starts by executing `main/0` and for which the source is loaded through `load.pl`, use the command

```
% pl --goal=main --stand_alone=true -o myprog -c load.pl
```

This performs exactly the same as executing

```
% pl
<banner>
?- [load].
?- qsave_program(myprog,
                      [ goal(main),
                        stand_alone(true)
                      ]).
?- halt.
```

## 2.11 Environment Control (Prolog flags)

The predicates `current_prolog_flag/2` and `set_prolog_flag/2` allow the user to examine and modify the execution environment. It provides access to whether optional features are available on this version, operating system, foreign-code environment, command-line arguments, version, as well as runtime flags to control the runtime behaviour of certain predicates to achieve compatibility with other Prolog environments.

### `current_prolog_flag(?Key, -Value)`

The predicate `current_prolog_flag/2` defines an interface to installation features: options compiled in, version, home, etc. With both arguments unbound, it will generate all defined prolog-flags. With the ‘Key’ instantiated it unify the value of the prolog-flag. Features come in three types: boolean prolog-flags, prolog-flags with an atom value and prolog-flags with an integer value. A boolean prolog-flag is true iff the prolog-flag is present and the `Value` is the atom `true`. Currently defined keys:

- **arch (atom)**
  
  Identifier for the hardware and operating system SWI-Prolog is running on. Used to select foreign files for the right architecture. See also section 6.4 and `file_search_path/2`.

- **version (integer)**
  
  The version identifier is an integer with value:

  \[10000 \times \text{Major} + 100 \times \text{Minor} + \text{Patch}\]

  Note that in releases up to 2.7.10 this prolog-flag yielded an atom holding the three numbers separated by dots. The current representation is much easier for implementing version-conditional statements.

- **home (atom)**
  
  SWI-Prolog’s notion of the home-directory. SWI-Prolog uses it’s home directory to find its startup file as `⟨home⟩/boot32.prc` (32-bit machines) or `⟨home⟩/boot64.prc` (64-bit machines) and to find its library as `⟨home⟩/library`. 
**executable (atom)**
Path-name of the running executable. Used by `qsave_program/2` as default emulator.

**argv (list)**
List is a list of atoms representing the command-line arguments used to invoke SWI-Prolog. Please note that all arguments are included in the list returned.

**pipe (bool, changeable)**
If true, `open(pipe(command), mode, Stream), etc. are supported. Can be changed to disable the use of pipes in applications testing this feature. Not recommended.

**open_shared_object (bool)**
If true, `open_shared_object/2` and friends are implemented, providing access to shared libraries (.so files) or dynamic link libraries (.DLL files).

**shared_object_extension (atom)**
Extension used by the operating system for shared objects. .so for most Unix systems and .dll for Windows. Used for locating files using the file_type executable. See also `absolute_file_name/3`.

**dynamic_stacks (bool)**
If true, the system uses some form of ‘sparse-memory management’ to realise the stacks. If false, `malloc()/realloc()` are used for the stacks. In earlier days this had consequences for foreign code. As of version 2.5, this is no longer the case.

Systems using ‘sparse-memory management’ are a bit faster as there is no stack-shifter, and checking the stack-boundary is often realised by the hardware using a ‘guard-page’. Also, memory is actually returned to the system after a garbage collection or call to `trim_stacks/0` (called by `prolog/0` after finishing a user-query).

**c_libs (atom)**
Libraries passed to the C-linker when SWI-Prolog was linked. May be used to determine the libraries needed to create statically linked extensions for SWI-Prolog. See section 6.7.

**c_cc (atom)**
Name of the C-compiler used to compile SWI-Prolog. Normally either gcc or cc. See section 6.7.

**c_ldflags (atom)**
Special linker flags passed to link SWI-Prolog. See section 6.7.

**readline (bool)**
If true, SWI-Prolog is linked with the readline library. This is done by default if you have this library installed on your system. It is also true for the Win32 plwin.exe version of SWI-Prolog, which realises a subset of the readline functionality.

**saved_program (bool)**
If true, Prolog is started from a state saved with `qsave_program/1,2`.

**runtime (bool)**
If true, SWI-Prolog is compiled with -DO_RUNTIME, disabling various useful development features (currently the tracer and profiler).

**max_integer (integer)**
Maximum integer value. Most arithmetic operations will automatically convert to floats if integer values above this are returned.
2.11. ENVIRONMENT CONTROL (PROLOG FLAGS)

**min_integer** (integer)
Minimum integer value.

**max_tagged_integer** (integer)
Maximum integer value represented as a ‘tagged’ value. Tagged integers require 4-bytes storage and are used for indexing. Larger integers are represented as ‘indirect data’ and require 16-bytes on the stacks (though a copy requires only 4 additional bytes).

**min_tagged_integer** (integer)
Start of the tagged-integer value range.

**float_format** (atom, changeable)
C printf() format specification used by write/1 and friends to determine how floating point numbers are printed. The default is %g. The specified value is passed to printf() without further checking. For example, if you want more digits printed, %.12g will print all floats using 12 digits instead of the default 6. See also format/[1,2], write/1, print/1 and portray/1.

**toplevel_print_options** (term, changeable)
This argument is given as option-list to write_term/2 for printing results of queries. Default is [quoted(true), portray(true), max_depth(10)].

**debugger_print_options** (term, changeable)
This argument is given as option-list to write_term/2 for printing goals by the debugger. Modified by the ‘w’, ‘p’ and ‘⟨N⟩d’ commands of the debugger. Default is [quoted(true), portray(true), max_depth(10)].

**debugger_show_context** (bool, changeable)
If true, show the context module while printing a stack-frame in the tracer. Normally controlled using the ‘C’ option of the tracer.

**compiled_at** (atom)
Describes when the system has been compiled. Only available if the C-compiler used to compile SWI-Prolog provides the __DATE__ and __TIME__ macros.

**character_escapes** (bool, changeable)
If true (default), read/1 interprets \ escape sequences in quoted atoms and strings. May be changed. This flag is local to the module in which it is changed.

**double_quotes** (codes,chars,atom,string, changeable)
This flag determines how double-quotes strings are read by Prolog and is —like character_escapes— maintained for each module. If codes (default), a list of character-codes is returned, if chars a list of one-character atoms, if atom double quotes are the same as single-quotes and finally, string reads the text into a Prolog string (see section 4.23). See also atom_chars/2 and atom_codes/2.

**allow_variable_name_as_functor** (bool, changeable)
If true (default is false), Functor(arg) is read as if it was written ’Functor’ (arg). Some applications use the Prolog read/1 predicate for reading an application defined script language. In these cases, it is often difficult to explain to non-Prolog users of the application that constants and functions can only start with a lowercase letter. Variables can be turned into atoms starting with an uppercase atom by calling read_term/2 using the option variable_names and binding the variables to their name. Using this feature, F(x) can be turned into valid syntax for such script languages. Suggested by Robert van Engelen. SWI-Prolog specific.
**history** (integer, changeable)

If integer > 0, support Unix csh(1) like history as described in section 2.7. Otherwise, only support reusing commands through the commandline editor. The default is to set this prolog-flag to 0 if a commandline editor is provided (see prolog-flag readline) and 15 otherwise.

**gc** (bool, changeable)

If true (default), the garbage collector is active. If false, neither garbage-collection, nor stack-shifts will take place, even not on explicit request. May be changed.

**age_margin** (integer, changeable)

If this amount of atoms has been created since the last atom-garbage collection, perform atom garbage collection at the first opportunity. Initial value is 10,000. May be changed.

A value of 0 (zero) disables atom garbage collection. See also PL_register_atom().

**iso** (bool, changeable)

Include some weird ISO compatibility that is incompatible to normal SWI-Prolog behaviour. Currently it has the following effect:

- is/2 and evaluation under flag/3 do not automatically convert floats to integers if the float represents an integer.
- The //2 (float division) always return a float, even if applied to integers that can be divided.
- In the standard order of terms (see section 4.6.1), all floats are before all integers.
- atom_length/2 yields an instantiation error if the first argument is a number.
- clause/[2,3] yields an error if the first argument is a number.
- abolish/[1,2] raises a permission error when accessing static predicates.

**optimise** (bool, changeable)

If true, compile in optimised mode. The initial value is true if Prolog was started with the -O commandline option.

Currently optimise compilation implies compilation of arithmetic, and deletion of redundant true/0 that may result from expand_goal/2.

Later versions might imply various other optimisations such as integrating small predicates into their callers, eliminating constant expressions and other predictable constructs.

Source code optimisation is never applied to predicates that are declared dynamic (see dynamic/1).

**char_conversion** (bool, changeable)

Determines whether character-conversion takes place while reading terms. See also char_conversion/2.

**autoload** (bool, changeable)

If true (default) autoloading of library functions is enabled. See section 2.13.

**verbose_autoload** (bool, changeable)

If true the normal consult message will be printed if a library is autoloaded. By default this message is suppressed. Intended to be used for debugging purposes.

**verbose_file_search** (bool, changeable)

If true (default false), print messages indicating the progress of absolute_file_name/[2,3] in locating files. Intended for debugging complicated file-search paths. See also file_search_path/2.
2.11. ENVIRONMENT CONTROL (PROLOG FLAGS) 35

**trace** *(true, changeable)*

If true (false is the default), garbage collections and stack-shifts will be reported on the terminal. May be changed.

**max arity** *(unbounded)*

ISO prolog-flag describing there is no maximum arity to compound terms.

**integer rounding function** *(down,toward_zero)*

ISO prolog-flag describing rounding by // and rem arithmetic functions. Value depends on the C-compiler used.

**bounded** *(true)*

ISO prolog-flag describing integer representation is bound by min_integer and min_integer.

**tty control** *(bool)*

Determines whether the terminal is switched to raw mode for get_single_char/1, which also reads the user-actions for the trace. May be set. See also the +/-tty command-line option.

**unknown** *(fail,warning,error, changeable)*

Determines the behaviour if an undefined procedure is encountered. If fail, the pred-icates fails silently. If warn, a warning is printed, and execution continues as if the predicate was not defined and if error (default), an existence_error exception is raised. This flag is local to each module.

**debug** *(bool, changeable)*

Switch debugging mode on/off. If debug mode is activated the system traps encountered spy-points (see spy/1) and trace-points (see trace/1). In addition, tail-recursion opt-imisation is disabled and the system is more conservative in destroying choice-points to simplify debugging.

Disabling these optimisations can cause the system to run out of memory on programs that behave correctly if debug mode is off.

**tail recursion optimisation** *(bool, changeable)*

Determines whether or not tail-recursion optimisation is enabled. Normally the value of this flag is equal to the debug flag. As programs may run out of stack if tail-recursion optimisation is omitted, it is sometimes necessary to enable it during debugging.

**abort with exception** *(bool, changeable)*

Determines how abort/0 is realised. See the description of abort/0 for details.

**debug on error** *(bool, changeable)*

If true, start the tracer after an error is detected. Otherwise just continue execution. The goal that raised the error will normally fail. See also fileerrors/2 and the prolog-flag report_error. May be changed. Default is true, except for the runtime version.

**report error** *(bool, changeable)*

If true, print error messages, otherwise suppress them. May be changed. See also the debug on error prolog-flag. Default is true, except for the runtime version.

**verbose** *(Atom, changeable)*

This flags is used by print_message/2. If its value is silent, messages of type informational and banner are supressed. The -q switches the value from the initial normal to silent.
file_name_variables \( (\text{bool, changeable}) \)

If \( \text{true} \) (default \( \text{false} \)), expand \$\text{varname} and \sim \) in arguments of builtin-predicates that accept a file name (open/3, exists_file/1, access_file/2, etc.). The predicate expand_file_name/2 should be used to expand environment variables and wildcard patterns. This prolog-flag is intended for backward compatibility with older versions of SWI-Prolog.

unix \( (\text{bool}) \)

If \( \text{true} \), the operating system is some version of Unix. Defined if the C-compiler used to compile this version of SWI-Prolog either defines \_\_\_unix\_\_ or unix.

windows \( (\text{bool}) \)

If \( \text{true} \), the operating system is an implementation of Microsoft Windows (3.1, 95, NT, etc.).

hwnd \( (\text{integer}) \)

In plwin.exe, this refers to the MS-Windows window-handle of the console window.

set_prolog_flag(+Key, +Value)

Define a new prolog-flag or change its value. \( \text{Key} \) is an atom. If the flag is a system-defined flag that is not marked \text{changeable} above, an attempt to modify the flag yields a \text{permission_error}. If the provided \( \text{Value} \) does not match the type of the flag, a \text{type_error} is raised.

In addition to ISO, SWI-Prolog allows for user-defined prolog flags. The type of the flag is determined from the initial value and cannot be changed afterwards.

2.12 An overview of hook predicates

SWI-Prolog provides a large number of hooks, mainly to control handling messages, debugging, startup, shut-down, macro-expansion, etc. Below is a summary of all defined hooks with an indication of their portability.

- portray/1
  Hook into write_term/3 to alter the way terms are printed (ISO).

- message_hook/3
  Hook into print_message/2 to alter the way system messages are printed (Quintus/SICStus).

- library_directory/1
  Hook into absolute_file_name/3 to define new library directories. (most Prolog system).

- file_search_path/2
  Hook into absolute_file_name/3 to define new search-paths (Quintus/SICStus).

- term_expansion/2
  Hook into load_files/1 to modify read terms before they are compiled (macro-processing) (most Prolog system).

- goal_expansion/2
  Same as term_expansion/2 for individual goals (SICStus).
2.13. AUTOMATIC LOADING OF LIBRARIES

• prolog_edit:locate/3
  Hook into edit/1 to locate objects (SWI).

• prolog_edit:edit_source/1
  Hook into edit/1 to call some internal editor (SWI).

• prolog_edit:edit_command/2
  Hook into edit/1 to define the external editor to use (SWI).

• prolog_list_goal/1
  Hook into the tracer to list the code associated to a particular goal (SWI).

• prolog_trace_interception/4
  Hook into the tracer to handle trace-events (SWI).

• prolog:debug_control_hook/1
  Hook in spy/1, nospy/1, nospyall/0 and debugging/0 to extend these control-
  predicates to higher-level libraries.

• prolog:help_hook/1
  Hook in help/0, help/1 and apropos/1 to extend the help-system.

• resource/3
  Defines a new resource (not really a hook, but similar) (SWI).

• exception/3
  Old attempt to a generic hook mechanism. Handles undefined predicates (SWI).

2.13 Automatic loading of libraries

If —at runtime— an undefined predicate is trapped the system will first try to import the predicate
from the module’s default module. If this fails the auto loader is activated. On first activation an index
to all library files in all library directories is loaded in core (see library_directory/1). If the
undefined predicate can be located in the one of the libraries that library file is automatically loaded
and the call to the (previously undefined) predicate is resumed. By default this mechanism loads
the file silently. The current_prolog_flag/2 verbose autoload is provided to get verbose
loading. The prolog-flag autoload can be used to enable/disable the entire auto load system.

The auto-loader only works if the unknown flag (see unknown/2) is set to trace (default). A
more appropriate interaction with this flag should be considered.

Autoloading only handles (library) source files that use the module mechanism described in chapter
5. The files are loaded with use_module/2 and only the trapped undefined predicate will be
imported to the module where the undefined predicate was called. Each library directory must hold a
file INDEX.pl that contains an index to all library files in the directory. This file consists of lines of
the following format:

index(Name, Arity, Module, File).

The predicate make/0 updates the autoload index. It searches for all library directories
(see library_directory/1 and file_search_path/2) holding the file MKINDEX.pl or
INDEX.pl. If the current user can write or create the file INDEX.pl and it does not exist or is older than the directory or one of its files, the index for this directory is updated. If the file MKINDEX.pl exists updating is achieved by loading this file, normally containing a directive calling make_library_index/2. Otherwise make_library_index/1 is called, creating an index for all *.pl files containing a module.

Below is an example creating a completely indexed library directory.

```
% mkdir ~/lib/prolog
% cd !$
% pl -g true -t 'make_library_index(.'
```

If there are more than one library files containing the desired predicate the following search schema is followed:

1. If there is a library file that defines the module in which the undefined predicate is trapped, this file is used.
2. Otherwise library files are considered in the order they appear in the library.directory/1 predicate and within the directory alphabetically.

**make_library_index(+Directory)**

Create an index for this directory. The index is written to the file 'INDEX.pl' in the specified directory. Fails with a warning if the directory does not exist or is write protected.

**make_library_index(+Directory, +ListOfPatterns)**

Normally used in MKINDEX.pl, this predicate creates INDEX.pl for Directory, indexing all files that match one of the file-patterns in ListOfPatterns.

Sometimes library packages consist of one public load file and a number of files used by this load-file, exporting predicates that should not be used directly by the end-user. Such a library can be placed in a sub-directory of the library and the files containing public functionality can be added to the index of the library. As an example we give the XPCE library's MKINDEX.pl, including the public functionality of trace/browse.pl to the autoloadable predicates for the XPCE package.

```prolog
:- make_library_index('.',
    [ '*.pl',
      'trace/browse.pl'
    ]).
```

### 2.14 Garbage Collection

SWI-Prolog provides garbage-collection, last-call optimization and atom garbage collection. These features are controlled using prolog flags (see current_prolog_flag/2).
2.15 Syntax Notes

SWI-Prolog uses standard ‘Edinburgh’ syntax. A description of this syntax can be found in the Prolog books referenced in the introduction. Below are some non-standard or non-common constructs that are accepted by SWI-Prolog:

- \0\langle char\rangle
  This construct is not accepted by all Prolog systems that claim to have Edinburgh compatible syntax. It describes the ASCII value of \langle char\rangle. To test whether \texttt{C} is a lower case character one can use \texttt{between(0\’a, 0\’z, C)}.

- /* .../* ...*/ ...*/
  The /* ...*/ comment statement can be nested. This is useful if some code with /* ...*/ comment statements in it should be commented out.

2.15.1 ISO Syntax Support

SWI-Prolog offers ISO compatible extensions to the Edinburgh syntax.

Character Escape Syntax

Within quoted atoms (using single quotes: ‘\langle atom\rangle’ special characters are represented using escape-sequences. An escape sequence is lead in by the backslash (\) character. The list of escape sequences is compatible with the ISO standard, but contains one extension and the interpretation of numerically specified characters is slightly more flexible to improve compatibility.

\a
  Alert character. Normally the ASCII character 7 (beep).

\b
  Backspace character.

\c
  No output. All input characters up to but not including the first non-layout character are skipped. This allows for the specification of pretty-looking long lines. For compatibility with Quintus Prolog. Not supported by ISO. Example:

  \texttt{format(’This is a long line that would look better if it was \c split across multiple physical lines in the input’)}

\(\texttt{(RETURN)}\)
  No output. Skips input till the next non-layout character or to the end of the next line. Same intention as \texttt{\c} but ISO compatible.

\f
  Form-feed character.

\n
  Next-line character.
\r
Carriage-return only (i.e. go back to the start of the line).

\t
Horizontal tab-character.

\v
Vertical tab-character (ASCII 11).

\x23
Hexadecimal specification of a character. 23 is just an example. The ‘x’ may be followed by a maximum of 2 hexadecimal digits. The closing \ is optional. The code \xa\3 emits the character 10 (hexadecimal ‘a’) followed by ‘3’. The code \x201 emits 32 (hexadecimal ‘20’) followed by ‘1’. According to ISO, the closing \ is obligatory and the number of digits is unlimited. The SWI-Prolog definition allows for ISO compatible specification, but is compatible with other implementations.

\40
Octal character specification. The rules and remarks for hexadecimal specifications apply to octal specifications too, but the maximum allowed number of octal digits is 3.

\langle character\rangle
Any character immediately preceded by a \ and not covered by the above escape sequences is copied verbatim. Thus, ‘\’ is an atom consisting of a single \ and ‘\’’ and ‘’’ both describe the atom with a single ‘’.

Character escaping is only available if the current_prolog_flag(character_escapes, true) is active (default). See current_prolog_flag/2. Character escapes conflict with writef/2 in two ways: \40 is interpreted as decimal 40 by writef/2, but character escapes handling by read has already interpreted as 32 (40 octal). Also, \l is translated to a single ‘l’. It is advised to use the more widely supported format/[2,3] predicate instead. If you insist upon using writef/2, either switch character_escapes to false, or use double \, as in writef(‘\l’).

Syntax for non-decimal numbers

SWI-Prolog implements both Edinburgh and ISO representations for non-decimal numbers. According to Edinburgh syntax, such numbers are written as $radix^{number}$, where $radix$ is a number between 2 and 36. ISO defines binary, octal and hexadecimal numbers using 0 [b xo] $number$. For example: A is 0b100 \ 0xf00 is a valid expression. Such numbers are always unsigned.

2.16 System limits

2.16.1 Limits on memory areas

SWI-Prolog has a number of memory areas which are only enlarged to a certain limit. The default sizes for these areas should suffice for most applications, but big applications may require larger ones. They are modified by command line options. The table below shows these areas. The first column gives the option name to modify the size of the area. The option character is immediately followed by
2.16. SYSTEM LIMITS

a number and optionally by a $k$ or $m$. With $k$ or no unit indicator, the value is interpreted in Kbytes (1024 bytes), with $m$, the value is interpreted in Mbytes ($1024 \times 1024$ bytes).

The local-, global- and trail-stack are limited to 128 Mbytes on 32 bit processors, or more generally to $2^{\text{bits-per-long}-5}$ bytes.

The PrologScript facility described in section 2.10.2 provides a mechanism for specifying options with the load-file. On Windows the default stack-sizes are controlled using the Windows registry on the key HKEY_CURRENT_USER\Software\SWI\Prolog using the names localSize, globalSize and trailSize. The value is a DWORD expressing the default stack size in Kbytes. A GUI for modifying these values is provided using the XPCE package. To use this, start the XPCE manual tools using manpce/0, after which you find Preferences in the File menu.

The heap

With the heap, we refer to the memory area used by malloc() and friends. SWI-Prolog uses the area to store atoms, functors, predicates and their clauses, records and other dynamic data. As of SWI-Prolog 2.8.5, no limits are imposed on the addresses returned by malloc() and friends.

On some machines, the runtime stacks described above are allocated using ‘sparse allocation’. Virtual space up to the limit is claimed at startup and committed and released while the area grows and shrinks. On Win32 platform this is realised using VirtualAlloc() and friends. On Unix systems this is realised using mmap().

2.16.2 Other Limits

Clauses The only limit on clauses is their arity (the number of arguments to the head), which is limited to 1024. Raising this limit is easy and relatively cheap, removing it is harder.

Atoms and Strings SWI-Prolog has no limits on the sizes of atoms and strings. read/1 and its derivatives however normally limit the number of newlines in an atom or string to 5 to improve error detection and recovery. This can be switched off with style_check/1.

The number of atoms is limited to 16777216 (16M) on 32-bit machines. On 64-bit machines this is virtually unlimited. See also section 6.6.2.

Address space SWI-Prolog data is packed in a 32-bit word, which contains both type and value information. The size of the various memory areas is limited to 128 Mb for each of the areas, except for the program heap, which is not limited.

Integers Integers are 32-bit (64 on 64-bit machines) to the user, but integers up to the value of the max_tagged_integer prolog-flag are represented more efficiently.

Floats Floating point numbers are represented as C-native double precision floats, 64 bit IEEE on most machines.

2.16.3 Reserved Names

The boot compiler (see -b option) does not support the module system. As large parts of the system are written in Prolog itself we need some way to avoid name clashes with the user’s predicates, database keys, etc. Like Edinburgh C-Prolog [Pereira, 1986] all predicates, database keys, etc. that should be hidden from the user start with a dollar ($) sign (see style_check/1).
<table>
<thead>
<tr>
<th>Option</th>
<th>Default</th>
<th>Area name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-L</td>
<td>2M</td>
<td>local stack</td>
<td>The local stack is used to store the execution environments of procedure invocations. The space for an environment is reclaimed when it fails, exits without leaving choice points, the alternatives are cut off with the !/0 predicate or no choice points have been created since the invocation and the last subclause is started (tail recursion optimisation).</td>
</tr>
<tr>
<td>-G</td>
<td>4M</td>
<td>global stack</td>
<td>The global stack is used to store terms created during Prolog's execution. Terms on this stack will be reclaimed by backtracking to a point before the term was created or by garbage collection (provided the term is no longer referenced).</td>
</tr>
<tr>
<td>-T</td>
<td>4M</td>
<td>trail stack</td>
<td>The trail stack is used to store assignments during execution. Entries on this stack remain alive until backtracking before the point of creation or the garbage collector determines they are no longer needed any longer.</td>
</tr>
<tr>
<td>-A</td>
<td>1M</td>
<td>argument stack</td>
<td>The argument stack is used to store one of the intermediate code interpreter's registers. The amount of space needed on this stack is determined entirely by the depth in which terms are nested in the clauses that constitute the program. Overflow is most likely when using long strings in a clause.</td>
</tr>
</tbody>
</table>

Table 2.2: Memory areas
Initialising and Managing a Prolog Project

Prolog text-books give you an overview of the Prolog language. The manual tells you what predicates are provided in the system and what they do. This chapter wants to explain how to run a project. There is no ultimate ‘right’ way to do this. Over the years we developed some practice in this area and SWI-Prolog’s commands are there to support this practice. This chapter describes the conventions and supporting commands.

The first two sections (section 3.1 and section 3.2) only require plain Prolog. The remainder discusses the use of the built-in graphical tools that require the XPCE graphical library installed on your system.

3.1 The project source-files

Organisation of source-files depends largely on the size of your project. If you are doing exercises for a Prolog course you’ll normally use one file for each exercise. If you have a small project you’ll work with one directory holding a couple of files and some files to link it all together. Even bigger projects will be organised in sub-projects each using their own directory.

3.1.1 File Names and Locations

File Name Extensions

The first consideration is what extension to use for the source-files. Tradition calls for .pl, but conflicts with Perl force the use of another extension on systems where extensions have global meaning, such as MS-Windows. On such systems .pro is the common alternative.

All versions of SWI-Prolog load files with the extension .pl as well as with the registered alternative extension without explicitly specifying the extension. For portability reasons we propose the following convention:

If there is no conflict because you do not use a conflicting application or the system does not force a unique relation between extension and application, use .pl.

With a conflict choose .pro and use this extension for the files you want to load through your file-manager. Use .pl for all other files for maximal portability.

Project Directories

Large projects are generally composed of sub-projects, each using their own directory or directory-structure. If nobody else will ever touch your files and you use only one computer there is little to
worry about, but this is rarely the case with a large project.

To improve portability, SWI-Prolog uses the POSIX notation for filenames, which uses the forward slash (/) to separate directories. Just before hitting the file-system it uses `prolog_to_os_filename/2` to convert the filename to the conventions used by the hosting operating system. It is **strongly** advised to write paths using the /, especially on systems using the \ for this purpose (MS-Windows). Using \\ violates the portability rules and requires you to double the \ due to the Prolog quoted-atom escape rules.

Portable code should use `prolog_to_os_filename/2` to convert computed paths into system-paths when constructing commands for `shell/1` and friends.

**Sub-projects using search-paths**

Thanks to Quintus, Prolog adapted an extensible mechanism for searching files using `file_search_path/2`. This mechanism allows for comfortable and readable specifications.

Suppose you have extensive library packages on graph-algorithms, set-operations and ui-primitives. These sub-projects are likely candidates for re-use in future projects. A good choice is to create a directory with sub-directories for each of these sub-projects.

Next, there are three options. One is to add the sub-projects to the directory-hierarchy of the current project. Another is to use a completely dislocated directory and finally the sub-project can be added to the SWI-Prolog hierarchy. Using local installation, a typical `file_search_path/2` is:

```prolog
:- prolog_load_context(directory, Dir),
   asserta(user:file_search_path(myapp, Dir)).

user:file_search_path(graph, myapp(graph)).
user:file_search_path(ui, myapp(ui)).
```

For using sub-projects in the SWI-Prolog hierarchy one should use the path-alias `swi` as basis. For a system-wide installation use an absolute-path.

Extensive sub-projects with a small well-defined API should define a load-file using `use_module/1` calls to import the various library-components and export the API.

**3.1.2 Project Special Files**

There are a number of tasks you typically carry out on your project, such as loading it, creating a saved-state, debugging it, etc. Good practice on large projects is to define small files that hold the commands to execute such a task, name this file after the task and give it a file-extension that makes starting easy (see section 3.1.1). The task `load` is generally central to these tasks. Here is a tentative list.

- **load.pl**
  Use this file to set up the environment (prolog flags and file search paths) and load the sources. Quite commonly this file also provides convenient predicates to parse command-line options and start the application.

- **run.pl**
  Use this file to start the application. Normally it loads `load.pl` in silent-mode, and calls one of the starting predicates from `load.pl`. 
3.2. USING MODULES

• **save.pl**  
  Use this file to create a saved-state of the application by loading load.pl and call qsave_program/2 to generate a saved-state with the proper options.

• **debug.pl**  
  Loads the program for debugging. In addition to loading load.pl this file defines rules for portray/1 to modify printing rules for complex terms and customisation rules for the debugger and editing environment. It may start some of these tools.

3.2 Using modules

Modules have been debated fiercely in the Prolog world. Despite all counter-arguments we feel they are extremely useful because

• **They hide local predicates**  
  This is the reason they have been invented in the first place. Hiding provides two features. They allow for short predicate names without worrying about conflicts. Given the flat namespace introduced by modules, they still require meaningful module names as well as meaningful names for exported predicates.

• **They document the interface**  
  Possibly more important then avoiding name-conflicts is their role in documenting which part of the file is for public usage and which is private. When editing a module you may assume you can reorganise anything but the name and semantics of the exported predicates without worrying.

• **They help the editor**  
  The PceEmacs built-in editor does on-the-fly cross-referencing of the current module, colouring predicates based on their origin and usage. Using modules, the editor can quickly find out what is provided by the imported modules by reading just the first term. This allows it to indicate real-time which predicates are not used or not defined.

Using modules is generally easy. Only if you write meta-predicates (predicates reasoning about other predicates) that are exported from a module good understanding of resolution of terms to predicates inside a module is required. Here is a typical example from library(readutil).

```prolog
:- module(read_util,
    [ read_line_to_codes/2, % +Fd, -Codes
      read_line_to_codes/3, % +Fd, -Codes, ?Tail
      read_stream_to_codes/2, % +Fd, -Codes
      read_stream_to_codes/3, % +Fd, -Codes, ?Tail
      read_file_to_codes/3, % +Fd, -Codes, +Options
      read_file_to_terms/3 % +File, -Terms, +Options
    ]).
```

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3.3 The test-edit-reload cycle

SWI-Prolog does not enforce the use of a particular editor for writing down Prolog source code. Editors are complicated programs that must be mastered in detail for real productive programming and if you are familiar with a specific editor you should not be forced to change. You may specify your favourite editor using the environment variable EDITOR or by defining rules for prolog_edit:edit_source/1 (see section 4.4).

The use of a built-in editor however has advantages. The XPCE editor object around which the built-in PceEmacs is built can be opened as a Prolog stream allowing analysis of your source by the real Prolog system.

3.3.1 Locating things to edit

The central predicate for editing something is edit/1, an extensible front-end that searches for objects (files, predicates, modules as well as XPCE classes and methods) in the Prolog database. If multiple matches are found it provides a choice. Together with the built-in completion on atoms bound to the TAB key this provides a quick way to edit objects:

?- edit(country).

Please select item to edit:

1 chat:country/10 '/staff/jan/lib/prolog/chat/countr.pl':16
2 chat:country/1 '/staff/jan/lib/prolog/chat/world0.pl':?2

Your choice?

3.3.2 Editing and incremental compilation

One of the nice features of Prolog is that the code can be modified while the program is running. Using pure Prolog you can trace a program, find it is misbehaving, enter a break environment, modify the source code, reload it and finally do retry on the misbehaving predicate and try again. This sequence is not uncommon for long-running programs. For faster programs one normally aborts after understanding the misbehaviour, edit the source, reload it and try again.

One of the nice features of SWI-Prolog is the availability of make/0, a simple predicate that checks all loaded source files to see which ones you have modified. It then reloads these files, considering the module from which the file was loaded originally. This greatly simplifies the trace-edit-verify development cycle. After the tracer reveals there is something wrong with prove/3, you do:

?- edit(prove).

Now edit the source, possibly switching to other files and making multiple changes. After finishing invoke make/0, either through the editor UI (Compile/Make (Control-C Control-M)) or on the toplevel and watch the files being reloaded.

?- make.
% show compiled into photo_gallery 0.03 sec, 3,360 bytes

---

2Watching these files is a good habit. If expected files are not reloaded you may have forgotten to save them from the editor or you may have been editing the wrong file (wrong directory).
3.4 Using the PceEmacs built-in editor

3.4.1 Activating PceEmacs

Initially edit/1 uses the editor specified in the EDITOR environment variable. There are two ways to force it to use the built-in editor. One is by loading library(emacs/swi_prolog), a source-file from the PceEmacs library that installs hooks which

- Cause edit/1 to use the built-in PceEmacs
- Intercept error and warning messages while loading sources, providing these messages in a window from which the related source can be found by double-clicking the message.

3.4.2 Bluffing through PceEmacs

PceEmacs closely mimics Richard Stallman’s GNU-Emacs commands, adding features from modern window-based editors to make it more acceptable for beginners.3

At the basis, PceEmacs maps keyboard sequences to methods defined on the extended editor object. Some frequently used commands are, with their key-binding, presented in the menu-bar above each editor window. A complete overview of the bindings for the current mode is provided through Help/Show key bindings (Control-h Control-b).

Edit modes

Modes are the heart of (Pce)Emacs. Modes define dedicated editing support for a particular kind of (source-)text. For our purpose we want Prolog mode. Their are various ways to make PceEmacs use Prolog mode for a file.

- *Using the proper extension*
  If the file ends in .pl or the selected alternative (e.g., .pro) extension, Prolog mode is selected.

- *Using #!/path/to/pl*
  If the file is a Prolog Script file, starting with the line #!/path/to/pl options -s, Prolog mode is selected regardless of the extension

- *Using -*- Prolog -*-*
  If the above sequence appears in the first line of the file (inside a Prolog comment) Prolog mode is sequence

- *Explicit selection*
  Finally, using File/Mode/Prolog (y)ou can switch to Prolog mode explicitly.

Frequently used editor commands

Below we list a few important commands and how to activate them.

3Decent merging with MS-Windows control-key conventions is difficult as many conflict with GNU-Emacs. Especially the cut/copy/paste commands conflict with important GNU-Emacs commands.
• Cut/Copy/Paste
  These commands follow Unix/X11 traditions. You’re best suited with a three-button mouse. After selecting using the left-mouse (double-click uses word-mode and triple line-mode), the selected text is automatically copied to the clipboard (X11 primary selection on Unix). Cut is achieved using the DEL key or by typing something else at the location. Paste is achieved using the middle-mouse (or wheel) button. If you don’t have a middle mouse-button, pressing the left- and right-button at the same time is interpreted as a middle-button click. If nothing helps there is the Edit/Paste menu-entry. Text is pasted at the caret-location.

• Undo
  Undo is bound to the GNU-Emacs Control-_, as well as the MS-Windows Control-Z sequence.

• Abort
  Multi-key sequences can be aborted at any stage using Control-G.

• Find
  Find (Search) is started using Control-S (forward) or Control-R (backward). PceEmacs implements incremental search. This is difficult to use for novices, but very powerful once you get the clue. After one of the above start-keys the system indicates search mode in the status line. As you are typing the search-string, the system searches for it, extending the search with every character you type. It illustrates the current match using a green background.

  If the target cannot be found, PceEmacs warns you and no longer extends the search-string. During search some characters have special meaning. Typing anything but these characters commits the search, re-starting normal edit mode. Special commands are:

  Control-S
    Search for next forwards.

  Control-R
    Search for next backwards.

  Control-W
    Extend search to next word-boundary.

  Control-G
    Cancel search, go back to where it started.

  ESC
    Commit search, leaving caret at found location.

  Backspace
    Remove a character from the search string.

• Dynamic Abbreviation
  Also called dabbrev is an important feature of Emacs clones to support programming. After typing the first few letters of an identifier you may hit Alt-/, causing PceEmacs to search backwards for identifiers that start the same and using it to complete the text you typed. A second Alt-/ searches further backwards. If there are no hits before the caret it starts searching forwards.

  With some practice, this system allows for very fast entering code with nice and readable identifiers (or other difficult long words).

4GNU-Emacs keeps extending the string, but why? Adding more text will not make it match.
3.4. USING THE PCEEMACS BUILT-IN EDITOR

- **Open (a file)**
  Is called File/Find file (Control-\text{x} Control-f). By default the file is loaded into the current window. If you want to keep this window, Hit Alt-s or click the little icon at the bottom-left to make the window sticky.

- **Split view**
  Sometimes you want to look at two places of the same file. To do this, use Control-x 2 to create a new window pointing to the same file. Do not worry, you can edit as well as move around in both. Control-\text{x} 1 kills all other windows running on the same file.

These were the most commonly used commands. In section section 3.4.3 we discuss specific support for dealing with Prolog source code.

### 3.4.3 Prolog Mode

In the previous section (section 3.4.2) we explained the basics of PceEmacs. Here we continue with Prolog specific functionality. Possibly the most interesting is **Syntax highlighting**. Unlike most editors where this is based on simple patterns, PceEmacs syntax highlighting is achieved by Prolog itself actually reading and interpreting the source as you type it. There are three moments at which PceEmacs checks (part of) the syntax.

- **After typing a .**
  After typing a . that is not preceeded by a symbol character the system assumes you completed a clause, tries to find the start of this clause and verifies the syntax. If this process succeeds it colours the elements of the clause according to the rules given below. Colouring is done using information from the last full check on this file. If it fails, the syntax error is displayed in the status line and the clause is not coloured.

- **After the command Control-c Control-s**
  Acronym for Ccheck Syntax it performs the same checks as above for the clause surrounding the caret. On a syntax error however, the caret is moved to the expected location of the error.\(^5\)

- **After pausing for two seconds**
  After a short pause (2 seconds), PceEmacs opens the edit-buffer and reads it as a whole, creating an index of defined, called, dynamic, imported and exported predicates. After completing this, it re-reads the file and colours all clauses and calls with valid syntax.

- **After typing Control-l Control-l**
  The Control-l commands re-centers the window (scrolls the window to make the caret the center of the window). Hitting this command twice starts the same process as above.

The **colour schema** itself is defined in library(emacs/prolog_colour). The colouring can be extended and modified using multfile predicates. Please check this source-file for details. In general, underlined objects have a popup (right-mouse button) associated for common commands such as viewing the documentation or source. **Bold** text is used to indicate the definition of objects (typically predicates when using plain Prolog). Other colours follow intuitive conventions. See table 3.4.3.

---

\(^5\)In most cases the location where the parser cannot proceed is further down the file than the actual error-location.
Layout support  Layout is not ‘just nice’, it is essential for writing readable code. There is much debate on the proper layout of Prolog. PceEmacs, being a rather small project supports only one particular style for layout.\(^6\) Below are examples of typical constructs.

head(arg1, arg2).

head(arg1, arg2) :- !.

head(Arg1, arg2) :- !,
    call1(Arg1).

head(Arg1, arg2) :-
    (   if(Arg1)
        -> then
            ;   else
    ).

head(Arg1) :-
    (   a
        ;   b
    ).

head :-
    a(many,
        long,
        arguments(with,
                    many,
                    more),
        and([ a,

\(^6\)Defined in Prolog in the file library(emacs/prolog_mode), you may wish to extend this. Please contribute your extensions!
3.5. THE GRAPHICAL DEBUGGER

PceEmacs uses the same conventions as GNU-Emacs. The TAB key indents the current line according to the syntax rules. Alt-q indents all lines of the current clause. It provides support for head, calls (indented 1 tab), if-then-else, disjunction and argument-lists broken across multiple lines as illustrated above.

Finding your way around

The command Alt-\. extracts name and arity from the caret location and jumps (after conformation or edit) to the definition of the predicate. It does so based on the source-location database of loaded predicates also used by edit/1. This makes locating predicates reliable if all sources are loaded and up-to-date (see make/0).

In addition, references to files in use_module/[1,2], consult/1, etc. are red if the file cannot be found and underlined blue if the file can be loaded. A popup allows for opening the referenced file.

3.5 The Graphical Debugger

SWI-Prolog offers two debuggers. One is the traditional text-console based 4-port Prolog tracer and the other is a window-based source-level debugger. The window-based debugger requires XPCE installed. It operates based on the prolog_trace_interception/4 hook and other low-level functionality described in chapter B.

Window-based tracing provides much better overview due to the eminent relation to your source-code, a clear list of named variables and their bindings as well as a graphical overview of the call and choice-point stack. There are some drawbacks though. Using a textual trace on the console one can scroll back and examine the past, while the graphical debugger just presents a (much better) overview of the current state.

3.5.1 Invoking the window-based debugger

Whether the text-based or window-based debugger is used is controlled using the predicates guitracer/0 and noguitracer/0. Entering debug mode is controlled using the normal predicates for this: trace/0 and spy/1. In addition, PceEmacs prolog mode provides the command Prolog/Break at (Control-c b) to insert a break-point at a specific location in the source-code.

guitracer

This predicate installs the above-mentioned hooks that redirect tracing to the window-based environment. No window appears. The debugger window appears as actual tracing is started through trace/0, by hitting a spy-point defined by spy/1 or a break-point defined using PceEmacs command Prolog/Break at (Control-c b).
noguitracer

Disable the hooks installed by guitracer/0, reverting to normal text-console based tracing.

### 3.6 The Prolog Navigator

Another tool is the **Prolog Navigator**. This tool can be started from PceEmacs using the command Browse/Prolog navigator, from the GUI debugger or using the predicate `prolog_navigator/1`.

`prolog_navigator(+DirOrLocation)`

Ensure the navigator exists and the indicated location is shown. `DirOrLocation` is either the name of a directory or `File:Line` to open and select the given location.

### 3.7 Summary of the iDE

The SWI-Prolog development environment consists of a number of interrelated but not (yet) integrated tools. Here is a list of the most important features and tips.

- **Atom completion**
  
The console¹ completes a partial atom on the TAB key and shows alternatives on the command Alt-?.

- **Use edit/1 to finding locations**
  
The command `edit/1` takes the name of a file, module, predicate or other entity registered through extensions and starts the users preferred editor at the right location.

- **Select editor**
  
External editors are selected using the EDITOR environment variable or by defining the hook `prolog_edit:edit_source/1`. The library(emacs/swi_prolog) library may be loaded from the personal initialisation-file to pre-select the usage of the built-in editor.

- **Update Prolog after editing**
  
Using `make/0`, all files you have edited are re-loaded.

- **PceEmacs**
  
Offers syntax-highlighting and checking based on real-time parsing of the editor’s buffer, layout-support and navigation support.

- **Using the graphical debugger**
  
The predicates `guitracer/0` and `noguitracer/0` switch between traditional text-based and window-based debugging. The tracer is activated using the `trace/0`, `spy/1` or menu-items from PceEmacs or the PrologNavigator.

- **The Prolog Navigator**
  
Shows the file-structure and structure inside the file. It allows for loading files, editing, setting spy-points, etc.

---

¹ On Windows this is realised by plwin.exe, on Unix through the GNU readline library, which is included automatically when found by configure.
4

Built-in predicates

4.1 Notation of Predicate Descriptions

We have tried to keep the predicate descriptions clear and concise. First the predicate name is printed in bold face, followed by the arguments in italics. Arguments are preceded by a ‘+’, ‘-’ or ‘?’ sign. ‘+’ indicates the argument is input to the predicate, ‘-’ denotes output and ‘?’ denotes ‘either input or output’. Constructs like ‘op/3’ refer to the predicate ‘op’ with arity ‘3’.

4.2 Character representation

In traditional (Edinburgh-) Prolog, characters are represented using character-codes. Character codes are integer indices into a specific character set. Traditionally the character set was 7-bits US-ASCII. 8-bit character sets have been allowed for a long time, providing support for national character sets, of which iso-latin-1 (ISO 8859-1) is applicable to many western languages. Text-files are supposed to represent a sequence of character-codes.

ISO Prolog introduces three types, two of which are used for characters and one for accessing binary streams (see open/4). These types are:

- **code**
  A character-code is an integer representing a single character. As files may use multi-byte encoding for supporting different character sets (utf-8 encoding for example), reading a code from a text-file is in general not the same as reading a byte.

- **char**
  Alternatively, characters may be represented as one-character-atoms. This is a very natural representation, hiding encoding problems from the programmer as well as providing much easier debugging.

- **byte**
  Bytes are used for accessing binary-streams.

The current version of SWI-Prolog does not provide support for multi-byte character encoding. This implies for example that it is not capable of breaking a multi-byte encoded atom into characters. For SWI-Prolog, bytes and codes are the same and one-character-atoms are simple atoms containing one byte.

To ease the pain of these multiple representations, SWI-Prolog’s built-in predicates dealing with character-data work as flexible as possible: they accept data in any of these formats as long as the interpretation is unambiguous. In addition, for output arguments that are instantiated, the character

1These marks do not suggest instantiation (e.g. var(+Var)).
is extracted before unification. This implies that the following two calls are identical, both testing whether the next input characters is an a.

\[
\text{peek\_code(Stream, \mathbf{a}).} \\
\text{peek\_code(Stream, 97).}
\]

These multiple-representations are handled by a large number of built-in predicates, all of which are ISO-compatible. For converting between code and character there is \texttt{char\_code/2}. For breaking atoms and numbers into characters are are \texttt{atom\_chars/2, atom\_codes/2, number\_codes/2} and \texttt{number\_chars/2}. For character I/O on streams there is \texttt{get\_char/[1,2], get\_byte/[1,2], peek\_char/[1,2], peek\_byte/[1,2], put\_code/[1,2], put\_char/[1,2] and put\_byte/[1,2]}. The prolog-flag \texttt{double\_quotes} (see \texttt{current\_prolog\_flag/2}) controls how text between double-quotes is interpreted.

### 4.3 Loading Prolog source files

This section deals with loading Prolog source-files. A Prolog source file is a text-file (often referred to as \texttt{ASCII-file}) containing a Prolog program or part thereof. Prolog source files come in three flavours:

A **traditional** Prolog source file contains a Prolog clauses and directives, but no \textit{module-declaration}. They are normally loaded using \texttt{consult/1} or \texttt{ensure\_loaded/1}.

A **module** Prolog source file starts with a module declaration. The subsequent Prolog code is loaded into the specified module and only the \textit{public} predicates are made available to the context loading the module. Module files are normally loaded using \texttt{use\_module/[1,2]}. See chapter 5 for details.

A **include** Prolog source file is loaded using the \texttt{include/1} directive and normally contains only directives.

Prolog source-files are located using \texttt{absolute\_file\_name/3} with the following options:

\[
\text{locate\_prolog\_file(Spec, Path) :-}
\text{absolute\_file\_name(Spec,}
\text{[ file\_type(prolog),}
\text{ access(read)}
\text{],}
\text{Path).}
\]

The \texttt{file\_type(prolog)} option is used to determine the extension of the file using \texttt{prolog\_file\_type/2}. The default extension is \texttt{.pl}. \textit{Spec} allows for the \textit{path-alias} construct defined by \texttt{absolute\_file\_name/3}. The most commonly used path-alias is \texttt{library(LibraryFile)}. The example below loads the library file \texttt{oset.pl} (containing predicates for manipulating ordered sets).

\[
\text{:- use\_module(library(oset)).}
\]
SWI-Prolog recognises grammar rules (DCG) as defined in [Clocksin & Melish, 1987]. The user may define additional compilation of the source file by defining the dynamic predicate `term_expansion/2`. Transformations by this predicate overrule the systems grammar rule transformations. It is not allowed to use `assert/1`, `retract/1` or any other database predicate in `term_expansion/2` other than for local computational purposes.\(^2\)

Directives may be placed anywhere in a source file, invoking any predicate. They are executed when encountered. If the directive fails, a warning is printed. Directives are specified by `:-/1` or `?-/1`. There is no difference between the two.

SWI-Prolog does not have a separate `reconsult/1` predicate. Reconsulting is implied automatically by the fact that a file is consulted which is already loaded.

### load_files(+Files, +Options)

The predicate `load_files/2` is the parent of all the other loading predicates. It currently supports a subset of the options of Quintus `load_files/2`. `Files` is either specifies a single, or a list of source-files. The specification for a source-file is handled `absolute_file_name/2`. See this predicate for the supported expansions. `Options` is a list of options using the format

\[\text{OptionName}(\text{OptionValue})\]

The following options are currently supported:

#### if(Condition)
Load the file only if the specified condition is satisfied. The value `true` loads the file unconditionally, `changed` loads the file if it was not loaded before, or has been modified since it was loaded the last time, `not_loaded` loads the file if it was not loaded before.

#### must_be_module(Bool)
If `true`, raise an error if the file is not a module file. Used by `use_module/[1,2]`.

#### imports(ListOrAll)
If `all` and the file is a module file, import all public predicates. Otherwise import only the named predicates. Each predicate is referred to as `⟨name⟩/⟨arity⟩`. This option has no effect if the file is not a module file.

#### silent(Bool)
If `true`, load the file without printing a message. The specified value is the default for all files loaded as a result of loading the specified files.

#### autoload(Bool)
If `true` (default `false`), indicate this load is a demand load. This implies that, depending on the setting of the prolog-flag `verbose_autoload` the load-action is printed at level informational or silent. See also `print_message/2` and `current_prolog_flag/2`.

#### qcompile(Bool)
If this call appears in a directive of a file that is compiled into Quick Load Format using `qcompile/1` and this flag is `true`, the contents of the argument files are included in the `.qlf` file instead of the loading directive.

---

\(^2\)It does work for normal loading, but not for `qcompile/1`. 
consult(+File)
Read File as a Prolog source file. File may be a list of files, in which case all members are consulted in turn. File may start with the csh(1) special sequences `~', ⟨user⟩ and $⟨var⟩. File may also be library(Name), in which case the libraries are searched for a file with the specified name. See also library_directory/1 and file_search_path/2. consult/1 may be abbreviated by just typing a number of file names in a list. Examples:

?- consult(load).        % consult load or load.pl
?- [library(quintus)].   % load Quintus compatibility library

Equivalent to load_files(Files, []).

ensure_loaded(+File)
If the file is not already loaded, this is equivalent to consult/1. Otherwise, if the file defines a module, import all public predicates. Finally, if the file is already loaded, is not a module file and the context module is not the global user module, ensure_loaded/1 will call consult/1.

With the semantics, we hope to get as closely possible to the clear semantics without the presence of a module system. Applications using modules should consider using use_module/[1,2].

Equivalent to load_files(Files, [if(changed)]).

include(+File)
Pretend the terms in File are in the source-file in which :- include(File) appears. The include construct is only honoured if it appears as a directive in a source-file. Normally File contains a sequence of directives.

require(+ListofNameAndArity)
declare that this file/module requires the specified predicates to be defined “with their commonly accepted definition”. This predicate originates from the Prolog portability layer for XPCE. It is intended to provide a portable mechanism for specifying that this module requires the specified predicates.

The implementation normally first verifies whether the predicate is already defined. If not, it will search the libraries and load the required library.

SWI-Prolog, having autoloading, does not load the library. Instead it creates a procedure header for the predicate if it does not exist. This will flag the predicate as ‘undefined’. See also check/0 and autoload/0.

make
Consult all source files that have been changed since they were consulted. It checks all loaded source files: files loaded into a compiled state using pl -c ... and files loaded using consult or one of its derivatives. The predicate make/0 is called after edit/1, automatically reloading all modified files. If the user uses an external editor (in a separate window), make/0 is normally used to update the program after editing.

library_directory(?Atom)
Dynamic predicate used to specify library directories. Default ./lib, `~/lib/prolog and the system’s library (in this order) are defined. The user may add library directories using assert/1, asserta/1 or remove system defaults using retract/1.
4.3. LOADING PROLOG SOURCE FILES

file_search_path(+Alias, ?Path)
Dynamic predicate used to specify ‘path-aliases’. This feature is best described using an example. Given the definition

\[
\text{file_search_path(demo, '/usr/lib/prolog/demo')}
\]

the file specification \text{demo(myfile)} will be expanded to \text{/usr/lib/prolog/demo/myfile}. The second argument of \text{file_search_path/2} may be another alias.

Below is the initial definition of the file search path. This path implies \text{swi((Path))} refers to a file in the SWI-Prolog home directory. The alias \text{foreign((Path))} is intended for storing shared libraries (.so or .DLL files). See also \text{load_foreign_library/[1,2]}.

\[
\begin{align*}
\text{user:file_search_path(library, X) :-} \\
&\quad \text{library_directory(X).} \\
\text{user:file_search_path(swi, Home) :-} \\
&\quad \text{current_prolog_flag(home, Home).} \\
\text{user:file_search_path(foreign, swi(ArchLib)) :-} \\
&\quad \text{current_prolog_flag(arch, Arch),} \\
&\quad \text{atom_concat('lib/', Arch, ArchLib).} \\
\text{user:file_search_path(foreign, swi(lib)).}
\end{align*}
\]

The file_search_path/2 expansion is used by all loading predicates as well as by \text{absolute_file_name/[2,3]}.

The prolog-flag \text{verbose_file_search} can be set to \text{true} to help debugging Prolog’s search for files.

expand_file_search_path(+Spec, -Path)
Unifies \text{Path} with all possible expansions of the file name specification \text{Spec}. See also \text{absolute_file_name/3}.

prolog_file_type(?Extension, ?Type)
This dynamic multifile predicate defined in module user determines the extensions considered by file_search_path/2. \text{Extension} is the filename extension without the leading dot, \text{Type} denotes the type as used by the \text{file_type(Type)} option of file_search_path/2. Here is the initial definition of prolog_file_type/2:

\[
\begin{align*}
\text{user:prolog_file_type(pl, prolog).} \\
\text{user:prolog_file_type(Ext, prolog) :-} \\
&\quad \text{current_prolog_flag(associate, Ext),} \\
&\quad \text{Ext \text{== pl}.} \\
\text{user:prolog_file_type(qlf, qlf).} \\
\text{user:prolog_file_type(Ext, executable) :-} \\
&\quad \text{current_prolog_flag(shared_object_extension, Ext).}
\end{align*}
\]

Users may wish to change the extension used for Prolog source files to avoid conflicts (for example with \text{perl}) as well as to be compatible with some specific implementation. The preferred alternative extension is .pro.
source_file(?File)
Succeeds if File is a loaded Prolog source file. File is the absolute and canonical path to the source-file.

source_file(?Pred, ?File)
Is true if the predicate specified by Pred was loaded from file File, where File is an absolute path name (see absolute_file_name/2). Can be used with any instantiation pattern, but the database only maintains the source file for each predicate. See also clause_property/2.

prolog_load_context(?Key, ?Value)
Determine loading context. The following keys are defined:

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>module</td>
<td>Module into which file is loaded</td>
</tr>
<tr>
<td>file</td>
<td>File loaded</td>
</tr>
<tr>
<td>stream</td>
<td>Stream identifier (see current_input/1)</td>
</tr>
<tr>
<td>directory</td>
<td>Directory in which File lives.</td>
</tr>
<tr>
<td>term_position</td>
<td>Position of last term read. Term of the form</td>
</tr>
<tr>
<td></td>
<td>'$stream_position' (0, ⟨Line⟩, 0, 0, 0)</td>
</tr>
</tbody>
</table>

Quintus compatibility predicate. See also source_location/2.

source_location(-File, -Line)
If the last term has been read from a physical file (i.e., not from the file user or a string), unify File with an absolute path to the file and Line with the line-number in the file. New code should use prolog_load_context/2.

term_expansion(+Term1, -Term2)
Dynamic predicate, normally not defined. When defined by the user all terms read during consulting that are given to this predicate. If the predicate succeeds Prolog will assert Term2 in the database rather than the read term (Term1). Term2 may be a term of the form ‘?- Goal’ or ‘:- Goal’. Goal is then treated as a directive. If Term2 is a list all terms of the list are stored in the database or called (for directives). If Term2 is of the form below, the system will assert Clause and record the indicated source-location with it.

    '$source_location'(⟨File⟩, ⟨Line⟩):⟨Clause⟩

When compiling a module (see chapter 5 and the directive module/2), expand_term/2 will first try term_expansion/2 in the module being compiled to allow for term-expansion rules that are local to a module. If there is no local definition, or the local definition fails to translate the term, expand_term/2 will try term_expansion/2 in module user. For compatibility with SICStus and Quintus Prolog, this feature should not be used. See also expand_term/2, goal_expansion/2 and expand_goal/2.

expand_term(+Term1, -Term2)
This predicate is normally called by the compiler to perform preprocessing. First it calls term_expansion/2. If this predicate fails it performs a grammar-rule translation. If this fails it returns the first argument.
4.3. LOADING PROLOG SOURCE FILES

**goal_expansion(+Goal1, -Goal2)**

Like `term_expansion/2`, `goal_expansion/2` provides for macro-expansion of Prolog source-code. Between `expand_term/2` and the actual compilation, the body of clauses analysed and the goals are handed to `expand_goal/2`, which uses the `goal_expansion/2` hook to do user-defined expansion.

The predicate `goal_expansion/2` is first called in the module that is being compiled, and then on the user module.

Only goals appearing in the body of clauses when reading a source-file are expanded using mechanism, and only if they appear literally in the clause, or as an argument to the meta-predicates `not/1`, `call/1` or `forall/2`. A real predicate definition is required to deal with dynamically constructed calls.

**expand_goal(+Goal1, -Goal2)**

This predicate is normally called by the compiler to perform preprocessing. First it calls `goal_expansion/2`. If this fails it returns the first argument.

**at_initialization(+Goal)**

Register `Goal` to be run when the system initialises. Initialisation takes place after reloading a `.qlf` (formerly `.wic`) file as well as after reloading a saved-state. The hooks are run in the order they were registered. A warning message is issued if `Goal` fails, but execution continues. See also `at_halt/1`.

**at_halt(+Goal)**

Register `Goal` to be run when the system halts. The hooks are run in the order they were registered. Success or failure executing a hook is ignored. These hooks may not call `halt/[0,1]`.

**initialization(+Goal)**

Call `Goal` and register it using `at_initialization/1`. Directives that do other things than creating clauses, records, flags or setting predicate attributes should normally be written using this tag to ensure the initialisation is executed when a saved system starts. See also `qsave_program/[1,2]`.

**compiling**

Succeeds if the system is compiling source files with the `-c` option or `qcompile/1` into an intermediate code file. Can be used to perform conditional code optimisations in `term_expansion/2` (see also the `-O` option) or to omit execution of directives during compilation.

**preprocessor(-Old, +New)**

Read the input file via a Unix process that acts as preprocessor. A preprocessor is specified as an atom. The first occurrence of the string `%f` is replaced by the name of the file to be loaded. The resulting atom is called as a Unix command and the standard output of this command is loaded. To use the Unix C preprocessor one should define:

```prolog
?- preprocessor(Old, '/lib/cpp -C -P %f'), consult(...).
```

```prolog
Old = none
```
4.3.1 Quick load files

SWI-Prolog supports compilation of individual or multiple Prolog source files into ‘Quick Load Files’. A ‘Quick Load Files’ (.qlf file) stores the contents of the file in a precompiled format.

These files load considerably faster than source files and are normally more compact. They are machine independent and may thus be loaded on any implementation of SWI-Prolog. Note however that clauses are stored as virtual machine instructions. Changes to the compiler will generally make old compiled files unusable.

Quick Load Files are created using qcompile/1. They are loaded using consult/1 or one of the other file-loading predicates described in section 4.3. If consult is given the explicit .pl file, it will load the Prolog source. When given the .qlf file, it will load the file. When no extension is specified, it will load the .qlf file when present and the .pl file otherwise.

qcompile(+File)
 Takes a single file specification like consult/1 (i.e., accepts constructs like library(LibFile) and creates a Quick Load File from File. The file-extension of this file is .qlf. The base name of the Quick Load File is the same as the input file.

If the file contains ‘:- consult(+File)’, ‘:- [+File]’ or :- load_files(+File, [qcompile(true), ...]) statements, the referred files are compiled into the same .qlf file. Other directives will be stored in the .qlf file and executed in the same fashion as when loading the .pl file.

For term_expansion/2, the same rules as described in section 2.10 apply.

Conditional execution or optimisation may test the predicate compiling/0.

Source references (source_file/2) in the Quick Load File refer to the Prolog source file from which the compiled code originates.

4.4 Listing and Editor Interface

SWI-Prolog offers an extensible interface which allows the user to edit objects of the program: predicates, modules, files, etc. The editor interface is implemented by edit/1 and consists of three parts: locating, selecting and starting the editor.

Any of these parts may be extended or redefined by adding clauses to various multi-file (see multifile/1) predicates defined in the module prolog_edit.

The built-in edit specifications for edit/1 (see prolog_edit:locate/3) are described below.

<table>
<thead>
<tr>
<th>Fully specified objects</th>
<th>Ambiguous specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>⟨Module⟩⟨Name⟩⟨Arity⟩</td>
<td>Refers this predicate in any module</td>
</tr>
<tr>
<td>module(Module)</td>
<td>Refers to a module</td>
</tr>
<tr>
<td>file(Path)</td>
<td>Refers to a file</td>
</tr>
<tr>
<td>source_file(Path)</td>
<td>Refers to a loaded source-file</td>
</tr>
<tr>
<td>⟨Name⟩⟨Arity⟩</td>
<td>Refers to (1) named predicate in any module with any arity, (2) a (source) file or (3) a module.</td>
</tr>
<tr>
<td>⟨Name⟩</td>
<td></td>
</tr>
</tbody>
</table>
4.4. LISTING AND EDITOR INTERFACE

edit(+Specification)
First exploits prolog_edit:locate/3 to translate Specification into a list of Locations. If there is more than one ‘hit’, the user is allowed to select from the found locations. Finally, prolog_edit:edit_source/1 is used to invoke the user’s preferred editor.

prolog_edit:locate(+Spec, -FullSpec, -Location)
Where Spec is the specification provided through edit/1. This multi-file predicate is used to enumerate locations at with an object satisfying the given Spec can be found. FullSpec is unified with the complete specification for the object. This distinction is used to allow for ambiguous specifications. For example, if Spec is an atom, which appears as the base-name of a loaded file and as the name of a predicate, FullSpec will be bound to file(Path) or Name/Arity.

Location is a list of attributes of the location. Normally, this list will contain the term file(File) and —if available— the term line(Line).

prolog_edit:locate(+Spec, -Location)
Same as prolog_edit:locate/3, but only deals with fully-specified objects.

prolog_edit:edit_source(+Location)
Start editor on Location. See prolog_edit:locate/3 for the format of a location term. This multi-file predicate is normally not defined. If it succeeds, edit/1 assumes the editor is started.

If it fails, edit/1 will invoke an external editor. The editor to be invoked is determined from the environment variable EDITOR, which may be set from the operating system or from the Prolog initialisation file using setenv/2. If no editor is defined, vi is the default in Unix systems, and notepad on Windows.

The predicate prolog_edit:edit_command/2 defines how the editor will be invoked.

prolog_edit:edit_command(+Editor, -Command)
Determines how Editor is to be invoked using shell/1. Editor is the determined editor (see edit_source/1), without the full path specification, and without possible (exe) extension. Command is an atom describing the command. The pattern %f is replaced by the full file-name of the location, and %d by the line number. If the editor can deal with starting at a specified line, two clauses should be provided, one holding only the %f pattern, and one holding both patterns.

The default contains definitions for vi, emacs, emacsclient, vim and notepad (latter without line-number version).

Please contribute your specifications to jan@swi.psy.uva.nl.

prolog_edit:load
Normally not-defined multi-file predicate. This predicate may be defined to provide loading hooks for user-extensions to the edit module. For example, XPCE provides the code below to load library(swi_edit), containing definitions to locate classes and methods as well as to bind this package to the PceEmacs built-in editor.

:- multifile prolog_edit:load/0.

prolog_edit:load :-
    ensure_loaded(library(swi_edit)).
CHAPTER 4. BUILT-IN PREDICATES

listing(+Pred)
List specified predicates (when an atom is given all predicates with this name will be listed).
The listing is produced on the basis of the internal representation, thus losing user’s layout and
variable name information. See also portray_clause/1.

listing
List all predicates of the database using listing/1.

portray_clause(+Clause)
Pretty print a clause. A clause should be specified as a term ‘⟨Head⟩ :- ⟨Body⟩’. Facts are
represented as ‘⟨Head⟩ :- true’.

4.5 Verify Type of a Term

var(+Term)
Succeeds if Term currently is a free variable.

nonvar(+Term)
Succeeds if Term currently is not a free variable.

integer(+Term)
Succeeds if Term is bound to an integer.

float(+Term)
Succeeds if Term is bound to a floating point number.

number(+Term)
Succeeds if Term is bound to an integer or a floating point number.

atom(+Term)
Succeeds if Term is bound to an atom.

string(+Term)
Succeeds if Term is bound to a string.

atomic(+Term)
Succeeds if Term is bound to an atom, string, integer or floating point number.

compound(+Term)
Succeeds if Term is bound to a compound term. See also functor/3 and =../2.

callable(+Term)
Succeeds if Term is bound to an atom or a compound term, so it can be handed without type-
error to call/1, functor/3 and =../2.

ground(+Term)
Succeeds if Term holds no free variables.
### 4.6 Comparison and Unification of Terms

#### 4.6.1 Standard Order of Terms

Comparison and unification of arbitrary terms. Terms are ordered in the so called “standard order”. This order is defined as follows:

1. **Variables < Atoms < Strings < Numbers < Terms**
2. **Old Variable < New Variable**
3. **Atoms** are compared alphabetically.
4. **Strings** are compared alphabetically.
5. **Numbers** are compared by value. Integers and floats are treated identically.
6. **Compound** terms are first checked on their arity, then on their functor-name (alphabetically) and finally recursively on their arguments, leftmost argument first.

If the prolog_flag (see current_prolog_flag/2) iso is defined, all floating point numbers precede all integers.

\[ +\text{Term1} == +\text{Term2} \]

Succeeds if \text{Term1} is equivalent to \text{Term2}. A variable is only identical to a sharing variable.

\[ +\text{Term1} \\neq\neq +\text{Term2} \]

Equivalent to \text{\textbackslash +Term1 == Term2}.

\[ +\text{Term1} = +\text{Term2} \]

Unify \text{Term1} with \text{Term2}. Succeeds if the unification succeeds.

\texttt{unify_with_occurs_check(+\text{Term1}, +\text{Term2})}

As \texttt{=/2}, but using sound-unification. That is, a variable only unifies to a term if this term does not contain the variable itself. To illustrate this, consider the two goals below:

\[ 1 \ ?- \ A = f(A). \]

\[ A = f(f(f(f(f(f(f(f(f(f(...)))))))))) \]

\[ 2 \ ?- \ unify\_with\_occurs\_check(A, f(A)). \]

\texttt{No}

I.e. the first creates a cyclic-term, which is printed as an infinitely nested \texttt{f/1} term (see the \texttt{max_depth} option of \texttt{write\_term/2}). The second executes logically sound unification and thus fails.

---

3 Strings might be considered atoms in future versions. See also section 4.23

4 In fact the variables are compared on their (dereferenced) addresses. Variables living on the global stack are always < than variables on the local stack. Programs should not rely on the order in which variables are sorted.
\+Term1 \(\neq\) +Term2
   
   Equivalent to \(+Term1 = Term2\).

\+Term1 \(\neq\) = +Term2

Succeeds if \(Term1\) is ‘structurally equal’ to \(Term2\). Structural equivalence is weaker than equivalence (\(\equiv/2\)), but stronger than unification (\(=/2\)). Two terms are structurally equal if their tree representation is identical and they have the same ‘pattern’ of variables. Examples:

\[a \neq A \quad \text{false}\]
\[A \neq B \quad \text{true}\]
\[x(A, A) \neq x(B, C) \quad \text{false}\]
\[x(A, A) \neq x(B, B) \quad \text{true}\]
\[x(A, B) \neq x(C, D) \quad \text{true}\]

\+Term1 \(\neq\) += +Term2
   
   Equivalent to ‘\(+Term1 =\neq Term2\’.

\+Term1 \(<\) +Term2

Succeeds if \(Term1\) is before \(Term2\) in the standard order of terms.

\+Term1 \(<\) = +Term2

Succeeds if both terms are equal (\(\equiv/2\)) or \(Term1\) is before \(Term2\) in the standard order of terms.

\+Term1 \(\geq\) = +Term2

Succeeds if \(Term1\) is after \(Term2\) in the standard order of terms.

\+Term1 \(\geq\) > +Term2

Succeeds if both terms are equal (\(\equiv/2\)) or \(Term1\) is after \(Term2\) in the standard order of terms.

\texttt{compare(?Order, +Term1, +Term2)}

Determine or test the \(Order\) between two terms in the standard order of terms. \(Order\) is one of \(<, >\) or \(=\), with the obvious meaning.

### 4.7 Control Predicates

The predicates of this section implement control structures. Normally these constructs are translated into virtual machine instructions by the compiler. It is still necessary to implement these constructs as true predicates to support meta-calls, as demonstrated in the example below. The predicate finds all currently defined atoms of 1 character long. Note that the cut has no effect when called via one of these predicates (see \(!0\)).

\begin{verbatim}
one_character_atoms(As) :-
    findall(A, (current_atom(A), atom_length(A, 1)), As).
\end{verbatim}

\texttt{fail}

Always fail. The predicate \texttt{fail/0} is translated into a single virtual machine instruction.
true
Always succeed. The predicate true/0 is translated into a single virtual machine instruction.

repeat
Always succeed, provide an infinite number of choice points.

! Cut. Discard choice points of parent frame and frames created after the parent frame. As of SWI-Prolog 3.3, the semantics of the cut are compliant with the ISO standard. This implies that the cut is transparent to ;/2, −→/2 and *−→/2. Cuts appearing in the condition part of −→/2 and *−→/2 as well as in \+/1 are local to the condition.5

\[\begin{align*}
t1 & : - (a, !, fail ; b). \quad \text{% cuts a/0 and t1/0} \\
t2 & : - (a \rightarrow b, ! ; c). \quad \text{% cuts b/0 and t2/0} \\
t3 & : - call((a, !, fail ; b)). \quad \text{% cuts a/0} \\
t4 & : - \+(a, !, fail ; b). \quad \text{% cuts a/0}
\end{align*}\]

+Goal1 , +Goal2
Conjunction. Succeeds if both ‘Goal1’ and ‘Goal2’ can be proved. It is defined as (this definition does not lead to a loop as the second comma is handled by the compiler):

\[\text{Goal1, Goal2 :- Goal1, Goal2.}\]

+Goal1 ; +Goal2
The ‘or’ predicate is defined as:

\[\begin{align*}
\text{Goal1 ; _Goal2 :- Goal1.} \\
\text{_Goal1 ; Goal2 :- Goal2.}
\end{align*}\]

+Goal1 | +Goal2
Equivalent to ;/2. Retained for compatibility only. New code should use ;/2.

+Condition −→ +Action
If-then and If-Then-Else. The −→/2 construct commits to the choices made at its left-hand side, destroying choice-points created inside the clause (by ;/2), or by goals called by this clause. Unlike !/0, the choicepoint of the predicate as a whole (due to multiple clauses) is not destroyed. The combination ;/2 and −→/2 is defines as:

\[\begin{align*}
\text{If −→ Then; _Else :- If, !, Then.} \\
\text{If −→ _Then; Else :- !, Else.} \\
\text{If −→ Then :- If, !, Then.}
\end{align*}\]

Note that the operator precedence relation between ; and −→ ensure If −→ Then ; Else is actually a term of the form ;(−→(If, Then), Else). The first two clauses belong to the definition of ;/2), while only the last defines −→/2.

\^\text{Up to version 4.0.6, the sequence X=!., X acted as a true cut. This feature has been deleted for ISO compliance.\}

\[\text{SWI-Prolog 5.0 Reference Manual}\]
+Condition *-> +Action ; +Else

This construct implements the so-called ‘soft-cut’. The control is defined as follows: If Condition succeeds at least once, the semantics is the same as (Condition, Action). If Condition does not succeed, the semantics is that of (Condition, Else). In other words, If Condition succeeds at least once, simply behave as the conjunction of Condition and Action, otherwise execute Else.

\+ +Goal

Succeeds if ‘Goal’ cannot be proven (mnemonic: + refers to provable and the backslash (\) is normally used to indicate negation).

4.8 Meta-Call Predicates

Meta call predicates are used to call terms constructed at run time. The basic meta-call mechanism offered by SWI-Prolog is to use variables as a subclause (which should of course be bound to a valid goal at runtime). A meta-call is slower than a normal call as it involves actually searching the database at runtime for the predicate, while for normal calls this search is done at compile time.

call(+Goal)

Invoke Goal as a goal. Note that clauses may have variables as subclauses, which is identical to call/1, except when the argument is bound to the cut. See !/0.

call(+Goal, +ExtraArg1, . . .)

Append ExtraArg1, ExtraArg2, . . . to the argument list of Goal and call the result. For example, call(plus(1), 2, X) will call plus/3, binding X to 3.

The call/[2..] construct is handled by the compiler, which implies that redefinition as a predicate has no effect. The predicates call/[2–6] are defined as true predicates, so they can be handled by interpreted code.

apply(+Term, +List)

Append the members of List to the arguments of Term and call the resulting term. For example: apply(plus(1), [2, X]) will call plus(1, 2, X). apply/2 is incorporated in the virtual machine of SWI-Prolog. This implies that the overhead can be compared to the overhead of call/1. New code should use call/[2..] if the length of List is fixed, which is more widely supported and faster because there is no need to build and examine the argument list.

not(+Goal)

Succeeds when Goal cannot be proven. Retained for compatibility only. New code should use \+/1.

once(+Goal)

Defined as:

\n once(Goal) :-
   Goal, !.

\n once/1 can in many cases be replaced with \->/2. The only difference is how the cut behaves (see !/0). The following two clauses are identical:
1) a :- once((b, c)), d.
2) a :- b, c -> d.

ignore(+Goal)

Calls Goal as once/1, but succeeds, regardless of whether Goal succeeded or not. Defined as:

    ignore(Goal) :-
        Goal, !.
    ignore(_).

call_with_depth_limit(+Goal, +Limit, -Result)

If Goal can be proven without recursion deeper than Limit levels, call_with_depth_limit/3 succeeds, binding Result to the deepest recursion level used during the proof. Otherwise, Result is unified with depth_limit_exceeded if the limit was exceeded during the proof, or the entire predicate fails if Goal fails without exceeding Limit.

The depth-limit is guarded by the internal machinery. This may differ from the depth computed based on a theoretical model. For example, true/0 is translated into an inlined virtual machine instruction. Also, repeat/0 is not implemented as below, but as a non-deterministic foreign predicate.

    repeat.
    repeat :-
        repeat.

As a result, call_with_depth_limit/3 may still loop infitely on programs that should theoretically finish in finite time. This problem can be cured by using Prolog equivalents to such built-in predicates.

This predicate may be used for theorem-provers to realise techniques like iterative deepening. It was implemented after discussion with Steve Moyle smoyle@ermine.ox.ac.uk.

call_cleanup(:Goal, +Catcher, :Cleanup)

Calls Goal. If Goal is completely finished, either by deterministic success, failure, its choice-point being cut or raising an exception and Catcher unifies to the termination code (see below), Cleanup is called. Success or failure of Cleanup is ignored and possibly choicepoints it created are destroyed (as once/1). If cleanup throws an exception this is executed as normal.

Catcher is unified with a term describing how the call has finished. If this unification fails, Cleanup is not called.

    exit
        Goal succeeded without leaving any choicepoints.

    fail
        Goal failed.
!  

Goal succeeded with choicepoints and these are now discarded by the execution of a cut (or other pruning of the search tree such as if-then-else).

**exception(Exception)**

Goal raised the given Exception.

Typical use of this predicate is cleanup of permanent data storage required to execute Goal, close file-descriptors, etc. The example below provides a non-deterministic search for a term in a file, closing the stream as needed.

```prolog
term_in_file(Term, File) :-
    open(File, read, In),
    call_cleanup(term_in_stream(Term, In), _, close(In)).

term_in_stream(Term, In) :-
    repeat,
    read(In, T),
    ( T == end_of_file
      -> !, fail
    ;   T = Term
    ).
```

Note that this predicate is impossible to implement in Prolog other then reading all terms into a list, close the file and call member/2 because without call_cleanup/3 there is no way to gain control if the choicepoint left by repeat is killed by a cut.

This predicate is a SWI-Prolog extension. See also call_cleanup/2 for compatibility to other Prolog implementations.

**call_cleanup(:Goal, :Cleanup)**

This predicate is equivalent to call_cleanup(Goal, _, Cleanup), calling Cleanup regardless of the reason for termination and without providing information. This predicate provides compatibility to a number of other Prolog implementations.

### 4.9 ISO compliant Exception handling

SWI-Prolog defines the predicates catch/3 and throw/1 for ISO compliant raising and catching of exceptions. In the current implementation (4.0.6), most of the built-in predicates generate exceptions, but some obscure predicates merely print a message, start the debugger and fail, which was the normal behaviour before the introduction of exceptions.

**catch(:Goal, +Catcher, :Recover)**

Behaves as call/1 if no exception is raised when executing Goal. If a exception is raised using throw/1 while Goal executes, and the Goal is the innermost goal for which Catcher unifies with the argument of throw/1, all choicepoints generated by Goal are cut, the system backtracks to the start of catch/3 while preserving the thrown exception term and Recover is called as in call/1.
The overhead of calling a goal through `catch/3` is very comparable to `call/1`. Recovery from an exception is much slower, especially if the exception-term is large due to the copying thereof.

**throw(+Exception)**

Raise an exception. The system looks for the innermost `catch/3` ancestor for which `Exception` unifies with the `Catcher` argument of the `catch/3` call. See `catch/3` for details.

ISO demands `throw/1` to make a copy of `Exception`, walk up the stack to a `catch/3` call, backtrack and try to unify the copy of `Exception` with `Catcher`. SWI-Prolog delays making a copy of `Exception` and backtracking until it actually found a matching `catch/3` goal. The advantage is that we can start the debugger at the first possible location while preserving the entire exception context if there is no matching `catch/3` goal. This approach can lead to different behaviour if `Goal` and `Catcher` of `catch/3` call share variables. We assume this to be highly unlikely and could not think of a scenario where this is useful.\(^6\)

If an exception is raised in a callback from C (see chapter 6) and not caught in the same call-back, `PL_next_solution()` fails and the exception context can be retrieved using `PL_exception()`.

### 4.9.1 Debugging and exceptions

Before the introduction of exceptions in SWI-Prolog a runtime error was handled by printing an error message, after which the predicate failed. If the `prolog_flag` (see `current_prolog_flag/2`) `debug_on_error` was in effect (default), the tracer was switched on. The combination of the error message and trace information is generally sufficient to locate the error.

With exception handling, things are different. A programmer may wish to trap an exception using `catch/3` to avoid it reaching the user. If the exception is not handled by user-code, the interactive toplevel will trap it to prevent termination.

If we do not take special precautions, the context information associated with an unexpected exception (i.e, a programming error) is lost. Therefore, if an exception is raised, which is not caught using `catch/3` and the toplevel is running, the error will be printed, and the system will enter trace mode.

If the system is in an non-interactive callback from foreign code and there is no `catch/3` active in the current context, it cannot determine whether or not the exception will be caught by the external routine calling Prolog. It will then base its behaviour on the `prolog_flag debug_on_error`:

- `current_prolog_flag(debug_on_error, false)`  
  The exception does not trap the debugger and is returned to the foreign routine calling Prolog, where it can be accessed using `PL_exception()`. This is the default.

- `current_prolog_flag(debug_on_error, true)`  
  If the exception is not caught by Prolog in the current context, it will trap the tracer to help analysing the context of the error.

While looking for the context in which an exception takes place, it is advised to switch on debug mode using the predicate `debug/0`.\(^6\)  

---

\(^6\) I’d like to acknowledge Bart Demoen for his clarifications on these matters.
4.9.2 The exception term

Built-in predicates generates exceptions using a term `error(Formal, Context)`. The first argument is the ‘formal’ description of the error, specifying the class and generic defined context information. When applicable, the ISO error-term definition is used. The second part describes some additional context to help the programmer while debugging. In its most generic form this is a term of the form `context(Name/Arity, Message)`, where `Name/Arity` describes the built-in predicate that raised the error, and `Message` provides an additional description of the error. Any part of this structure may be a variable if no information was present.

4.9.3 Printing messages

The predicate `print_message/2` may be used to print a message term in a human readable format. The other predicates from this section allow the user to refine and extend the message system. The most common usage of `print_message/2` is to print error messages from exceptions. The code below prints errors encountered during the execution of `Goal`, without further propagating the exception and without starting the debugger.

```prolog
..., catch(Goal, E, ( print_message(error, E), fail ) ), ...
```

Another common use is to defined `message_hook/3` for printing messages that are normally `silent`, suppressing messages, redirecting messages or make something happen in addition to printing the message.

**print_message(+Kind, +Term)**

The predicate `print_message/2` is used to print messages, notably from exceptions in a human-readable format. `Kind` is one of informational, banner, warning, error, help or silent. A human-readable message is printed to the stream `user_error`.

If the prolog flag (see `current_prolog_flag/2`) `verbose` is `silent`, messages with `Kind` informational, or banner are treated as silent. See `-q`.

This predicate first translates the `Term` into a list of ‘message lines’ (see `print_message_lines/3` for details). Next it will call the hook `message_hook/3` to allow the user intercepting the message. If `message_hook/3` fails it will print the message unless `Kind` is silent.

The `print_message/2` predicate and its rules are in the file `<plhome>/boot/messages.pl`, which may be inspected for more information on the error messages and related error terms.

See also `message_to_string/2`.

**print_message_lines(+Stream, +Prefix, +Lines)**

Print a message (see `print_message/2`) that has been translated to a list of message elements. The elements of this list are:
4.10. HANDLING SIGNALS

\{Format\}-\{Args\}

Where Format is an atom and Args is a list of format argument. Handed to \texttt{format/3}.

\texttt{flush}

If this appears as the last element, Stream is flushed (see \texttt{flush_output/1}) and no final newline is generated.

\texttt{at_same_line}

If this appears as first element, no prefix is printed for the first line and the line-position is not forced to 0 (see \texttt{format/1, ~N}).

\{Format\}

Handed to \texttt{format/3} as \texttt{format(Stream, Format, [])}.

\texttt{nl}

A new line is started and if the message is not complete the Prefix is printed too.

See also \texttt{print_message/2} and \texttt{message\_hook/3}.

\texttt{message\_hook(+Term, +Kind, +Lines)}

Hook predicate that may be define in the module \texttt{user} to intercept messages from \texttt{print_message/2}. \texttt{Term} and \texttt{Kind} are the same as passed to \texttt{print_message/2}. \texttt{Lines} is a list of format statements as described with \texttt{print_message_lines/3}. See also \texttt{message\_to\_string/2}.

This predicate should be defined dynamic and multifile to allow other modules defining clauses for it too.

\texttt{message\_to\_string(+Term, -String)}

Translates a message-term into a string object (see section 4.23. Primarily intended to write messages to Windows in XPCE (see section 1.5) or other GUI environments.

4.10 Handling signals

As of version 3.1.0, SWI-Prolog is capable to handle software interrupts (signals) in Prolog as well as in foreign (C) code (see section 6.6.12).

Signals are used to handle internal errors (execution of a non-existing CPU instruction, arithmetic domain errors, illegal memory access, resource overflow, etc.), as well as for dealing asynchronous inter-process communication.

Signals are defined by the Posix standard and part of all Unix machines. The MS-Windows Win32 provides a subset of the signal handling routines, lacking the vital functionality to raise a signal in another thread for achieving asynchronous inter-process (or inter-thread) communication (Unix \texttt{kill()} function).

\texttt{on\_signal(+Signal, -Old, :New)}

Determines the reaction on Signal. Old is unified with the old behaviour, while the behaviour is switched to New. As with similar environment-control predicates, the current value is retrieved using \texttt{on\_signal(Signal, Current, Current)}.

The action description is an atom denoting the name of the predicate that will be called if Signal arrives. \texttt{on\_signal/3} is a meta predicate, which implies that \texttt{\langle Module\rangle:\langle Name\rangle} refers the \texttt{\langle Name\rangle/1} in the module \texttt{\langle Module\rangle}. 
Two predicate-names have special meaning. `throw` implies Prolog will map the signal onto a Prolog exception as described in section 4.9. `default` resets the handler to the settings active before SWI-Prolog manipulated the handler.

Signals bound to a foreign function through `PL_signal()` are reported using the term $foreign\_function(Address)$.

After receiving a signal mapped to `throw`, the exception raised has the structure

\[
\text{error(signal}((\text{SigName}), (\text{SigNum})), (\text{Context}))
\]

One possible usage of this is, for example, to limit the time spent on proving a goal. This requires a little C-code for setting the alarm timer (see chapter 6):

```c
#include <SWI-Prolog.h>
#include <unistd.h>

foreign_t
pl_alarm(term_t time)
{
  double t;

  if ( PL_get_float(time, &t) )
  {
    alarm((long)(t+0.5));
    PL_succeed;
  }

  PL_fail;
}

install_t
install()
{
  PL_register_foreign("alarm", 1, pl_alarm, 0);
}
```

Next, we can define the following Prolog code:

\begin{verbatim}
:- load_foreign_library(alarm).
:- on_signal(alrm, throw).
:- module_transparent
    call_with_time_limit/2.

call_with_time_limit(Goal, MaxTime) :-
  alarm(MaxTime),
  catch(Goal, error(signal(alrm, _), _, fail), !,
\end{verbatim}
4.11. THE ‘BLOCK’ CONTROL-STRUCTURE

4.11.1 Notes on signal handling

Before deciding to deal with signals in your application, please consider the following:

- **Portibility**
  On MS-Windows, the signal interface is severely limited. Different Unix brands support different sets of signals, and the relation between signal name and number may vary.

- **Safety**
  Signal handling is not completely safe in the current implementation, especially if `throw` is used in combination with external foreign code. The system will use the C `longjmp()` construct to direct control to the innermost `PL_next_solution()`, thus forcing an external procedure to be abandoned at an arbitrary moment. Most likely not all SWI-Prologs own foreign code is (yet) safe too.

- **Garbage Collection**
  The garbage collector will block all signals that are handled by Prolog. While handling a signal, the garbage-collector is disabled.

- **Time of delivery**
  Normally delivery is immediate (or as defined by the operating system used). Signals are blocked when the garbage collector is active, and internally delayed if they occur within in a ‘critical section’. The critical sections are generally very short.

4.11 The ‘block’ control-structure

The `block/3` predicate and friends have been introduced before ISO compatible `catch/3` exception handling for compatibility with some Prolog implementation. The only feature not covered by `catch/3` and `throw/1` is the possibility to execute global cuts. New code should use `catch/3` and `throw/1` to deal with exceptions.

```prolog
alarm(0).
call_with_time_limit(_, _) :-
  alarm(0),
  fail.
```

The signal names are defined by the C-Posix standards as symbols of the form `SIG_{SIGNAME}`. The Prolog name for a signal is the lowercase version of `{SIGNAME}`. The predicate `current_signal/3` may be used to map between names and signals.

Initially, some signals are mapped to `throw`, while all other signals are `default`. The following signals throw an exception: `ill`, `fpe`, `segv`, `pipe`, `alm`, `bus`, `xcpu`, `xfsz` and `vtalrm`.

`current_signal(?Name, ?Id, ?Handler)`

Enumerate the currently defined signal handling. `Name` is the signal name, `Id` is the numerical identifier and `Handler` is the currently defined handler (see `on_signal/3`).
**block (+Label, +Goal, -ExitValue)**

Execute Goal in a block. Label is the name of the block. Label is normally an atom, but the system imposes no type constraints and may even be a variable. ExitValue is normally unified to the second argument of an exit/2 call invoked by Goal.

**exit (+Label, +Value)**

Calling exit/2 makes the innermost block which Label unifies exit. The block’s ExitValue is unified with Value. If this unification fails the block fails.

**fail (+Label)**

Calling fail/1 makes the innermost block which Label unifies fail immediately. Implemented as

```prolog
fail(Label) :- !(Label), fail.
```

**( +Label)**

Cut all choice-points created since the entry of the innermost block which Label unifies.

### 4.12 DCG Grammar rules

Grammar rules form a comfortable interface to difference-lists. They are designed both to support writing parsers that build a parse-tree from a list as for generating a flat list from a term. Unfortunately, Definite Clause Grammar (DCG) handling is not part of the Prolog standard. Most Prolog engines implement DCG, but the details differ slightly.

Grammar rules look like ordinary clauses using -->/2 for separating the head and body rather then :-/2. Expanding grammar rules is done by expand_term/2, which adds two additional argument to each term for representing the difference list. We will illustrate the behaviour by defining a rule-set for parsing an integer.

```prolog
integer(I) -->
    digit(D0),
    digits(D),
    { number_chars(I, [D0|D]) }
.

digits([D|T]) -->
    digit(D), !,
    digits(T).

digits([]) -->
    [].

digit(D) -->
    [D],
    { code_type(D, digit) }
.
```

---

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4.13. DATABASE

The body of a grammar rule can contain three types of terms. A compound term interpreted as a reference to a grammar-rule. Code between {...} is interpreted as a reference to ordinary Prolog code and finally, a list is interpreted as a sequence of literals. The Prolog control-constructs (\+/1, ->/2, ;//2, ,/2 and !/0) can be used in grammar rules.

Grammar rule-sets are called using the builtin predicates phrase/2 and phrase/3:

\[\text{phrase}(+\text{RuleSet}, +\text{InputList})\]
Equivalent to phrase(RuleSet, InputList, []).

\[\text{phrase}(+\text{RuleSet}, +\text{InputList}, -\text{Rest})\]
Activate the rule-set with given name. ‘InputList’ is the list of tokens to parse, ‘Rest’ is unified with the remaining tokens if the sentence is parsed correctly. The example below calls the rule-set ‘integer’ defined above.

?- phrase(integer(X), "42 times", Rest).
\[X = 42\]
\[\text{Rest} = \{32, 116, 105, 109, 101, 115\}\]

4.13 Database

SWI-Prolog offers three different database mechanisms. The first one is the common assert/retract mechanism for manipulating the clause database. As facts and clauses asserted using assert/1 or one of its derivatives become part of the program these predicates compile the term given to them. retract/1 and retractall/1 have to unify a term and therefore have to decompile the program. For these reasons the assert/retract mechanism is expensive. On the other hand, once compiled, queries to the database are faster than querying the recorded database discussed below. See also dynamic/1.

The second way of storing arbitrary terms in the database is using the “recorded database”. In this database terms are associated with a key. A key can be an atom, integer or term. In the last case only the functor and arity determine the key. Each key has a chain of terms associated with it. New terms can be added either at the head or at the tail of this chain. This mechanism is considerably faster than the assert/retract mechanism as terms are not compiled, but just copied into the heap.

The third mechanism is a special purpose one. It associates an integer or atom with a key, which is an atom, integer or term. Each key can only have one atom or integer associated with it. It is faster than the mechanisms described above, but can only be used to store simple status information like counters, etc.

\[\text{abolish}(\text{PredicateIndicator})\]
Removes all clauses of a predicate with functor Functo and arity Arity from the database. All predicate attributes (dynamic, multifile, index, etc.) are reset to their defaults. Abolishing an imported predicate only removes the import link; the predicate will keep its old definition in its definition module.

According to the ISO standard, abolish/1 can only be applied to dynamic procedures. This is odd, as for dealing with dynamic procedures there is already retract/1 and
retractall/1. The abolish/1 predicate has been introduced in DEC-10 Prolog precisely for dealing with static procedures. In SWI-Prolog, abolish/1 works on static procedures, unless the prolog flag iso is set to true.

It is advised to use retractall/1 for erasing all clauses of a dynamic predicate.

abolish(+Name, +Arity)
Same as abolish(Name/Arity). The predicate abolish/2 conforms to the Edinburgh standard, while abolish/1 is ISO compliant.

redefine_system_predicate(+Head)
This directive may be used both in module user and in normal modules to redefine any system predicate. If the system definition is redefined in module user, the new definition is the default definition for all sub-modules. Otherwise the redefinition is local to the module. The system definition remains in the module system.

Redefining system predicate facilitates the definition of compatibility packages. Use in other context is discouraged.

retract(+Term)
When Term is an atom or a term it is unified with the first unifying fact or clause in the database. The fact or clause is removed from the database.

retractall(+Head)
All facts or clauses in the database for which the head unifies with Head are removed.

assert(+Term)
Assert a fact or clause in the database. Term is asserted as the last fact or clause of the corresponding predicate.

asserta(+Term)
Equivalent to assert/1, but Term is asserted as first clause or fact of the predicate.

assertz(+Term)
Equivalent to assert/1.

assert(+Term, -Reference)
Equivalent to assert/1, but Reference is unified with a unique reference to the asserted clause. This key can later be used with clause/3 or erase/1.

asserta(+Term, -Reference)
Equivalent to assert/2, but Term is asserted as first clause or fact of the predicate.

assertz(+Term, -Reference)
Equivalent to assert/2.

recorda(+Key, +Term, -Reference)
Assert Term in the recorded database under key Key. Key is an integer, atom or term. Reference is unified with a unique reference to the record (see erase/1).

recorda(+Key, +Term)
Equivalent to recorda(Key, Value, _).
recordz(+Key, +Term, -Reference)
Equivalent to recorda/3, but puts the Term at the tail of the terms recorded under Key.

recordz(+Key, +Term)
Equivalent to recordz(Key, Value, _).

recorded(+Key, -Value, -Reference)
Unify Value with the first term recorded under Key which does unify. Reference is unified with the memory location of the record.

recorded(+Key, -Value)
Equivalent to recorded(Key, Value, _).

erase(+Reference)
Erase a record or clause from the database. Reference is an integer returned by recorda/3 or recorded/3, clause/3, assert/2, asserta/2 or assertz/2. Other integers might conflict with the internal consistency of the system. Erase can only be called once on a record or clause. A second call also might conflict with the internal consistency of the system.

flag(+Key, -Old, +New)
Key is an atom, integer or term. Unify Old with the old value associated with Key. If the key is used for the first time Old is unified with the integer 0. Then store the value of New, which should be an integer, float, atom or arithmetic expression, under Key. flag/3 is a very fast mechanism for storing simple facts in the database. Example:

```prolog
:- module_transparent succeeds_n_times/2.

succeeds_n_times(Goal, Times) :-
    (   flag(succeeds_n_times, Old, 0),
        Goal,
        flag(succeeds_n_times, N, N+1),
        fail
    ;   flag(succeeds_n_times, Times, Old)
    ).
```

### 4.13.1 Update view

Traditionally, Prolog systems used the *immediate update view*: new clauses became visible to predicates backtracking over dynamic predicates immediately and retracted clauses became invisible immediately.

Starting with SWI-Prolog 3.3.0 we adhere the *logical update view*, where backtrackable predicates that enter the definition of a predicate will not see any changes (either caused by assert/1 or retract/1) to the predicate. This view is the ISO standard, the most commonly used and the most ‘safe’. Logical updates are realised by keeping reference-counts on predicates and generation information on clauses. Each change to the database causes an increment of the generation of the

---

7BUG: The system should have a special type for pointers, thus avoiding the Prolog user having to worry about consistency matters. Currently some simple heuristics are used to determine whether a reference is valid.

8For example, using the immediate update view, no call to a dynamic predicate is deterministic.
database. Each goal is tagged with the generation in which it was started. Each clause is flagged with the generation it was created as well as the generation it was erased. Only clauses with ‘created’ … ‘erased’ interval that encloses the generation of the current goal are considered visible.

4.13.2 Indexing databases

By default, SWI-Prolog, as most other implementations, indexes predicates on their first argument. SWI-Prolog allows indexing on other and multiple arguments using the declaration index/1.

For advanced database indexing, it defines hash_term/2:

```
hash_term(+Term, -HashKey)
```

If Term is a ground term (see ground/1), HashKey is unified with a positive integer value that may be used as a hash-key to the value. If Term is not ground, the predicate succeeds immediately, leaving HashKey an unbound variable.

This predicate may be used to build hash-tables as well as to exploit argument-indexing to find complex terms more quickly.

The hash-key does not rely on temporary information like addresses of atoms and may be assumed constant over different invocations of SWI-Prolog.

4.14 Declaring predicates properties

This section describes directives which manipulate attributes of predicate definitions. The functors dynamic/1, multifile/1 and discontiguous/1 are operators of priority 1150 (see op/3), which implies the list of predicates they involve can just be a comma separated list:

```
:- dynamic
    foo/0,
    baz/2.
```

On SWI-Prolog all these directives are just predicates. This implies they can also be called by a program. Do not rely on this feature if you want to maintain portability to other Prolog implementations.

```
dynamic +Functor/+Arity, ...
```

Informs the interpreter that the definition of the predicate(s) may change during execution (using assert/1 and/or retract/1). Currently dynamic/1 only stops the interpreter from complaining about undefined predicates (see unknown/2). Future releases might prohibit assert/1 and retract/1 for not-dynamic declared procedures.

```
multifile +Functor/+Arity, ...
```

Informs the system that the specified predicate(s) may be defined over more than one file. This stops consult/1 from redefining a predicate when a new definition is found.

```
discontiguous +Functor/+Arity, ...
```

Informs the system that the clauses of the specified predicate(s) might not be together in the source file. See also style_check/1.
Index the clauses of the predicate with the same name and arity as Head on the specified arguments. Head is a term of which all arguments are either ‘1’ (denoting ‘index this argument’) or ‘0’ (denoting ‘do not index this argument’). Indexing has no implications for the semantics of a predicate, only on its performance. If indexing is enabled on a predicate a special purpose algorithm is used to select candidate clauses based on the actual arguments of the goal. This algorithm checks whether indexed arguments might unify in the clause head. Only atoms, integers and compound terms are considered. Compound terms are indexed on the combination of their name and arity. Indexing is very useful for predicates with many clauses representing facts.

Due to the representation technique used at most 4 arguments can be indexed. All indexed arguments should be in the first 32 arguments of the predicate. If more than 4 arguments are specified for indexing only the first 4 will be accepted. Arguments above 32 are ignored for indexing.

By default all predicates with $\langle$arity$\rangle \geq 1$ are indexed on their first argument. It is possible to redefine indexing on predicates that already have clauses attached to them. This will initiate a scan through the predicates clause list to update the index summary information stored with each clause.

If—for example—one wants to represents sub-types using a fact list ‘sub_type(Sub, Super)’ that should be used both to determine sub- and super types one should declare sub_type/2 as follows:

```prolog
:- index(sub_type(1, 1)).

sub_type(horse, animal).
...
...
```

### 4.15 Examining the program

**current_atom(–Atom)**

Successively unifies Atom with all atoms known to the system. Note that current_atom/1 always succeeds if Atom is instantiated to an atom.

**current_functor(?Name, ?Arity)**

Successively unifies Name with the name and Arity with the arity of functors known to the system.

**current_flag(-FlagKey)**

Successively unifies FlagKey with all keys used for flags (see flag/3).

**current_key(-Key)**

Successively unifies Key with all keys used for records (see recorda/3, etc.).

**current_predicate(?Name, ?Head)**

Successively unifies Name with the name of predicates currently defined and Head with the most general term built from Name and the arity of the predicate. This predicate succeeds for
all predicates defined in the specified module, imported to it, or in one of the modules from which the predicate will be imported if it is called.

**current_predicate(:Name/Arity)**
ISO compliant implementation of `current_predicate/2`. Unlike `current_predicate/2`, the current implementation of `current_predicate/1` does not consider predicates that can be autoloaded ‘current’.

**predicate_property(?Head, ?Property)**
Succeeds if `Head` refers to a predicate that has property `Property`. Can be used to test whether a predicate has a certain property, obtain all properties known for `Head`, find all predicates having `property` or even obtaining all information available about the current program. `Property` is one of:

- **interpreted**
  Is true if the predicate is defined in Prolog. We return true on this because, although the code is actually compiled, it is completely transparent, just like interpreted code.

- **built_in**
  Is true if the predicate is locked as a built-in predicate. This implies it cannot be redefined in its definition module and it can normally not be seen in the tracer.

- **foreign**
  Is true if the predicate is defined in the C language.

- **dynamic**
  Is true if the predicate is declared dynamic using the `dynamic/1` declaration.

- **multifile**
  Is true if the predicate is declared multifile using the `multifile/1` declaration.

- **undefined**
  Is true if a procedure definition block for the predicate exists, but there are no clauses in it and it is not declared dynamic. This is true if the predicate occurs in the body of a loaded predicate, an attempt to call it has been made via one of the meta-call predicates or the predicate had a definition in the past. See the library package `check` for example usage.

- **transparent**
  Is true if the predicate is declared transparent using the `module_transparent/1` declaration.

- **exported**
  Is true if the predicate is in the public list of the context module.

- **imported_from(Module)**
  Is true if the predicate is imported into the context module from module `Module`.

- **indexed(Head)**
  Predicate is indexed (see `index/1`) according to `Head`. `Head` is a term whose name and arity are identical to the predicate. The arguments are unified with ‘1’ for indexed arguments, ‘0’ otherwise.

- **file(FileName)**
  Unify `FileName` with the name of the source file in which the predicate is defined. See also `source_file/2`.
4.15. EXAMINING THE PROGRAM

line_count(LineNumber)
Unify LineNumber with the line number of the first clause of the predicate. Fails if the predicate is not associated with a file. See also source_file/2.

number_of_clauses(ClauseCount)
Unify ClauseCount to the number of clauses associated with the predicate. Fails for foreign predicates.

dwim_predicate(+Term, -Dwim)
‘Do What I Mean’ (‘dwim’) support predicate. Term is a term, which name and arity are used as a predicate specification. Dwim is instantiated with the most general term built from Name and the arity of a defined predicate that matches the predicate specified by Term in the ‘Do What I Mean’ sense. See dwim_match/2 for ‘Do What I Mean’ string matching. Internal system predicates are not generated, unless style_check(+dollar) is active. Backtracking provides all alternative matches.

clause(?Head, ?Body)
Succeeds when Head can be unified with a clause head and Body with the corresponding clause body. Gives alternative clauses on backtracking. For facts Body is unified with the atom true. Normally clause/2 is used to find clause definitions for a predicate, but it can also be used to find clause heads for some body template.

clause(?Head, ?Body, ?Reference)
Equivalent to clause/2, but unifies Reference with a unique reference to the clause (see also assert/2, erase/1). If Reference is instantiated to a reference the clause’s head and body will be unified with Head and Body.

nth_clause(?Pred, ?Index, ?Reference)
Provides access to the clauses of a predicate using their index number. Counting starts at 1. If Reference is specified it unifies Pred with the most general term with the same name/arity as the predicate and Index with the index-number of the clause. Otherwise the name and arity of Pred are used to determine the predicate. If Index is provided Reference will be unified with the clause reference. If Index is unbound, backtracking will yield both the indices and the references of all clauses of the predicate. The following example finds the 2nd clause of member/2:

?- nth_clause(member(_,_), 2, Ref), clause(Head, Body, Ref).

Ref = 160088
Head = system : member(G575, [G578|G579])
Body = member(G575, G579)

clause_property(+ClauseRef, -Property)
Queries properties of a clause. ClauseRef is a reference to a clause as produced by clause/3, nth_clause/3 or prolog_frame_attribute/3. Property is one of the following:

file(FileName)
Unify FileName with the name of the source file in which the clause is defined. Fails if the clause is not associated to a file.
line_count(LineNumber)

Unify LineNumber with the line number of the clause. Fails if the clause is not associated to a file.

fact

True if the clause has no body.

erased

True if the clause has been erased, but not yet reclaimed because it is referenced.

4.16 Input and output

SWI-Prolog provides two different packages for input and output. One conforms to the Edinburgh standard. This package has a notion of ‘current-input’ and ‘current-output’. The reading and writing predicates implicitly refer to these streams. In the second package, streams are opened explicitly and the resulting handle is used as an argument to the reading and writing predicate to specify the source or destination. Both packages are fully integrated; the user may switch freely between them.

4.16.1 Input and output using implicit source and destination

The package for implicit input and output destination is upwards compatible to DEC-10 and C-Prolog. The reading and writing predicates refer to resp. the current input- and output stream. Initially these streams are connected to the terminal. The current output stream is changed using tell/1 or append/1. The current input stream is changed using see/1. The streams current value can be obtained using telling/1 for output- and seeing/1 for input streams. The table below shows the valid stream specifications. The reserved names user_input, user_output and user_error are for neat integration with the explicit streams.

<table>
<thead>
<tr>
<th>Source/destination</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>user</td>
<td>This reserved name refers to the terminal</td>
</tr>
<tr>
<td>user_input</td>
<td>Input from the terminal</td>
</tr>
<tr>
<td>user_output</td>
<td>Output to the terminal</td>
</tr>
<tr>
<td>user_error</td>
<td>Unix error stream (output only)</td>
</tr>
<tr>
<td>⟨Atom⟩</td>
<td>Name of a Unix file</td>
</tr>
<tr>
<td>pipe(⟨Atom⟩)</td>
<td>Name of a Unix command</td>
</tr>
</tbody>
</table>

Source and destination are either a file, one of the reserved words above, or a term ‘pipe(Command)’. In the predicate descriptions below we will call the source/destination argument ‘SrcDest’. Below are some examples of source/destination specifications.

?- see(data).
% Start reading from file ‘data’.

?- tell(user_error).
% Start writing on the error stream.

?- tell(pipe(lpr)).
% Start writing to the printer.

Another example of using the pipe/1 construct is shown below. Note that the pipe/1 construct is not part of Prolog’s standard I/O repertoire.

getwd(Wd) :-
    seeing(Old), see(pipe(pwd)),
    collect_wd(String),
4.16. INPUT AND OUTPUT

\[\text{seen, see(Old), atom_codes(Wd, String)}.\]

\[\text{collect_wd([C|R]) :- get0(C), C \neq -1, !, collect_wd(R).}\]

\[\text{collect_wd([]).}\]

\[\text{see(+SrcDest)}\]
Make \text{SrcDest} the current input stream. If \text{SrcDest} was already opened for reading with see/1 and has not been closed since, reading will be resumed. Otherwise \text{SrcDest} will be opened and the file pointer is positioned at the start of the file.

\[\text{tell(+SrcDest)}\]
Make \text{SrcDest} the current output stream. If \text{SrcDest} was already opened for writing with tell/1 or append/1 and has not been closed since, writing will be resumed. Otherwise the file is created or—when existing—truncated. See also append/1.

\[\text{append(+File)}\]
Similar to tell/1, but positions the file pointer at the end of \text{File} rather than truncating an existing file. The pipe construct is not accepted by this predicate.

\[\text{seeing(?SrcDest)}\]
Unify the name of the current input stream with \text{SrcDest}.

\[\text{telling(?SrcDest)}\]
Unify the name of the current output stream with \text{SrcDest}.

\[\text{seen}\]
Close the current input stream. The new input stream becomes \text{user}.

\[\text{told}\]
Close the current output stream. The new output stream becomes \text{user}.

4.16.2 Explicit Input and Output Streams

The predicates below are part of the Quintus compatible stream-based I/O package. In this package streams are explicitly created using the predicate \text{open/3}. The resulting stream identifier is then passed as a parameter to the reading and writing predicates to specify the source or destination of the data.

\[\text{open(+SrcDest, +Mode, -Stream, +Options)}\]
ISO compliant predicate to open a stream. \text{SrcDest} is either an atom, specifying a Unix file, or a term `pipe(Command)`, like see/1 and tell/1. \text{Mode} is one of read, write, append or update. Mode append opens the file for writing, positioning the file-pointer at the end. Mode update opens the file for writing, positioning the file-pointer at the beginning of the file without truncating the file. \text{Stream} is either a variable, in which case it is bound to an integer identifying the stream, or an atom, in which case this atom will be the stream identifier.\(^9\) The \text{Options} list can contain the following options:

\(^9\)New code should use the \text{alias(Alias)} option for compatibility to the ISO standard
type(Type)
Using type text (default), Prolog will write a text-file in an operating-system compatible way. Using type binary the bytes will be read or written without any translation. Note there is no difference between the two on Unix systems.

alias(Atom)
Gives the stream a name. Below is an example. Be careful with this option as stream-names are global. See also set_stream/2.

?- open(data, read, Fd, [alias(input)]).
   ...
   read(input, Term),
   ...

eof_action(Action)
Defines what happens if the end of the input stream is reached. Action eof_code makes \texttt{get0/1} and friends return $-1$ and \texttt{read/1} and friends return the atom \texttt{end_of_file}. Repetitive reading keeps yielding the same result. Action \texttt{error} is like \texttt{eof_code}, but repetitive reading will raise an error. With action \texttt{reset}, Prolog will examine the file again and return more data if the file has grown.

buffer(Buffering)
Defines output buffering. The atom full (default) defines full buffering, line buffering by line, and false implies the stream is fully unbuffered. Smaller buffering is useful if another process or the user is waiting for the output as it is being produced. See also \texttt{flush_output/0}. This option is not an ISO option.

close_on_abort(Bool)
If true (default), the stream is closed on an abort (see \texttt{abort/0}). If false, the stream is not closed. If it is an output stream, it will be flushed however. Useful for logfiles and if the stream is associated to a process (using the \texttt{pipe/1} construct).

lock(LockingMode)
Try to obtain a lock on the open file. Default is none, which does not lock the file. The value read or shared means other processes may read the file, but not write it. The value write or exclusive means no other process may read or write the file.

Locks are acquired through the POSIX function \texttt{fcntl()} using the command \texttt{F_SETLKW}, which makes a blocked call wait for the lock to be released. Please note that \texttt{fcntl()} locks are \textit{advisory} and therefore only other applications using the same advisory locks honour your lock. As there are many issues around locking in Unix, especially related to NFS (network file system), please study the \texttt{fcntl()} manual page before trusting your locks!

The lock option is a SWI-Prolog extension.

The option reposition is not supported in SWI-Prolog. All streams connected to a file may be repositioned.

open(+SrcDest, +Mode, ?Stream)
Equivalent to open/4 with an empty option-list.
open_null_stream(?Stream)

Open a stream that produces no output. All counting functions are enabled on such a stream. An attempt to read from a null-stream will immediately signal end-of-file. Similar to Unix /dev/null. *Stream* can be an atom, giving the null-stream an alias name.

close(+Stream)

Close the specified stream. If *Stream* is not open an error message is displayed. If the closed stream is the current input or output stream the terminal is made the current input or output.

close(+Stream, +Options)

Provides close(Stream, [force(true)]) as the only option. Called this way, any resource error (such as write-errors while flushing the output buffer) are ignored.

stream_property(?Stream, ?StreamProperty)

ISO compatible predicate for querying status of open I/O streams. *StreamProperty* is one of:

file_name(Atom)

If *Stream* is associated to a file, unify *Atom* to the name of this file.

mode(IOMode)

Unify *IOMode* to the mode given to open/4 for opening the stream. Values are: read, write, append and the SWI-Prolog extension update.

input

True if *Stream* has mode read.

output

True if *Stream* has mode write, append or update.

alias(Atom)

If *Atom* is bound, test of the stream has the specified alias. Otherwise unify *Atom* with the first alias of the stream. ⑩

position(Term)

Unify *Term* with the current stream-position. A stream-position is a term of format $stream_position(CharIndex, LineNo, LinePos). See also set_stream_position/3.

deac_of_stream(E)

If *Stream* is an input stream, unify *E* with one of the atoms not, at or past. See also at_end_of_stream/[0,1].

eof_action(A)

Unify *A* with one of eof_code, reset or error. See open/4 for details.

reposition(Bool)

Unify *Bool* with true if the position of the stream can be set (see seek/4). It is assumed the position can be set if the stream has a seek-function and is not based on a POSIX file-descriptor that is not associated to a regular file.

type(T)

Unify *Bool* with text or binary.

⑩BUG: Backtracking does not give other alias'es.
file_no(Integer)
   If the stream is associated with a POSIX file-descriptor, unify Integer with the descriptor number. SWI-Prolog extension used primarily for integration with foreign code. See also Sfileno() from SWI-Stream.h.

buffer(Buffering)
   SWI-Prolog extension to query the buffering mode of this stream. Buffering is one of full, line or false. See also open/4.

current_stream(?Object, ?Mode, ?Stream)
   The predicate current_stream/3 is used to access the status of a stream as well as to generate all open streams. Object is the name of the file opened if the stream refers to an open file, an integer file-descriptor if the stream encapsulates an operating-system stream or the atom [] if the stream refers to some other object. Mode is one of read or write.

set_stream_position(+Stream, +Pos)
   Set the current position of Stream to Pos. Pos is a term as returned by stream_property/2 using the position(Pos) property. See also seek/4.

seek(+Stream, +Offset, +Method, -NewLocation)
   Reposition the current point of the given Stream. Method is one of bof, current or eof, indicating positioning relative to the start, current point or end of the underlying object. NewLocation is unified with the new offset, relative to the start of the stream.

   If the seek modifies the current location, the line number and character position in the line are set to 0.

   If the stream cannot be repostioned, a reposition error is raised. The predicate seek/4 is compatible to Quintus Prolog, though the error conditions and signalling is ISO compliant. See also stream_property/2 and set_stream_position/3.

set_stream(+Stream, +Attribute)
   Modify an attribute of an existing stream. Attribute specifies the stream property to set. See also stream_property/2 and open/4.

alias(AliasName)
   Set the alias of an already created stream. If AliasName is the name of one of the standard streams is used, this stream is rebound. Thus, set_stream(S, current_input) is the same as set_input/1 and by setting the alias of a stream to user_input, etc. all user terminal input is read from this stream. See also interactor/0.

buffer(Buffering)
   Set the buffering mode of an already created stream. Buffering is one of full, line or false.

eof_action(Action)
   Set end-of-file handling to one of eof_code, reset or error.

close_on_abort(Bool)
   Determine whether or not the stream is closed by abort/0. By default streams are closed.
4.17. STATUS OF STREAMS

4.16.3 Switching Between Implicit and Explicit I/O

The predicates below can be used for switching between the implicit- and the explicit stream based I/O predicates.

`set_input(+Stream)`
Set the current input stream to become `Stream`. Thus, `open(file, read, Stream), set_input(Stream)` is equivalent to `see(file)`.

`set_output(+Stream)`
Set the current output stream to become `Stream`.

`current_input(-Stream)`
Get the current input stream. Useful to get access to the status predicates associated with streams.

`current_output(-Stream)`
Get the current output stream.

4.17 Status of streams

`wait_for_input(+ListOfStreams, -ReadyList, +TimeOut)`
Wait for input on one of the streams in `ListOfStreams` and return a list of streams on which input is available in `ReadyList`. `wait_for_input/3` waits for at most `TimeOut` seconds. `Timeout` may be specified as a floating point number to specify fractions of a second. If `Timeout` equals 0, `wait_for_input/3` waits indefinitely. This predicate can be used to implement timeout while reading and to handle input from multiple sources. The following example will wait for input from the user and an explicitly opened second terminal. On return, `Inputs` may hold `user` or `P4` or both.

```prolog
?- open('/dev/ttyp4', read, P4),
   wait_for_input([user, P4], Inputs, 0).
```

This predicate relies on the `select()` call on most operating systems. On Unix this call is implemented for any stream referring to a file-handle, which implies all OS-based streams: sockets, terminals, pipes, etc. On non-Unix systems `select()` is generally only implemented for socket-based streams. See also `library(socket)` from the `clib` package.

`character_count(+Stream, -Count)`
Unify `Count` with the current character index. For input streams this is the number of characters read since the open, for output streams this is the number of characters written. Counting starts at 0.

`line_count(+Stream, -Count)`
Unify `Count` with the number of lines read or written. Counting starts at 1.

`line_position(+Stream, -Count)`
Unify `Count` with the position on the current line. Note that this assumes the position is 0 after the open. Tabs are assumed to be defined on each 8-th character and backspaces are assumed to reduce the count by one, provided it is positive.
fileerrors(-Old, +New)

Define error behaviour on errors when opening a file for reading or writing. Valid values are the atoms on (default) and off. First Old is unified with the current value. Then the new value is set to New.11

4.18 Primitive character I/O

See section 4.2 for an overview of supported character representations.

nl

Write a newline character to the current output stream. On Unix systems \texttt{nl/0} is equivalent to \texttt{put(10)}.

\texttt{nl(+Stream)}

Write a newline to \texttt{Stream}.

\texttt{put(+Char)}

Write \texttt{Char} to the current output stream. \texttt{Char} is either an integer-expression evaluating to an ASCII value (0 ≤ \texttt{Char} ≤ 255) or an atom of one character.

\texttt{put(+Stream, +Char)}

Write \texttt{Char} to \texttt{Stream}.

\texttt{put_byte(+Byte)}

Alias for \texttt{put/1}.

\texttt{put_byte(+Stream, +Byte)}

Alias for \texttt{put/2}

\texttt{put_char(+Char)}

Alias for \texttt{put_char/1}.

\texttt{put(+Stream, +Char)}

Alias for \texttt{put/2}

\texttt{put_code(+Code)}

Alias for \texttt{put/1}.

\texttt{put_code(+Stream, +Code)}

Alias for \texttt{put/2}

\texttt{tab(+Amount)}

Writes \texttt{Amount} spaces on the current output stream. \texttt{Amount} should be an expression that evaluates to a positive integer (see section 4.26).

\texttt{tab(+Stream, +Amount)}

Writes \texttt{Amount} spaces to \texttt{Stream}.

11Note that Edinburgh Prolog defines \texttt{fileerrors/0} and \texttt{nofileerrors/0}. As this does not allow you to switch back to the old mode I think this definition is better.
flush_output
Flush pending output on current output stream. flush_output/0 is automatically generated by read/1 and derivatives if the current input stream is user and the cursor is not at the left margin.

flush_output(+Stream)
Flush output on the specified stream. The stream must be open for writing.

ttyflush
Flush pending output on stream user. See also flush_output/[0,1].

get_byte(-Byte)
Read the current input stream and unify the next byte with Byte (an integer between 0 and 255. Byte is unified with -1 on end of file.

get_byte(+Stream, -Byte)
Read the next byte from Stream.

get_code(-Code)
Read the current input stream and unify Code with the character code of the next character. Char is unified with -1 on end of file. See also get_char/1.

get_code(+Stream, -Code)
Read the next character-code from Stream.

get_char(-Char)
Read the current input stream and unify Char with the next character as a one-character-atom. See also atom_chars/2. On end-of-file, Char is unified to the atom end_of_file.

get_char(+Stream, -Char)
Unify Char with the next character from Stream as a one-character-atom. See also get_char/2, get_byte/2 and get_code/2.

get0(-Char)
Edinburgh version of the ISO get_byte/1 predicate.

get0(+Stream, -Char)
Edinburgh version of the ISO get_byte/2 predicate.

get(-Char)
Read the current input stream and unify the next non-blank character with Char. Char is unified with -1 on end of file.

get(+Stream, -Char)
Read the next non-blank character from Stream.

peek_byte(-Byte)
Reads the next input byte like get_byte/1, but does not remove it from the input stream.

peek_byte(+Stream, -Byte)
Reads the next input byte like get_byte/2, but does not remove it from the stream.
peek_code(-Code)
Reads the next input code like get_code/1, but does not remove it from the input stream.

peek_code(+Stream, -Code)
Reads the next input code like get_code/2, but does not remove it from the stream.

peek_char(-Char)
Reads the next input character like get_char/1, but does not remove it from the input stream.

peek_char(+Stream, -Char)
Reads the next input character like get_char/2, but does not remove it from the stream.

skip(+Char)
Read the input until Char or the end of the file is encountered. A subsequent call to get0/1 will read the first character after Char.

skip(+Stream, +Char)
Skip input (as skip/1) on Stream.

get_single_char(-Char)
Get a single character from input stream ‘user’ (regardless of the current input stream). Unlike get0/1 this predicate does not wait for a return. The character is not echoed to the user’s terminal. This predicate is meant for keyboard menu selection etc. If SWI-Prolog was started with the -tty option this predicate reads an entire line of input and returns the first non-blank character on this line, or the ASCII code of the newline (10) if the entire line consisted of blank characters.

at_end_of_stream
Succeeds after the last character of the current input stream has been read. Also succeeds if there is no valid current input stream.

at_end_of_stream(+Stream)
Succeeds after the last character of the named stream is read, or Stream is not a valid input stream. The end-of-stream test is only available on buffered input stream (unbuffered input streams are rarely used, see open/4).

copy_stream_data(+StreamIn, +StreamOut, +Len)
Copy Len bytes from stream StreamIn to StreamOut.

copy_stream_data(+StreamIn, +StreamOut)
Copy data all (remaining) data from stream StreamIn to StreamOut.

4.19 Term reading and writing
This section describes the basic term reading and writing predicates. The predicates term_to_atom/2, atom_to_term/3 and sformat/3 provide means for translating atoms and strings to terms. The predicates format/[1,2] and writef/2 provide formatted output.

There are two ways to manipulate the output format. The predicate print/[1,2] may be programmed using portray/1. The format of floating point numbers may be manipulated using the prolog_flag (see current_prolog_flag/2) float_format.
Reading is sensitive to the prolog_flag character_escapes, which controls the interpretation of the \ character in quoted atoms and strings.

**write_term(+Term, +Options)**

The predicate write_term/2 is the generic form of all Prolog term-write predicates. Valid options are:

- **quoted(true or false)**
  - If true, atoms and functors that need quotes will be quoted. The default is false.

- **character_escapes(true or false)**
  - If true, and quoted(true) is active, special characters in quoted atoms and strings are emitted as ISO escape-sequences. Default is taken from the reference module (see below).

- **ignore_ops(true or false)**
  - If true, the generic term-representation (⟨functor⟩(⟨args⟩...) will be used for all terms, Otherwise (default), operators, list-notation and { }/1 will be written using their special syntax.

- **module(Module)**
  - Define the reference module (default user). This defines the default value for the character_escapes option as well as the operator definitions to use. See also op/3.

- **numbervars(true or false)**
  - If true, terms of the format $VAR(N), where ⟨N⟩ is a positive integer, will be written as a variable name. The default is false.

- **portray(true or false)**
  - If true, the hook portray/1 is called before printing a term that is not a variable. If portray/1 succeeds, the term is considered printed. See also print/1. The default is false. This option is an extension to the ISO write_term options.

- **max_depth(Integer)**
  - If the term is nested deeper than Integer, print the remainder as eclipse (...). A 0 (zero) value (default) imposes no depth limit. This option also delimits the number of printed for a list. Example:

```
?- write_term(a(s(s(s(0)))), [a,b,c,d,e,f]), [max_depth(3)]).
```

```
a(s(s(...)), [a, b|...])
```

Yes

Used by the toplevel and debugger to limit screen output. See also the prolog-flags toplevel_print_options and debugger_print_options.

**write_term(+Stream, +Term, +Options)**

As write_term/2, but output is sent to Stream rather than the current output.

**write_canonical(+Term)**

Write Term on the current output stream using standard parenthesised prefix notation (i.e., ignoring operator declarations). Atoms that need quotes are quoted. Terms written with this predicate can always be read back, regardless of current operator declarations. Equivalent to write_term/2 using the options ignore_ops and quoted.
write_canonical(+Stream, +Term)
    Write Term in canonical form on Stream.

write(+Term)
    Write Term to the current output, using brackets and operators where appropriate. See current_prolog_flag/2 for controlling floating point output format.

write(+Stream, +Term)
    Write Term to Stream.

writeq(+Term)
    Write Term to the current output, using brackets and operators where appropriate. Atoms that need quotes are quoted. Terms written with this predicate can be read back with read/1 provided the currently active operator declarations are identical.

writeq(+Stream, +Term)
    Write Term to Stream, inserting quotes.

print(+Term)
    Prints Term on the current output stream similar to write/1, but for each (sub)term of Term first the dynamic predicate portray/1 is called. If this predicate succeeds print assumes the (sub)term has been written. This allows for user defined term writing.

print(+Stream, +Term)
    Print Term to Stream.

portray(+Term)
    A dynamic predicate, which can be defined by the user to change the behaviour of print/1 on (sub)terms. For each subterm encountered that is not a variable print/1 first calls portray/1 using the term as argument. For lists only the list as a whole is given to portray/1. If portray succeeds print/1 assumes the term has been written.

read(-Term)
    Read the next Prolog term from the current input stream and unify it with Term. On a syntax error read/1 displays an error message, attempts to skip the erroneous term and fails. On reaching end-of-file Term is unified with the atom end_of_file.

read(+Stream, -Term)
    Read Term from Stream.

read_clause(-Term)
    Equivalent to read/1, but warns the user for variables only occurring once in a term (singleton variables) which do not start with an underscore if style_check(singleton) is active (default). Used to read Prolog source files (see consult/1). New code should use read_term/2 with the option singletons(warning).

read_clause(+Stream, -Term)
    Read a clause from Stream. See read_clause/1.
4.19. TERM READING AND WRITING

read_term(-Term, +Options)

Read a term from the current input stream and unify the term with Term. The reading is controlled by options from the list of Options. If this list is empty, the behaviour is the same as for read/1. The options are upward compatible to Quintus Prolog. The argument order is according to the ISO standard. Syntax-errors are always reported using exception-handling (see catch/3). Options:

variables(Vars)

Unify Vars with a list of variables in the term. The variables appear in the order they have been read. See also free_variables/2. (ISO).

variable_names(Vars)

Unify Vars with a list of ‘Name = Var’, where Name is an atom describing the variable name and Var is a variable that shares with the corresponding variable in Term. (ISO).

singleton(Vars)

As variable_names, but only reports the variables occurring only once in the Term read. Variables starting with an underscore (‘.’) are not included in this list. (ISO).

syntax_errors(Atom)

If error (default), throw and exception on a syntax error. Other values are fail, which causes a message to be printed using print_message/2, after which the predicate fails, quiet which causes the predicate to fail silently and dec10 which causes syntax errors to be printed, after which read_term/[2,3] continues reading the next term. Using dec10, read_term/[2,3] never fails. (Quintus, SICStus).

module(Module)

Specify Module for operators, character_escapes flag and double_quotes flag. The value of the latter two is overruled if the corresponding read_term/3 option is provided. If no module is specified, the current ‘source-module’ is used. (SWI-Prolog).

character_escapes(Bool)

Defines how to read \ escape-sequences in quoted atoms. See the prolog-flags character_escapes, current_prolog_flag/2. (SWI-Prolog).

double_quotes(Bool)

Defines how to read “…” strings. See the prolog-flags double_quotes, current_prolog_flag/2. (SWI-Prolog).

term_position(Pos)

Unifies Pos with the starting position of the term read. Pos if of the same format as use by stream_property/3.

subterm_positions(TermPos)

Describes the detailed layout of the term. The formats for the various types of terms if given below. All positions are character positions. If the input is related to a normal stream, these positions are relative to the start of the input, when reading from the terminal, they are relative to the start of the term.

From-To

Used for primitive types (atoms, numbers, variables).

string_position(From, To)

Used to indicate the position of a string enclosed in double quotes (").
brace_term_position(From, To, Arg)
Term of the form \{ \ldots \}, as used in DCG rules. \( \text{Arg} \) describes the argument.

list_position(From, To, Elms, Tail)
A list. \( \text{Elms} \) describes the positions of the elements. If the list specifies the tail as \( |\langle \text{TailTerm} \rangle \)\), \( \text{Tail} \) is unified with the term-position of the tail, otherwise with the atom none.

term_position(From, To, FFrom, FTo, SubPos)
Used for a compound term not matching one of the above. \( \text{FFrom} \) and \( \text{FTo} \) describe the position of the functor. \( \text{SubPos} \) is a list, each element of which describes the term-position of the corresponding subterm.

read_term(+Stream, -Term, +Options)
Read term with options from \( \text{Stream} \). See read_term/2.

read_history(+Show, +Help, +Special, +Prompt, -Term, -Bindings)
Similar to read_term/2 using the option variable_names, but allows for history substitutions. read_history/6 is used by the top level to read the user’s actions. \( \text{Show} \) is the command the user should type to show the saved events. \( \text{Help} \) is the command to get an overview of the capabilities. \( \text{Special} \) is a list of commands that are not saved in the history. \( \text{Prompt} \) is the first prompt given. Continuation prompts for more lines are determined by prompt/2. A \%\( \text{w} \) in the prompt is substituted by the event number. See section 2.7 for available substitutions.

SWI-Prolog calls read_history/6 as follows:

read_history(h, '!h', [trace], '%w ?- ', Goal, Bindings)

prompt(-Old, +New)
Set prompt associated with read/1 and its derivatives. \( \text{Old} \) is first unified with the current prompt. On success the prompt will be set to \( \text{New} \) if this is an atom. Otherwise an error message is displayed. A prompt is printed if one of the read predicates is called and the cursor is at the left margin. It is also printed whenever a newline is given and the term has not been terminated. Prompts are only printed when the current input stream is user.

prompt1(+Prompt)
Sets the prompt for the next line to be read. Continuation lines will be read using the prompt defined by prompt/2.

4.20 Analysing and Constructing Terms

functor(?Term, ?Functor, ?Arity)
Succeeds if \( \text{Term} \) is a term with functor \( \text{Functor} \) and arity \( \text{Arity} \). If \( \text{Term} \) is a variable it is unified with a new term holding only variables. \( \text{functor}/3 \) silently fails on instantiation faults\(^{12}\). If \( \text{Term} \) is an atom or number, \( \text{Functor} \) will be unified with \( \text{Term} \) and arity will be unified with the integer 0 (zero).

\(^{12}\)In version 1.2 instantiation faults led to error messages. The new version can be used to do type testing without the need to catch illegal instantiations first.
arg(\(\text{?Arg}, \, \text{?Term}, \, \text{?Value}\))

Term should be instantiated to a term, Arg to an integer between 1 and the arity of Term. Value is unified with the Arg-th argument of Term. Arg may also be unbound. In this case Value will be unified with the successive arguments of the term. On successful unification, Arg is unified with the argument number. Backtracking yields alternative solutions.\(^{13}\)

The predicate arg/3 fails silently if \(\text{Arg} = 0\) or \(\text{Arg} > \text{arity}\) and raises the exception domain_error(not_less_than_zero, \text{Arg}) if \(\text{Arg} < 0\).

setarg(\(+\text{Arg}, +\text{Term}, +\text{Value}\))

Extra-logical predicate. Assigns the Arg-th argument of the compound term Term with the given Value. The assignment is undone if backtracking brings the state back into a position before the setarg/3 call.

This predicate may be used for destructive assignment to terms, using them as and extra-logical storage bin.

?Term = .. ?List

List is a list which head is the functor of Term and the remaining arguments are the arguments of the term. Each of the arguments may be a variable, but not both. This predicate is called ‘Univ’. Examples:

?- foo(hello, X) =.. List.

List = [foo, hello, X]

?- Term =.. [baz, foo(1)]

Term = baz(foo(1))

numbervars(+Term, +Functor, +Start, -End)

Unify the free variables of Term with a term constructed from the atom Functor with one argument. The argument is the number of the variable. Counting starts at Start. End is unified with the number that should be given to the next variable. Example:

?- numbervars(foo(A, B, A), this_is_a_variable, 0, End).

A = this_is_a_variable(0)
B = this_is_a_variable(1)
End = 2

In Edinburgh Prolog the second argument is missing. It is fixed to be $VAR.$

free_variables(+Term, -List)

Unify List with a list of variables, each sharing with a unique variable of Term. For example:

?- free_variables(a(X, b(Y, X), Z), L).

\(^{13}\)The instantiation pattern (-, +, ?) is an extension to ‘standard’ Prolog.
L = [G367, G366, G371]
X = G367
Y = G366
Z = G371

copy_term(+In, -Out)
Make a copy of term In and unify the result with Out. Ground parts of In are shared by Out. Provided In and Out have no sharing variables before this call they will have no sharing variables afterwards. copy_term/2 is semantically equivalent to:

copy_term(In, Out) :-
    recorda(copy_key, In, Ref),
    recorded(copy_key, Out, Ref),
    erase(Ref).

4.21 Analysing and Constructing Atoms

These predicates convert between Prolog constants and lists of ASCII values. The predicates atom_codes/2, number_codes/2 and name/2 behave the same when converting from a constant to a list of ASCII values. When converting the other way around, atom_codes/2 will generate an atom, number_codes/2 will generate a number or exception and name/2 will return a number if possible and an atom otherwise.

The ISO standard defines atom_chars/2 to describe the ‘broken-up’ atom as a list of one-character atoms instead of a list of codes. Upto version 3.2.x, SWI-Prolog’s atom_chars/2 behaved, compatible to Quintus and SICStus Prolog, like atom_codes. As of 3.3.x SWI-Prolog atom_codes/2 and atom_chars/2 are compliant to the ISO standard.

To ease the pain of all variations in the Prolog community, all SWI-Prolog predicates behave as flexible as possible. This implies the ‘list-side’ accepts either a code-list or a char-list and the ‘atom-side’ accept all atomic types (atom, number and string).

atom_codes(?Atom, ?String)
Convert between an atom and a list of ASCII values. If Atom is instantiated, if will be translated into a list of ASCII values and the result is unified with String. If Atom is unbound and String is a list of ASCII values, it will Atom will be unified with an atom constructed from this list.

atom_chars(?Atom, ?CharList)
As atom_codes/2, but CharList is a list of one-character atoms rather than a list of ASCII values\(^\text{14}\).

?- atom_chars(hello, X).
X = [h, e, l, l, o]

\(^\text{14}\)Upto version 3.2.x, atom_chars/2 behaved as the current atom_codes/2. The current definition is compliant with the ISO standard.
4.21. ANALYSING AND CONSTRUCTING ATOMS

char_code(?Atom, ?ASCII)
Convert between character and ASCII value for a single character.\(^{15}\)

number_chars(?Number, ?CharList)
Similar to atom_chars/2, but converts between a number and its representation as a list of one-character atoms. Fails with a representation_error if Number is unbound and CharList does not describe a number.

number_codes(?Number, ?CodeList)
As number_chars/2, but converts to a list of character codes (normally ASCII values) rather than one-character atoms. In the mode -, +, both predicates behave identically to improve handling of non-ISO source.

name(?AtomOrInt, ?String)
String is a list of ASCII values describing Atom. Each of the arguments may be a variable, but not both. When String is bound to an ASCII value list describing an integer and Atom is a variable Atom will be unified with the integer value described by String (e.g. 'name(N, "300"), 400 is N + 100' succeeds).

int_to_atom(+Int, +Base, -Atom)
Convert Int to an ASCII representation using base Base and unify the result with Atom. If Base \(\neq 10\) the base will be prepended to Atom. Base = 0 will try to interpret Int as an ASCII value and return 0\(^{'}\langle c\rangle\). Otherwise \(2 \leq Base \leq 36\). Some examples are given below.

\[
\begin{align*}
\text{int_to_atom}(45, 2, A) & \quad \rightarrow \quad A = 2'101101 \\
\text{int_to_atom}(97, 0, A) & \quad \rightarrow \quad A = 0'a \\
\text{int_to_atom}(56, 10, A) & \quad \rightarrow \quad A = 56
\end{align*}
\]

int_to_atom(+Int, -Atom)
Equivalent to int_to_atom(Int, 10, Atom).

term_to_term(+Term, ?Atom)
Succeeds if Atom describes a term that unifies with Term. When Atom is instantiated Atom is converted and then unified with Term. If Atom has no valid syntax, a syntax_error exception is raised. Otherwise Term is “written” on Atom using write/1.

atom_to_term(+Atom, -Term, -Bindings)
Use Atom as input to read_term/2 using the option variable_names and return the read term in Term and the variable bindings in Bindings. Bindings is a list of Name = Var couples, thus providing access to the actual variable names. See also read_term/2. If Atom has no valid syntax, a syntax_error exception is raised.

atom_concat(?Atom1, ?Atom2, ?Atom3)
Atom3 forms the concatenation of Atom1 and Atom2. At least two of the arguments must be instantiated to atoms, integers or floating point numbers. For ISO compliance, the instantiation-pattern -, -, + is allowed too, non-deterministically splitting the 3-th argument into two parts (as append/3 does for lists). See also string_concat/3.

---

\(^{15}\)This is also called atom_char/2 in older versions of SWI-Prolog as well as some other Prolog implementations. atom_char/2 is available from the library backcomp.pl
**concat_atom(+List, -Atom)**

*List* is a list of atoms, integers or floating point numbers. Succeeds if *Atom* can be unified with the concatenated elements of *List*. If *List* has exactly 2 elements it is equivalent to `atom_concat/3`, allowing for variables in the list.

**concat_atom(?List, +Separator, ?Atom)**

Creates an atom just like `concat_atom/2`, but inserts *Separator* between each pair of atoms. For example:

```prolog
?- concat_atom([gnu, gnat], ', ', A).
A = 'gnu, gnat'
```

This predicate can also be used to split atoms by instantiating *Separator* and *Atom*:

```prolog
?- concat_atom(L, -, 'gnu-gnat').
L = [gnu, gnat]
```

**atom_length(+Atom, -Length)**

Succeeds if *Atom* is an atom of *Length* characters long. This predicate also works for strings (see section **??**). If the prolog flag `iso` is *not* set, it also accepts integers and floats, expressing the number of characters output when given to `write/1` as well as code-lists and character-lists, expressing the length of the list.\(^\text{16}\)

**atom_prefix(+Atom, +Prefix)**

Succeeds if *Atom* starts with the characters from *Prefix*. Its behaviour is equivalent to 

```prolog
?- concat(Prefix, _, Atom),
```

but avoids the construction of an atom for the ‘remainder’.


ISO predicate for breaking atoms. It maintains the following relation: *Sub* is a sub-atom of *Atom* that starts at *Before*, has *Len* characters and *Atom* contains *After* characters after the match.

```prolog
?- sub_atom(abc, 1, 1, A, S).
A = 1, S = b
```

The implementation minimalises non-determinism and creation of atoms. This is a very flexible predicate that can do search, prefix- and suffix-matching, etc.

\(^\text{16}\)BUG: Note that [] is both an atom an empty code/character list. The predicate `atom_length/2` returns 2 for this atom.
4.22 Classifying characters

SWI-Prolog offers two comprehensive predicates for classifying characters and character-codes. These predicates are defined as built-in predicates to exploit the C-character classification’s handling of locale (handling of local character-sets). These predicates are fast, logical and deterministic if applicable.

In addition, there is the library library(ctype) providing compatibility to some other Prolog systems. The predicates of this library are defined in terms of code_type/2.

**char_type(?Char, ?Type)**
Tests or generates alternative Types or Chars. The character-types are inspired by the standard C <ctype.h> primitives.

- **alnum**
  - *Char* is a letter (upper- or lowercase) or digit.

- **alpha**
  - *Char* is a letter (upper- or lowercase).

- **csym**
  - *Char* is a letter (upper- or lowercase), digit or the underscore (_). These are valid C- and Prolog symbol characters.

- **csymf**
  - *Char* is a letter (upper- or lowercase) or the underscore (_). These are valid first characters for C- and Prolog symbols

- **ascii**
  - *Char* is a 7-bits ASCII character (0..127).

- **white**
  - *Char* is a space or tab. E.i. white space inside a line.

- **cntrl**
  - *Char* is an ASCII control-character (0..31).

- **digit**
  - *Char* is a digit.

- **digit(Weight)**
  - *Char* is a digit with value *Weight*. I.e. char_type(?X, digit(?6)) yields *X* = ‘6’. Useful for parsing numbers.

- **xdigit(Weight)**
  - *Char* is a haxe-decimal digit with value *Weight*. I.e. char_type(a, xdigit(X)) yields *X* = ‘10’. Useful for parsing numbers.

- **graph**
  - *Char* produces a visible mark on a page when printed. Note that the space is not included!

- **lower**
  - *Char* is a lower-case letter.

- **lower(Upper)**
  - *Char* is a lower-case version of *Upper*. Only true if *Char* is lowercase and *Upper* uppercase.
to_lower(Upper)
    Char is a lower-case version of Upper. For non-letters, or letter without case, Char and Lower are the same.

upper
    Char is an upper-case letter.

upper(Lower)
    Char is an upper-case version of Lower. Only true if Char is uppercase and Lower lowercase.

to_upper(Lower)
    Char is an upper-case version of Lower. For non-letters, or letter without case, Char and Lower are the same.

punct
    Char is a punctuation character. This is a graph character that is not a letter or digit.

space
    Char is some form of layout character (tab, vertical-tab, newline, etc.).

end_of_file
    Char is -1.

drop
    Char ends a line (ASCII: 10..13).

newline
    Char is a the newline character (10).

period
    Char counts as the end of a sentence (.,!,?).

quote
    Char is a quote-character (",", ",").

paren(Close)
    Char is an open-parenthesis and Close is the corresponding close-parenthesis.

code_type(?Code, ?Type)
    As char_type/2, but uses character-codes rather than one-character atoms. Please note that both predicates are as flexible as possible. They handle either representation if the argument is instantiated and only will instantiate with an integer code or one-character atom depending of the version used. See also the prolog-flag double_quotes, atom_chars/2 and atom_codes/2.

4.23 Representing text in strings

SWI-Prolog supports the data type string. Strings are a time and space efficient mechanism to handle text text in Prolog. Strings are stores as a byte array on the global (term) stack and thus destroyed on backtracking and reclaimed by the garbage collector.

Strings were added to SWI-Prolog based on an early draft of the ISO standard, offering a mechanism to represent temporary character data efficiently. As SWI-Prolog strings can handle 0-bytes, they are frequently used through the foreign language interface (section 6) for storing arbitrary byte-sequences.
Starting with version 3.3, SWI-Prolog offers garbage collection on the atom-space as well as representing 0-bytes in atoms. Although strings and atoms still have different features, new code should consider using atoms to avoid too many representations for text as well as for compatibility to other Prolog systems. Below are some of the differences:

- **creation**
  Creating strings is fast, as the data is simply copied to the global stack. Atoms are unique and therefore more expensive in terms of memory and time to create. On the other hand, if the same text has to be represented multiple times, atoms are more efficient.

- **destruction**
  Backtracking destroys strings at no cost. They are cheap to handle by the garbage collector, but it should be noted that extensive use of strings will cause many garbage collections. Atom garbage collection is generally faster.

See also the prolog-flag `double_quotes`.

**string_to_atom(?String, ?Atom)**
Logical conversion between a string and an atom. At least one of the two arguments must be instantiated. Atom can also be an integer or floating point number.

**string_to_list(?String, ?List)**
Logical conversion between a string and a list of ASCII characters. At least one of the two arguments must be instantiated.

**string_length(+String, -Length)**
Unify Length with the number of characters in String. This predicate is functionally equivalent to `atom_length/2` and also accepts atoms, integers and floats as its first argument.

**string_concat(?String1, ?String2, ?String3)**
Similar to `atom_concat/3`, but the unbound argument will be unified with a string object rather than an atom. Also, if both `String1` and `String2` are unbound and `String3` is bound to text, it breaks `String3`, unifying the start with `String1` and the end with `String2` as append does with lists. Note that this is not particularly fast on long strings as for each redo the system has to create two entirely new strings, while the list equivalent only creates a single new list-cell and moves some pointers around.

**sub_string(+String, ?Start, ?Length, ?After, ?Sub)**
Sub is a substring of String starting at Start, with length Length and String has After characters left after the match. See also `sub_atom/5`.

### 4.24 Operators

Operators are defined to improve the readability of source-code. For example, without operators, to write \(2 \times 3 + 4 \times 5\) one would have to write `+(*(2, 3), *(4, 5))`. In Prolog, a number of operators have been predefined. All operators, except for the comma (,.) can be redefined by the user.

Some care has to be taken before defining new operators. Defining too many operators might make your source ‘natural’ looking, but at the same time lead to hard to understand the limits of your syntax. To ease the pain, as of SWI-Prolog 3.3.0, operators are local to the module in which they are defined.
defined. The module-table of the module user acts as default table for all modules. This global table can be modified explicitly from inside a module:

```prolog
:- module(prove, []).
:- op(900, xfx, user:(=>)).
```

Unlike what many users think, operators and quoted atoms have no relation: defining a atom as an operator does not influence parsing characters into atoms and quoting an atom does not stop it from acting as an operator. To stop an atom acting as an operator, enclose it in braces like this: (myop).

### `op(+Precedence, +Type, :Name)`

Declare Name to be an operator of type Type with precedence Precedence. Name can also be a list of names, in which case all elements of the list are declared to be identical operators. Precedence is an integer between 0 and 1200. Precedence 0 removes the declaration. Type is one of: xf, yf, xfx, xfy, yfx, yfy, fy or fx. The ‘f’ indicates the position of the functor, while x and y indicate the position of the arguments. ‘y’ should be interpreted as “on this position a term with precedence lower or equal to the precedence of the functor should occur”. For ‘x’ the precedence of the argument must be strictly lower. The precedence of a term is 0, unless its principal functor is an operator, in which case the precedence is the precedence of this operator. A term enclosed in brackets (…) has precedence 0.

The predefined operators are shown in table 4.1. Note that all operators can be redefined by the user.

<table>
<thead>
<tr>
<th>Precedence</th>
<th>Operator</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>[ ]</td>
</tr>
</tbody>
</table>
4.25 Character Conversion

Although I wouldn’t really know for what you would like to use these features, they are provided for ISO complicity.

char_conversion(+CharIn, +CharOut)
Define that term-input (see read_term/3) maps each character read as CharIn to the character CharOut. Character conversion is only executed if the prolog-flag char_conversion is set to true and not inside quoted atoms or strings. The initial table maps each character onto itself. See also current_char_conversion/2.

current_char_conversion(?CharIn, ?CharOut)
Queries the current character conversion-table. See char_conversion/2 for details.

4.26 Arithmetic

Arithmetic can be divided into some special purpose integer predicates and a series of general predicates for floating point and integer arithmetic as appropriate. The integer predicates are as “logical” as possible. Their usage is recommended whenever applicable, resulting in faster and more “logical” programs.

The general arithmetic predicates are optionally compiled now (see set_prolog_flag/2 and the -O command line option). Compiled arithmetic reduces global stack requirements and improves performance. Unfortunately compiled arithmetic cannot be traced, which is why it is optional.

The general arithmetic predicates all handle expressions. An expression is either a simple number or a function. The arguments of a function are expressions. The functions are described in section 4.27.

between(+Low, +High, ?Value)
Low and High are integers, High ≥ Low. If Value is an integer, Low ≤ Value ≤ High. When Value is a variable it is successively bound to all integers between Low and High.

succ(?Int1, ?Int2)
Succeeds if Int2 = Int1 + 1. At least one of the arguments must be instantiated to an integer.

plus(?Int1, ?Int2, ?Int3)
Succeeds if Int3 = Int1 + Int2. At least two of the three arguments must be instantiated to integers.

+Expr1 > +Expr2
Succeeds when expression Expr1 evaluates to a larger number than Expr2.

+Expr1 < +Expr2
Succeeds when expression Expr1 evaluates to a smaller number than Expr2.

+Expr1 =< +Expr2
Succeeds when expression Expr1 evaluates to a smaller or equal number to Expr2.
+Expr1 >= +Expr2
    Succeeds when expression Expr1 evaluates to a larger or equal number to Expr2.

+Expr1 \=\= +Expr2
    Succeeds when expression Expr1 evaluates to a number non-equal to Expr2.

+Expr1 =:= +Expr2
    Succeeds when expression Expr1 evaluates to a number equal to Expr2.

-Number is +Expr
    Succeeds when Number has successfully been unified with the number Expr evaluates to. If
    Expr evaluates to a float that can be represented using an integer (i.e. the value is integer and
    within the range that can be described by Prolog’s integer representation), Expr is unified with
    the integer value.

    Note that normally, is/2 will be used with unbound left operand. If equality is to be tested,
    =:=/2 should be used. For example:

    |- 1.0 is sin(pi/2).
    Fails!. sin(pi/2) evaluates to 1.0, but
    is/2 will represent this as the integer 1,
    after which unify will fail.

    |- 1.0 is float(sin(pi/2)).
    Succeeds, as the float/1 function
    forces the result to be float.

    |- 1.0 =:= sin(pi/2).
    Succeeds as expected.

4.27 Arithmetic Functions

Arithmetic functions are terms which are evaluated by the arithmetic predicates described above.
SWI-Prolog tries to hide the difference between integer arithmetic and floating point arithmetic from
the Prolog user. Arithmetic is done as integer arithmetic as long as possible and converted to floating
point arithmetic whenever one of the arguments or the combination of them requires it. If a function
returns a floating point value which is whole it is automatically transformed into an integer. There are
three types of arguments to functions:

    Expr  Arbitrary expression, returning either a floating point value or an
           integer.

    IntExpr Arbitrary expression that should evaluate into an integer.

    Int    An integer.

    In case integer addition, subtraction and multiplication would lead to an integer overflow the
    operands are automatically converted to floating point numbers. The floating point functions (sin/1,
    exp/1, etc.) form a direct interface to the corresponding C library functions used to compile SWI-
    Prolog. Please refer to the C library documentation for details on precision, error handling, etc.

- +Expr
    Result = -Expr

+Expr1 + +Expr2
    Result = Expr1 + Expr2
4.27. ARITHMETIC FUNCTIONS

\[ +\text{Expr}_1 - +\text{Expr}_2 \]
\[ \text{Result} = \text{Expr}_1 - \text{Expr}_2 \]

\[ +\text{Expr}_1 \times +\text{Expr}_2 \]
\[ \text{Result} = \text{Expr}_1 \times \text{Expr}_2 \]

\[ +\frac{\text{Expr}_1}{+\text{Expr}_2} \]
\[ \text{Result} = \frac{\text{Expr}_1}{\text{Expr}_2} \]

\[ +\text{IntExpr}_1 \mod +\text{IntExpr}_2 \]
Modulo: \[ \text{Result} = \text{IntExpr}_1 - (\text{IntExpr}_1 \div \text{IntExpr}_2) \times \text{IntExpr}_2 \]
The function \( \mod/2 \) is implemented using the C \% operator. It’s behaviour with negative values is illustrated in the table below.

\[
\begin{align*}
2 & = 17 \mod 5 \\
2 & = 17 \mod -5 \\
-2 & = -17 \mod 5 \\
-2 & = -17 \mod 5
\end{align*}
\]

\[ +\text{IntExpr}_1 \rem +\text{IntExpr}_2 \]
Remainder of division: \[ \text{Result} = \text{float_fractional_part} (\text{IntExpr}_1/\text{IntExpr}_2) \]

\[ +\text{IntExpr}_1 \div +\text{IntExpr}_2 \]
Integer division: \[ \text{Result} = \text{truncate} (\text{Expr}_1/\text{Expr}_2) \]

\[ \text{abs}(\text{Expr}) \]
Evaluate \( \text{Expr} \) and return the absolute value of it.

\[ \text{sign}(\text{Expr}) \]
Evaluate to -1 if \( \text{Expr} < 0 \), 1 if \( \text{Expr} > 0 \) and 0 if \( \text{Expr} = 0 \).

\[ \max (+\text{Expr}_1, +\text{Expr}_2) \]
Evaluates to the largest of both \( \text{Expr}_1 \) and \( \text{Expr}_2 \).

\[ \min (+\text{Expr}_1, +\text{Expr}_2) \]
Evaluates to the smallest of both \( \text{Expr}_1 \) and \( \text{Expr}_2 \).

\[ (+\text{Int}, []) \]
A list of one element evaluates to the element. This implies "a" evaluates to the ASCII value of the letter ‘a’ (97). This option is available for compatibility only. It will not work if ‘style_check(+string)’ is active as "a" will then be transformed into a string object. The recommended way to specify the ASCII value of the letter ‘a’ is 0’a.

\[ \text{random}(+\text{Int}) \]
Evaluates to a random integer \( i \) for which \( 0 \leq i < \text{Int} \). The seed of this random generator is determined by the system clock when SWI-Prolog was started.

\[ \text{round}(+\text{Expr}) \]
Evaluates \( \text{Expr} \) and rounds the result to the nearest integer.
integer(+Expr)
   Same as round/1 (backward compatibility).

float(+Expr)
   Translate the result to a floating point number. Normally, Prolog will use integers whenever possible. When used around the 2nd argument of is/2, the result will be returned as a floating point number. In other contexts, the operation has no effect.

float_fractional_part(+Expr)
   Fractional part of a floating-point number. Negative if Expr is negative, 0 if Expr is integer.

float_integer_part(+Expr)
   Integer part of floating-point number. Negative if Expr is negative, Expr if Expr is integer.

truncate(+Expr)
   Truncate Expr to an integer. Same as float_integer_part/1.

floor(+Expr)
   Evaluates Expr and returns the largest integer smaller or equal to the result of the evaluation.

ceiling(+Expr)
   Evaluates Expr and returns the smallest integer larger or equal to the result of the evaluation.

ceil(+Expr)
   Same as ceiling/1 (backward compatibility).

+IntExpr >> +IntExpr
   Bitwise shift IntExpr1 by IntExpr2 bits to the right.

+IntExpr << +IntExpr
   Bitwise shift IntExpr1 by IntExpr2 bits to the left.

+IntExpr \ / +IntExpr
   Bitwise ‘or’ IntExpr1 and IntExpr2.

+IntExpr /\ +IntExpr
   Bitwise ‘and’ IntExpr1 and IntExpr2.

+IntExpr xor +IntExpr
   Bitwise ‘exclusive or’ IntExpr1 and IntExpr2.

\ +IntExpr
   Bitwise negation.

sqrt(+Expr)
   Result = \sqrt{Expr}

sin(+Expr)
   Result = \sin{Expr}. Expr is the angle in radians.

cos(+Expr)
   Result = \cos{Expr}. Expr is the angle in radians.
4.28. ADDING ARITHMETIC FUNCTIONS

\[
\tan(+\text{Expr}) \\
\text{Result} = \tan \text{Expr}. \text{Expr is the angle in radians.}
\]

\[
\text{asin}(+\text{Expr}) \\
\text{Result} = \arcsin \text{Expr}. \text{Result is the angle in radians.}
\]

\[
\text{acos}(+\text{Expr}) \\
\text{Result} = \arccos \text{Expr}. \text{Result is the angle in radians.}
\]

\[
\text{atan}(+\text{Expr}) \\
\text{Result} = \arctan \text{Expr}. \text{Result is the angle in radians.}
\]

\[
\text{atan}(+Y\text{Expr}, +X\text{Expr}) \\
\text{Result} = \arctan \frac{Y\text{Expr}}{X\text{Expr}}. \text{Result is the angle in radians. The return value is in the range } [-\pi \ldots \pi]. \text{Used to convert between rectangular and polar coordinate system.}
\]

\[
\log(+\text{Expr}) \\
\text{Result} = \ln \text{Expr}
\]

\[
\log_{10}(+\text{Expr}) \\
\text{Result} = \lg \text{Expr}
\]

\[
\exp(+\text{Expr}) \\
\text{Result} = e^{\text{Expr}}
\]

\[
+\text{Expr1} ** +\text{Expr2} \\
\text{Result} = \text{Expr1}^{\text{Expr2}}
\]

\[
+\text{Expr1} ^{ +\text{Expr2}} \\
\text{Same as } **/2. \text{ (backward compatibility).}
\]

\[
\pi \\
\text{Evaluates to the mathematical constant } \pi (3.141593).
\]

\[
e \\
\text{Evaluates to the mathematical constant } e (2.718282).
\]

\[
cputime \\
\text{Evaluates to a floating point number expressing the CPU time (in seconds) used by Prolog up till now. See also statistics/2 and time/1.}
\]

4.28 Adding Arithmetic Functions

Prolog predicates can be given the role of arithmetic function. The last argument is used to return the result, the arguments before the last are the inputs. Arithmetic functions are added using the predicate arithmetic_function/1, which takes the head as its argument. Arithmetic functions are module sensitive, that is they are only visible from the module in which the function is defined and declared. Global arithmetic functions should be defined and registered from module user. Global definitions can be overruled locally in modules. The builtin functions described above can be redefined as well.
arithmetic_function(+Head)

Register a Prolog predicate as an arithmetic function (see is/2, >/2, etc.). The Prolog predicate should have one more argument than specified by Head, which it either a term Name/Arity, an atom or a complex term. This last argument is an unbound variable at call time and should be instantiated to an integer or floating point number. The other arguments are the parameters. This predicate is module sensitive and will declare the arithmetic function only for the context module, unless declared from module user. Example:

1 ?- [user].
   :- arithmetic_function(mean/2).

mean(A, B, C) :-

  C is (A+B)/2.

user compiled, 0.07 sec, 440 bytes.

Yes
2 ?- A is mean(4, 5).
A = 4.500000

current_arithmetic_function(?Head)

Successively unifies all arithmetic functions that are visible from the context module with Head.

4.29 List Manipulation

is_list(+Term)

Succeeds if Term is bound to the empty list ([]) or a term with functor ‘.’ and arity 2 and the second argument is a list. This predicate acts as if defined by the following definition:

\[
\text{is_list}(X) :-
\begin{align*}
\text{var}(X),!,&,\text{fail}.
\text{is_list}([]). \\
\text{is_list}([_|T]) :- &\text{is_list}(T).
\end{align*}
\]

append(?List1, ?List2, ?List3)

Succeeds when List3 unifies with the concatenation of List1 and List2. The predicate can be used with any instantiation pattern (even three variables).

member(?Elem, ?List)

Succeeds when Elem can be unified with one of the members of List. The predicate can be used with any instantiation pattern.

\[\text{In versions before 5.0.1, is_list/1 just checked for }[] \text{ or }[|\_\|] \text{ and proper_list/1 had the role of the current is_list/1. The current definition is conform the de-facto standard. Assuming proper coding standards, there should only be very few cases where a quick-and-dirty is_list/1 is a good choice. Richard O'Keefe pointed at this issue.}\]
4.30. SET MANIPULATION

\[
\text{memberchk}(\text{?Elem}, +\text{List})
\]
Equivalent to \text{member}/2, but leaves no choice point.

\[
\text{delete}(+\text{List1}, \text{?Elem}, ?\text{List2})
\]
Delete all members of \text{List1} that simultaneously unify with \text{Elem} and unify the result with \text{List2}.

\[
\text{select}(\text{?Elem}, \text{?List}, ?\text{Rest})
\]
Select \text{Elem} from \text{List} leaving \text{Rest}. It behaves as \text{member}/2, returning the remaining elements in \text{Rest}. Note that besides selecting elements from a list, it can also be used to insert elements.\(^{18}\)

\[
\text{nth0}(\text{?Index}, \text{?List}, \text{?Elem})
\]
Succeeds when the \text{Index}-th element of \text{List} unifies with \text{Elem}. Counting starts at 0.

\[
\text{nth1}(\text{?Index}, \text{?List}, \text{?Elem})
\]
Succeeds when the \text{Index}-th element of \text{List} unifies with \text{Elem}. Counting starts at 1.

\[
\text{last}(\text{?Elem}, \text{?List})
\]
Succeeds if \text{Elem} unifies with the last element of \text{List}. If \text{List} is a proper list \text{last}/2 is deterministic. If \text{List} has an unbound tail, backtracking will cause \text{List} to grow.

\[
\text{reverse}(+\text{List1}, -\text{List2})
\]
Reverse the order of the elements in \text{List1} and unify the result with the elements of \text{List2}.

\[
\text{flatten}(+\text{List1}, -\text{List2})
\]
Transform \text{List1}, possibly holding lists as elements into a ‘flat’ list by replacing each list with its elements (recursively). Unify the resulting flat list with \text{List2}. Example:

\[
?- \text{flatten}([a, [b, [c, d]], e]], X).
\]
\[
X = [a, b, c, d, e]
\]

\[
\text{length}(\text{?List}, \text{?Int})
\]
Succeeds if \text{Int} represents the number of elements of list \text{List}. Can be used to create a list holding only variables.

\[
\text{merge}(+\text{List1}, +\text{List2}, -\text{List3})
\]
\text{List1} and \text{List2} are lists, sorted to the standard order of terms (see section 4.6). \text{List3} will be unified with an ordered list holding both the elements of \text{List1} and \text{List2}. Duplicates are not removed.

4.30 Set Manipulation

\[
\text{is_set}(+\text{Set})
\]
Succeeds if \text{Set} is a list (see \text{is_list}/1) without duplicates.

\[
\text{list_to_set}(+\text{List}, -\text{Set})
\]
Unifies \text{Set} with a list holding the same elements as \text{List} in the same order. If \text{list} contains duplicates, only the first is retained. See also \text{sort/2}. Example:

\(^{18}\)BUG: Upto SWI-Prolog 3.3.10, the definition of this predicate was not according to the de-facto standard. The first two arguments were in the wrong order.
?- list_to_set([a,b,a], X)

X = [a,b]

intersection(+Set1, +Set2, -Set3)
Succeeds if Set3 unifies with the intersection of Set1 and Set2. Set1 and Set2 are lists without duplicates. They need not be ordered.

subtract(+Set, +Delete, -Result)
Delete all elements of set ‘Delete’ from ‘Set’ and unify the resulting set with ‘Result’.

union(+Set1, +Set2, -Set3)
Succeeds if Set3 unifies with the union of Set1 and Set2. Set1 and Set2 are lists without duplicates. They need not be ordered.

subset(+Subset, +Set)
Succeeds if all elements of Subset are elements of Set as well.

merge_set(+Set1, +Set2, -Set3)
Set1 and Set2 are lists without duplicates, sorted to the standard order of terms. Set3 is unified with an ordered list without duplicates holding the union of the elements of Set1 and Set2.

4.31 Sorting Lists

sort(+List, -Sorted)
Succeeds if Sorted can be unified with a list holding the elements of List, sorted to the standard order of terms (see section 4.6). Duplicates are removed. Implemented by translating the input list into a temporary array, calling the C-library function qsort(3) using PL_compare() for comparing the elements, after which the result is translated into the result list.

msort(+List, -Sorted)
Equivalent to sort/2, but does not remove duplicates.

keysort(+List, -Sorted)
List is a proper list whose elements are Key-Value, that is, terms whose principal functor is (-)/2, whose first argument is the sorting key, and whose second argument is the satellite data to be carried along with the key. keysort/2 sorts List like msort/2, but only compares the keys. Can be used to sort terms not on standard order, but on any criterion that can be expressed on a multi-dimensional scale. Sorting on more than one criterion can be done using terms as keys, putting the first criterion as argument 1, the second as argument 2, etc. The order of multiple elements that have the same Key is not changed.

predsort(+Pred, +List, -Sorted)
Sorts similar to sort/2, but determines the order of two terms by calling Pred(-Delta, +E1, +E2). This call must unify Delta with one of <, const> or =. If built-in predicate compare/3 is used, the result is the same as sort/2. See also keysort/2.19

19Please note that the semantics have changed between 3.1.1 and 3.1.2
4.32 Finding all Solutions to a Goal

findall(+Var, +Goal, -Bag)
Creates a list of the instantiations Var gets successively on backtracking over Goal and unifies the result with Bag. Succeeds with an empty list if Goal has no solutions. findall/3 is equivalent to bagof/3 with all free variables bound with the existence operator (~), except that bagof/3 fails when goal has no solutions.

bagof(+Var, +Goal, -Bag)
Unify Bag with the alternatives of Var, if Goal has free variables besides the one sharing with Var bagof will backtrack over the alternatives of these free variables, unifying Bag with the corresponding alternatives of Var. The construct +Var~Goal tells bagof not to bind Var in Goal. bagof/3 fails if Goal has no solutions.

The example below illustrates bagof/3 and the ~ operator. The variable bindings are printed together on one line to save paper.

2 ?- listing(foo).
foo(a, b, c).
foo(a, b, d).
foo(b, c, e).
foo(b, c, f).
foo(c, c, g).

Yes
3 ?- bagof(C, foo(A, B, C), Cs).
A = a, B = b, C = G308, Cs = [c, d] ;
A = b, B = c, C = G308, Cs = [e, f] ;
A = c, B = c, C = G308, Cs = [g] ;

No
4 ?- bagof(C, A~foo(A, B, C), Cs).
A = G324, B = b, C = G326, Cs = [c, d] ;
A = G324, B = c, C = G326, Cs = [e, f, g] ;

No
5 ?-

setof(+Var, +Goal, -Set)
Equivalent to bagof/3, but sorts the result using sort/2 to get a sorted list of alternatives without duplicates.
4.33 Invoking Predicates on all Members of a List

All the predicates in this section call a predicate on all members of a list or until the predicate called fails. The predicate is called via call/2, which implies common arguments can be put in front of the arguments obtained from the list(s). For example:

?- maplist(plus(1), [0, 1, 2], X).
X = [1, 2, 3]

we will phrase this as “Predicate is applied on . . .”

\[ \text{checklist}(+Pred, +List) \]

\[ Pred \] is applied successively on each element of \( List \) until the end of the list or \( Pred \) fails. In the latter case the checklist/2 fails.

\[ \text{maplist}(+Pred, ?List1, ?List2) \]

Apply \( Pred \) on all successive pairs of elements from \( List1 \) and \( List2 \). Fails if \( Pred \) can not be applied to a pair. See the example above.

\[ \text{sublist}(+Pred, +List1, ?List2) \]

Unify \( List2 \) with a list of all elements of \( List1 \) to which \( Pred \) applies.

4.34 Forall

\[ \text{forall}(+Cond, +Action) \]

For all alternative bindings of \( Cond Action \) can be proven. The example verifies that all arithmetic statements in the list \( L \) are correct. It does not say which is wrong if one proves wrong.

?- forall(member(Result = Formula, [2 = 1 + 1, 4 = 2 * 2]),
Result =:= Formula).

4.35 Formatted Write

The current version of SWI-Prolog provides two formatted write predicates. The first is writef/[1,2], which is compatible with Edinburgh C-Prolog. The second is format/[1,2], which is compatible with Quintus Prolog. We hope the Prolog community will once define a standard formatted write predicate. If you want performance use format/[1,2] as this predicate is defined in C. Otherwise compatibility reasons might tell you which predicate to use.

4.35.1 Writef

\[ \text{writeln}(+Term) \]

Equivalent to write(Term), nl.

\[ \text{writef}(+Atom) \]

Equivalent to writef(Atom, []).
### 4.35. FORMATTED WRITE

**writef(+Format, +Arguments)**

Formatted write. *Format* is an atom whose characters will be printed. *Format* may contain certain special character sequences which specify certain formatting and substitution actions. *Arguments* then provides all the terms required to be output.

Escape sequences to generate a single special character:

<table>
<thead>
<tr>
<th>Escape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\n</td>
<td>Output a newline character (see also <code>n1/1</code>/0,1)</td>
</tr>
<tr>
<td>\l</td>
<td>Output a line separator (same as <code>\n</code>)</td>
</tr>
<tr>
<td>\r</td>
<td>Output a carriage-return character (ASCII 13)</td>
</tr>
<tr>
<td>\t</td>
<td>Output the ASCII character TAB (9)</td>
</tr>
<tr>
<td>\1</td>
<td>The character <code>\</code> is output</td>
</tr>
<tr>
<td>%</td>
<td>The character <code>%</code> is output</td>
</tr>
<tr>
<td>\nnn</td>
<td>where <code>&lt;nnn&gt;</code> is an integer (1-3 digits) the character with ASCII code <code>&lt;nnn&gt;</code> is output (NB: <code>&lt;nnn&gt;</code> is read as decimal)</td>
</tr>
</tbody>
</table>

Note that `\l`, `\nnn` and `\1` are interpreted differently when character-escapes are in effect. See section 2.15.1.

Escape sequences to include arguments from *Arguments*. Each time a `%` escape sequence is found in *Format* the next argument from *Arguments* is formatted according to the specification.

<table>
<thead>
<tr>
<th>Escape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%t</td>
<td><code>print/1</code> the next item (mnemonic: term)</td>
</tr>
<tr>
<td>%w</td>
<td><code>write/1</code> the next item</td>
</tr>
<tr>
<td>%q</td>
<td><code>writeq/1</code> the next item</td>
</tr>
<tr>
<td>%d</td>
<td>Write the term, ignoring operators. See also <code>write_term/2</code>. Mnemonic: old Edinburgh <code>display/1</code>.</td>
</tr>
<tr>
<td>%p</td>
<td><code>print/1</code> the next item (identical to %t)</td>
</tr>
<tr>
<td>%n</td>
<td>Put the next item as a character (i.e., it is an ASCII value)</td>
</tr>
<tr>
<td>%r</td>
<td>Write the next item N times where N is the second item (an integer)</td>
</tr>
<tr>
<td>%s</td>
<td>Write the next item as a String (so it must be a list of characters)</td>
</tr>
<tr>
<td>%f</td>
<td>Perform a <code>ttyflush/0</code> (no items used)</td>
</tr>
<tr>
<td>%Nc</td>
<td>Write the next item Centered in <code>N</code> columns.</td>
</tr>
<tr>
<td>%Nl</td>
<td>Write the next item Left justified in <code>N</code> columns.</td>
</tr>
<tr>
<td>%Nr</td>
<td>Write the next item Right justified in <code>N</code> columns. <code>N</code> is a decimal number with at least one digit. The item must be an atom, integer, float or string.</td>
</tr>
</tbody>
</table>

**swritef(-String, +Format, +Arguments)**

Equivalent to `writef/2`, but “writes” the result on `String` instead of the current output stream.

Example:
?- swritef(S, '%15L%w', ['Hello', 'World']).
S = "Hello World"

swritef(String, +Format)
Equivalent to swritef(String, Format, []).

4.35.2 Format

format(+Format)
Defined as ‘format(Format) :- format(Format, []).’

format(+Format, +Arguments)
Format is an atom, list of ASCII values, or a Prolog string. Arguments provides the arguments required by the format specification. If only one argument is required and this is not a list of ASCII values the argument need not be put in a list. Otherwise the arguments are put in a list.

Special sequences start with the tilde (~), followed by an optional numeric argument, followed by a character describing the action to be undertaken. A numeric argument is either a sequence of digits, representing a positive decimal number, a sequence \langle character\rangle, representing the ASCII value of the character (only useful for ~t) or a asterisk (*), in when the numeric argument is taken from the next argument of the argument list, which should be a positive integer.

Actions are:

~ Output the tilde itself.
a Output the next argument, which should be an atom. This option is equivalent to w. Compatibility reasons only.
c Output the next argument as an ASCII value. This argument should be an integer in the range [0, …, 255] (including 0 and 255).
d Output next argument as a decimal number. It should be an integer. If a numeric argument is specified a dot is inserted argument positions from the right (useful for doing fixed point arithmetic with integers, such as handling amounts of money).
D Same as d, but makes large values easier to read by inserting a comma every three digits left to the dot or right.
e Output next argument as a floating point number in exponential notation. The numeric argument specifies the precision. Default is 6 digits. Exact representation depends on the C library function printf(). This function is invoked with the format % . (precision)e.
E Equivalent to e, but outputs a capital E to indicate the exponent.
f Floating point in non-exponential notation. See C library function printf().
g Floating point in e or f notation, whichever is shorter.
G Floating point in E or f notation, whichever is shorter.
i Ignore next argument of the argument list. Produces no output.
k Give the next argument to displayq/1 (canonical write).
n Output a newline character.
N Only output a newline if the last character output on this stream was not a newline. Not properly implemented yet.

p Give the next argument to print/1.

q Give the next argument to writeq/1.

r Print integer in radix the numeric argument notation. Thus \~16r prints its argument hexadecimal. The argument should be in the range \[2, \ldots, 36\]. Lower case letters are used for digits above 9.

R Same as r, but uses upper case letters for digits above 9.

s Output a string of ASCII characters or a string (see string/1 and section 4.23) from the next argument.

t All remaining space between 2 tabs tops is distributed equally over \~t statements between the tabs tops. This space is padded with spaces by default. If an argument is supplied this is taken to be the ASCII value of the character used for padding. This can be used to do left or right alignment, centering, distributing, etc. See also \~| and \~+ to set tab stops. A tabs top is assumed at the start of each line.

| Set a tabs top on the current position. If an argument is supplied set a tabs top on the position of that argument. This will cause all \~t’s to be distributed between the previous and this tabs top.

+ Set a tabs top relative to the current position. Further the same as \~|

w Give the next argument to write/1.

W Give the next two argument to write_term/2. This option is SWI-Prolog specific.

Example:

```
simple_statistics :-
    <obtain statistics> % left to the user
    format(\(~tStatistics\~t72|\~n\n'),
    format(\(~tRunTime: \~t2f34| Inferences: \~tD72|\~n',
        [RunT, Inf]),
    ....
```

Will output

```
Statistics

Runtime: .................. 3.45 Inferences: ............ 60,345
```

format(+Stream, +Format, +Arguments)
As format/2, but write the output on the given Stream.

sformat(-String, +Format, +Arguments)
Equivalent to format/2, but “writes” the result on String instead of the current output stream.
Example:
?- sformat(S, '˜w˜t¹5|˜w', ["Hello", 'World']).

S = "Hello World"

sformat(-String, +Format)
Equivalent to 'sformat(String, Format, []).'

4.35.3 Programming Format

format(predicate(+Char, +Head))
If a sequence ˜c (tilde, followed by some character) is found, the format derivatives will first check whether the user has defined a predicate to handle the format. If not, the built in formatting rules described above are used. Char is either an ASCII value, or a one character atom, specifying the letter to be (re)defined. Head is a term, whose name and arity are used to determine the predicate to call for the redefined formatting character. The first argument to the predicate is the numeric argument of the format command, or the atom default if no argument is specified. The remaining arguments are filled from the argument list. The example below redefines ˜n to produce Arg times return followed by linefeed (so a (Grr.) DOS machine is happy with the output).

:- format_predicate(n, dos_newline(_Arg)).
dos_newline(Arg) :-
    between(1, Ar, _), put(13), put(10), fail ; true.

current_format_predicate(?Code, :?Head)
Enumerates all user-defined format predicates. Code is the character code of the format character. Head is unified with a term with the same name and arity as the predicate. If the predicate does not reside in module user, Head is qualified with the definition module of the predicate.

4.36 Terminal Control

The following predicates form a simple access mechanism to the Unix termcap library to provide terminal independent I/O for screen terminals. These predicates are only available on Unix machines. The SWI-Prolog Windows consoles accepts the ANSI escape sequences.

tty_get_capability(+Name, +Type, -Result)
Get the capability named Name from the termcap library. See termcap(5) for the capability names. Type specifies the type of the expected result, and is one of string, number or bool. String results are returned as an atom, number result as an integer and bool results as the atom on or off. If an option cannot be found this predicate fails silently. The results are only computed once. Successive queries on the same capability are fast.

tty_goto(+X, +Y)
Goto position (X, Y) on the screen. Note that the predicates line_count/2 and line_position/2 will not have a well defined behaviour while using this predicate.
4.37 OPERATING SYSTEM INTERACTION

**tty_put(+Atom, +Lines)**
Put an atom via the termcap library function tputs(). This function decodes padding information in the strings returned by `tty_get_capability/3` and should be used to output these strings. *Lines* is the number of lines affected by the operation, or 1 if not applicable (as in almost all cases).

**set tty(-OldStream, +NewStream)**
Set the output stream, used by `tty_put/2` and `tty_goto/2` to a specific stream. Default is `user_output`.

**tty_size(-Rows, -Columns)**
Determine the size of the terminal. If the system provides `ioctl` calls for this these are used and `tty_size/2` properly reflects the actual size after a user resize of the window. As a fallback, the system uses `tty_get_capability/2` using `li` and `co` capabilities. In this case the reported size reflects the size at the first call and is not updated after a user-initiated resize of the terminal.

### 4.37 Operating System Interaction

**shell(+Command, -Status)**
Execute *Command* on the operating system. *Command* is given to the Bourne shell (/bin/sh). *Status* is unified with the exit status of the command.

On Win32 systems, `shell([1,2])` executes the command using the CreateProcess() API and waits for the command to terminate. If the command ends with a & sign, the command is handed to the WinExec() API, which does not wait for the new task to terminate. See also `win_exec/2` and `win_shell/2`. Please note that the CreateProcess() API does not imply the Windows command interpreter (command.exe on Windows 95/98 and cmd.exe on Windows-NT) and therefore commands built-in to the command-interpreter can only be activated using the command interpreter. For example: `command.exe /C copy file1.txt file2.txt`

**shell(+Command)**
Equivalent to `shell(Command, 0)`.

**shell**
Start an interactive Unix shell. Default is `/bin/sh`, the environment variable SHELL overrides this default. Not available for Win32 platforms.

**win_exec(+Command, +Show)**
Win32 systems only. Spawns a Windows task without waiting for its completion. *Show* is either iconic or normal and dictates the initial status of the window. The iconic option is notably handy to start (DDE) servers.

**win_shell(+Operation, +File)**
Win32 systems only. Opens the document *File* using the windows shell-rules for doing so. *Operation* is one of open, print or explore or another operation registered with the shell for the given document-type. On modern systems it is also possible to pass a URL as *File*, opening the URL in Windows default browser. This call interfaces to the Win32 API ShellExecute().
win_registry_get_value(+Key, +Name, -Value)
Win32 systems only. Fetches the value of a Win32 registry key. Key is an atom formed as a path-name describing the desired registry key. Name is the desired attribute name of the key. Value is unified with the value. If the value is of type DWORD, the value is returned as an integer. If the value is a string it is returned as a Prolog atom. Other types are currently not supported. The default ‘root’ is HKEY_CURRENT_USER. Other roots can be specified explicitly as HKEY_CLASSES_ROOT, HKEY_CURRENT_USER, HKEY_LOCAL_MACHINE or HKEY_USERS. The example below fetches the extension to use for Prolog files (see README.TXT on the Windows version):

?- win_registry_get_value('HKEY_LOCAL_MACHINE/Software/SWI/Prolog',
fileExtension,
   Ext).

Ext = pl

getenv(+Name, -Value)
Get environment variable. Fails silently if the variable does not exist. Please note that environment variable names are case-sensitive on Unix systems and case-insensitive on Windows.

setenv(+Name, +Value)
Set environment variable. Name and Value should be instantiated to atoms or integers. The environment variable will be passed to shell/[0-2] and can be requested using getenv/2. They also influence expand_file_name/2.

unsetenv(+Name)
Remove environment variable from the environment.

unix(+Command)
This predicate comes from the Quintus compatibility library and provides a partial implementation thereof. It provides access to some operating system features and unlike the name suggests, is not operating system specific. Currently it is the only way to fetch the Prolog command-line arguments. Defined Command’s are below.

system(+Command)
Equivalent to calling shell/1. Use for compatibility only.

shell(+Command)
Equivalent to calling shell/1. Use for compatibility only.

shell
Equivalent to calling shell/0. Use for compatibility only.

cd
Equivalent to calling working_directory/2 to the expansion (see expand_file_name/2) of “. For compatibility only.

cd(+Directory)
Equivalent to calling working_directory/2. Use for compatibility only.
argv(-Argv)

Unify Argv with the list of commandline arguments provides to this Prolog run. Please note that Prolog system-arguments and application arguments are separated by --. Integer arguments are passed as Prolog integers, float arguments and Prolog floating point numbers and all other arguments as Prolog atoms. New applications should use the prolog-flag argv.

A stand-alone program could use the following skeleton to handle command-line arguments. See also section 5.

main :-
    unix(argv(Argv)),
    append(_PrologArgs, [--|AppArgs], Argv), !,
    main(AppArgs).

4.37.1 Dealing with time and date

There is no standard for time-representation in the Prolog community. SWI-Prolog represents it as a floating-point number using the same basic representation as the POSIX standard, seconds elapsed since the January 1970, 0 hours. This format is also used for predicates accessing time-information from files (see time_file/2).

get_time(-Time)

Return the number of seconds that elapsed since the epoch of the POSIX, time representation: January 1970, 0 hours. Time is a floating point number. The granularity is system dependent.

convert_time(+Time, -Year, -Month, -Day, -Hour, -Minute, -Second, -MilliSeconds)

Convert a time stamp, provided by get_time/1, time_file/2, etc. Year is unified with the year, Month with the month number (January is 1), Day with the day of the month (starting with 1), Hour with the hour of the day (0–23), Minute with the minute (0–59). Second with the second (0–59) and MilliSecond with the milliseconds (0–999). Note that the latter might not be accurate or might always be 0, depending on the timing capabilities of the system. See also convert_time/2.

convert_time(+Time, -String)

Convert a time-stamp as obtained though get_time/1 into a textual representation using the C-library function ctime(). The value is returned as a SWI-Prolog string object (see section 4.23). See also convert_time/8.

4.37.2 Handling the menu in programPLWIN.EXE

The Windows executable PLWIN.EXE has a menu-bar displayed at the top that can be programmed from Prolog. Being totally non-portable, we do not advice using it for your own application, but use XPCE or another portable GUI platform instead. We give the predicates for reference here.

win_insert_menu(+Label, +Before)

Insert a new entry (pulldown) in the menu. If the menu already contains this entry, nothing is done. The Label is the label and using the Windows conventions, a letter prefixed with & is underlined and defines the associated accelerator key. Before is the label before which this one
must be inserted. Using – adds the new entry at the end (right). For example, the call below adds a Application entry just before the Help menu.

\[
\text{win_insert_menu}(&\text{Application}', &\text{Help}')
\]

\[
\text{win_insert_menu_item} (+\text{Pulldown}, +\text{Label}, +\text{Before}, :\text{Goal})
\]

Add an item to the named Pulldown menu. Label and Before are handled as in \text{win_insert_menu/2}, but the label – inserts a separator. Goal is called if the user selects the item.

### 4.38 File System Interaction

\[
\text{access_file} (+\text{File}, +\text{Mode})
\]

Succeeds if File exists and can be accessed by this prolog process under mode Mode. Mode is one of the atoms read, write, append, exist, none or execute. File may also be the name of a directory. Fails silently otherwise. access_file(File, none) simply succeeds without testing anything.

If ‘Mode’ is write or append, this predicate also succeeds if the file does not exist and the user has write-access to the directory of the specified location.

\[
\text{exists_file} (+\text{File})
\]

Succeeds when File exists. This does not imply the user has read and/or write permission for the file.

\[
\text{file_directory_name} (+\text{File}, -\text{Directory})
\]

Extracts the directory-part of File. The returned Directory name does not end in /. There are two special cases. The directory-name of / is / itsel and the directory-name if File does not contain any / characters is ..

\[
\text{file_base_name} (+\text{File}, -\text{BaseName})
\]

Extracts the filename part from a path specification. If File does not contain any directory separators, File is returned.

\[
\text{same_file} (+\text{File}1, +\text{File}2)
\]

Succeeds if both filenames refer to the same physical file. That is, if File1 and File2 are the same string or both names exist and point to the same file (due to hard or symbolic links and/or relative vs. absolute paths).

\[
\text{exists_directory} (+\text{Directory})
\]

Succeeds if Directory exists. This does not imply the user has read, search and or write permission for the directory.

\[
\text{delete_file} (+\text{File})
\]

Remove File from the file system.

\[
\text{rename_file} (+\text{File}1, +\text{File}2)
\]

Rename File1 into File2. Currently files cannot be moved across devices.
**4.38. FILE SYSTEM INTERACTION**

size_file(+File, -Size)
Unify Size with the size of File in characters.

time_file(+File, -Time)
Unify the last modification time of File with Time. Time is a floating point number expressing
the seconds elapsed since Jan 1, 1970. See also convert_time/[2,8] and get_time/1.

absolute_file_name(+File, -Absolute)
Expand a local file-name into an absolute path. The absolute path is canonised: references to . and .. are deleted. This predicate ensures that expanding a file-name it returns the same absolute path regardless of how the file is addressed. SWI-Prolog uses absolute file names to register source files independent of the current working directory. See also absolute_file_name/3. See also absolute_file_name/3 and expand_file_name/2.

absolute_file_name(+Spec, +Options, -Absolute)
Converts the given file specification into an absolute path. Option is a list of options to guide the conversion:

extensions(ListOfExtensions)
List of file-extensions to try. Default is ‘’. For each extension, absolute_file_name/3 will first add the extension and then verify the conditions imposed by the other options. If the condition fails, the next extension of the list is tried. Extensions may be specified both as .ext or plain ext.

access(Mode)
Imposes the condition access_file(File, Mode). Mode is on of read, write, append, exist or none. See also access_file/2.

file_type(Type)
Defines extensions. Current mapping: txt implies [’’], prolog implies [’pl’, ’’], executable implies [’so’, ’’], qlf implies [’qlf’, ’’] and directory implies [’’].

file_errors(fail/error)
If error (default), throw and existence_error exception if the file cannot be found. If fail, stay silent. 20

solutions(first/all)
If first (default), the predicates leaves no choice-point. Otherwise a choice-point will be left and backtracking may yield more solutions.

The prolog-flag verbose_file_search can be set to true to help debugging Prolog’s search for files.

is_absolute_file_name(+File)
True if File specifies and absolute path-name. On Unix systems, this implies the path starts with a ‘/’. For Microsoft based systems this implies the path starts with ⟨letter⟩:. This predicate is intended to provide platform-independent checking for absolute paths. See also absolute_file_name/2 and prolog_to_os_filename/2.

---

20 Silent operation was the default up to version 3.2.6.
**file_name_extension(Base, Extension, Name)**

This predicate is used to add, remove or test filename extensions. The main reason for its introduction is to deal with different filename properties in a portable manner. If the file system is case-insensitive, testing for an extension will be done case-insensitive too. *Extension* may be specified with or without a leading dot (.). If an *Extension* is generated, it will not have a leading dot.

**expand_file_name(WildCard, List)**

Unify *List* with a sorted list of files or directories matching *WildCard*. The normal Unix wild-card constructs ‘?’, ‘*’, ‘[ ... ]’ and ‘{ ... }’ are recognised. The interpretation of ‘{ ... }’ is interpreted slightly different from the C shell (csh(1)). The comma separated argument can be arbitrary patterns, including ‘{ ... }’ patterns. The empty pattern is legal as well: ‘\{.pl, \}’ matches either ‘.pl’ or the empty string.

If the pattern does contains wildcard characters, only existing files and directories are returned. Expanding a ‘pattern’ without wildcard characters returns the argument, regardless on whether or not it exists.

Before expanding wildcards, the construct $var is expanded to the value of the environment variable *var* and a possible leading `~` character is expanded to the user’s home directory.21

**prolog_to_os_filename(PrologPath, OsPath)**

Converts between the internal Prolog pathname conventions and the operating-system pathname conventions. The internal conventions are Unix and this predicates is equivalent to =/2 (unify) on Unix systems. On DOS systems it will change the directory-separator, limit the filename length map dots, except for the last one, onto underscores.

**read_link(File, Link, Target)**

If *File* points to a symbolic link, unify *Link* with the value of the link and *Target* to the file the link is pointing to. *Target* points to a file, directory or non-existing entry in the file system, but never to a link. Fails if *File* is not a link. Fails always on systems that do not support symbolic links.

**tmp_file(Base, TmpName)**

Create a name for a temporary file. *Base* is an identifier for the category of file. The *TmpName* is guaranteed to be unique. If the system halts, it will automatically remove all created temporary files.

**make_directory(Directory)**

Create a new directory (folder) on the filesystem. Raises an exception on failure. On Unix systems, the directory is created with default permissions (defined by the process umask setting).

**delete_directory(Directory)**

Delete directory (folder) from the filesystem. Raises an exception on failure. Please note that in general it will not be possible to delete a non-empty directory.

---

21On Windows, the home directory is determined as follows: if the environment variable `HOME` exists, this is used. If the variables `HOMEDRIVE` and `HOMEPATH` exist (Windows-NT), these are used. At initialisation, the system will set the environment variable `HOME` to point to the SWI-Prolog home directory if neither `HOME` nor `HOMEPATH` and `HOMEDRIVE` are defined.
working_directory(-Old, +New)

Unify Old with an absolute path to the current working directory and change working directory to New. Use the pattern working_directory(CWD, CWD) to get the current directory. See also absolute_file_name/2 and chdir/1.

chdir(+Path)

Compatibility predicate. New code should use working_directory/2.

4.39 Multi-threading (alpha code)

The features described in this section are only enabled on Unix systems providing POSIX threads and if the system is configured using the --enable-mt option. SWI-Prolog multithreading support is experimental and in some areas not safe.

SWI-Prolog multithreading is based on standard C-language multithreading support. It is not like ParLog or other parallel implementations of the Prolog language. Prolog threads have their own stacks and only share the Prolog heap: predicates, records, flags and other global non-backtrackable data. SWI-Prolog thread support is designed with the following goals in mind.

- **Multi-threaded server applications**
  Todays computing services often focus on (internet) server applications. Such applications often have need for communication between services and/or fast non-blocking service to multiple concurrent clients. The shared heap provides fast communication and thread creation is relatively cheap (A Pentium-II/450 can create and join approx. 10,000 threads per second on Linux 2.2).

- **Interactive applications**
  Interactive applications often need to perform extensive computation. If such computations are executed in a new thread, the main thread can process events and allow the user to cancel the ongoing computation. User interfaces can also use multiple threads, each thread dealing with input from a distinct group of windows.

- **Natural integration with foreign code**
  Each Prolog thread runs in a C-thread, automatically making them cooperate with MT-safe foreign-code. In addition, any foreign thread can create its own Prolog engine for dealing with calling Prolog from C-code.

thread_create(:Goal, -Id, +Options)

Create a new Prolog thread (and underlying C-thread) and start it by executing Goal. If the thread is created succesfully, the thread-identifier of the created thread is unified to Id. Options is a list of options. Currently defined options are:

- **local(K-Bytes)**
  Set the limit to which the local stack of this thread may grow. If omitted, the limit of the calling thread is used. See also the -L commandline option.

---

22 BUG: Some of the file-I/O predicates use local filenames. Changing directory while file-bound streams are open causes wrong results on telling/1, seeing/1 and current_stream/3
global\((K-Bytes)\)
Set the limit to which the global stack of this thread may grow. If omitted, the limit of the calling thread is used. See also the \(-G\) commandline option.

trail\((K-Bytes)\)
Set the limit to which the trail stack of this thread may grow. If omitted, the limit of the calling thread is used. See also the \(-T\) commandline option.

argument\((K-Bytes)\)
Set the limit to which the argument stack of this thread may grow. If omitted, the limit of the calling thread is used. See also the \(-A\) commandline option.

alias\((AliasName)\)
Associate an ‘alias-name’ with the thread. This named may be used to refer to the thread and remains valid until the thread is joined (see \texttt{thread\_join/2}).

detached\((Bool)\)
If \texttt{false} (default), the thread can be waited for using \texttt{thread\_join/2}. \texttt{thread\_join/2} must be called on this thread to reclaim the all resources associated to the thread. If \texttt{true}, the system will reclaim all associated resources automatically after the thread finishes. Please note that thread identifiers are freed for reuse after a detached thread finishes or a normal thread has been joined.

The \textit{Goal} argument is \textit{copied} to the new Prolog engine. This implies further instantiation of this term in either thread does not have consequences for the other thread: Prolog threads do not share data from their stacks.

\texttt{thread\_self(-Id)}
Get the Prolog thread identifier of the running thread. If the thread has an alias, the alias-name is returned.

current\_thread\((?Id, ?Status)\)
Enumerates identifiers and status of all currently known threads. Calling \texttt{current\_thread/2} does not influence any thread. See also \texttt{thread\_join/2}. For threads that have an alias-name, this name is returned in \textit{Id} instead of the numerical thread identifier. \textit{Status} is one of:

\begin{itemize}
  \item \texttt{running}
    \begin{itemize}
      \item The thread is running. This is the initial status of a thread. Please note that threats waiting for something are considered running too.
    \end{itemize}
  \item \texttt{false}
    \begin{itemize}
      \item The \textit{Goal} of the thread has been completed and failed.
    \end{itemize}
  \item \texttt{true}
    \begin{itemize}
      \item The \textit{Goal} of the thread has been completed and succeeded.
    \end{itemize}
  \item \texttt{exited\((Term)\)}
    \begin{itemize}
      \item The \textit{Goal} of the thread has been terminated using \texttt{thread\_exit/1} with \textit{Term} as argument.
    \end{itemize}
  \item \texttt{exception\((Term)\)}
    \begin{itemize}
      \item The \textit{Goal} of the thread has been terminated due to an uncaught exception (see \texttt{throw/1} and \texttt{catch/3}).
    \end{itemize}
\end{itemize}
4.39. MULTI-THREADING (ALPHA CODE)

thread_join(+Id, -Status)
Wait for the termination of thread with given Id. Then unify the result-status (see thread_exit/1) of the thread with Status. After this call, Id becomes invalid and all resources associated with the thread are reclaimed. See also current_thread/2.

A thread that has been completed without thread_join/2 being called on it is partly reclaimed: the Prolog stacks are released and the C-thread is destroyed. A small data-structure representing the exit-status of the thread is retained until thread_join/2 is called on the thread.

thread_exit(+Term)
Terminates the thread immediately, leaving exited(Term) as result-state. The Prolog stacks and C-thread are reclaimed.

thread_at_exit(:Goal)
Run Goal after the execution of this thread has terminated. This is to be compared to at_halt/1, but only for the current thread. These hooks are run regardless of why the execution of the thread has been completed. As these hooks are run, the return-code is already available through current_thread/2.

4.39.1 Thread communication

Prolog threads can exchange data using dynamic predicates, database records, and other globally shared data. In addition, they can send messages to each other. If a thread needs to wait for another thread until that thread has produced some data, using only the database forces the waiting thread to poll the database continuously. Waiting for a message suspends the thread execution until the message has arrived in its message queue.

thread_send_message(+ThreadId, +Term)
Place Term in the message queue of the indicated thread (which can even be the message queue of itself (see thread_self/1). Any term can be placed in a message queue, but note that the term is copied to the receiving thread and variable-bindings are thus lost. This call returns immediately.

thread_get_message(?Term)
Examines the thread message-queue and if necessary blocks execution until a term that unifies to Term arrives in the queue. After a term from the queue has been unified unified to Term, this term is deleted from the queue and this predicate returns.

Please note that not-unifying messages remain in the queue. After the following has been executed, thread 1 has the term b(gnu) in its queue and continues execution using A is gnat.

<thread 1>
thread_get_message(a(A)),

<thread 2>
thread_send_message(b(gnu)),
thread_send_message(a(gnat)),

See also thread Peek_message/1.
thread\_peek\_message(?Term)
Examine the thread message-queue and compares the queued terms with Term until one unifies or the end of the queue has been reached. In the first case the call succeeds (possibly instantiating Term. If no term from the queue unifies this call fails.

thread\_signal(+ThreadId, :Goal)
Make thread ThreadId execute Goal at the first opportunity. In the current implementation, this implies at the first pass through the Call-port. The predicate thread\_signal/2 itself places Goal into the signalled-thread’s signal queue and returns immediately.

Signals (interrupts) do not cooperate well with the world of multi-threading, mainly because the status of mutexes cannot be guaranteed easily. At the call-port, the Prolog virtual machine holds no locks and therefore the asynchronous execution is safe.

Goal can be any valid Prolog goal, including throw/1 to make the receiving thread generate an exception and trace/0 to start tracing the receiving thread.

4.39.2 Thread synchronisation

All internal Prolog operations are thread-safe. This implies two Prolog threads can operate on the same dynamic predicate without corrupting the consistency of the predicate. This section deals with user-level \textit{mutexes} (called monitors in ADA or critical-sections by Microsoft). A mutex is a MUTual EXclusive device, which implies at most one thread can hold a mutex.

Mutexes are used to realise related updates to the Prolog database. With ‘related’, we refer to the situation where a ‘transaction’ implies two or more changes to the Prolog database. For example, we have a predicate address/2, representing the address of a person and we want to change the address by retracting the old and asserting the new address. Between these two operations the database is invalid: this person has either no address or two addresses (depending on the assert/retract order).

Here is how to realise a correct update:

```prolog
:- initialization
    mutex\_create(addressbook).

change\_address(Id, Address) :-
    mutex\_lock(addressbook),
    retractall(address(Id, _)),
    asserta(address(Id, Address)),
    mutex\_unlock(addressbook).
```

mutex\_create(?MutexId)
Create a mutex. If MutexId is an atom, a named mutex is created. If it is a variable, an anonymous mutex reference is returned. There is no limit to the number of mutexes that can be created.

mutex\_destroy(+MutexId)
Destroy a mutex. After this call, MutexId becomes invalid and further references yield an existence\_error exception.
mutex_lock(+MutexId)
Lock the mutex. Prolog mutexes are recursive mutexes: they can be locked multiple times by
the same thread. Only after unlocking it as many times as it is locked, the mutex becomes
available for locking by other threads. If another thread has locked the mutex the calling thread
is suspended until to mutex is unlocked.

If MutexId is an atom, and there is no current mutex with that name, the mutex is created
automatically using mutex_create/1. This implies named mutexes need not be declared
explicitly.

Please note that locking and unlocking mutexes should be paired carefully. Especially make
sure to unlock mutexes even if the protected code fails or raises an exception. For most common
cases use with_mutex/2, which provides a safer way for handling prolog-level mutexes.

mutex_trylock(+MutexId)
As mutex_lock/1, but if the mutex is held by another thread, this predicate fails immediately.

mutex_unlock(+MutexId)
Unlock the mutex. This can only be called if the mutex is held by the calling thread. If this is
not the case, a permission_error exception is raised.

mutex_unlock_all
Unlock all mutexes held by the current thread. This call is especially useful to handle thread-
termination using abort/0 or exceptions. See also thread_signal/2.

current_mutex(?MutexId, ?ThreadId, ?Count)
Enumerates all existing mutexes. If the mutex is held by some thread, ThreadId is unified with
the identifier of the holding thread and Count with the recursive count of the mutex. Otherwise,
ThreadId is [] and Count is 0.

with_mutex(+MutexId, :Goal)
Execute Goal while holding MutexId. If Goal leaves choicepoints, these are destroyed (as
in once/1). The mutex is unlocked regardless of whether Goal succeeds, fails or raises an
exception. An exception thrown by Goal is re-thrown after the mutex has been successfully
unlocked. See also mutex_create/2.

Although described in the thread-section, this predicate is also available in the single-threaded
version, where it behaves simply as once/1.

4.39.3 Thread-support library(threadutil)
This library defines a couple of useful predicates for demonstrating and debugging multi-threaded
applications. This library is certainly not complete.

threads
Lists all current threads and their status. In addition, all ‘zombie’ threads (finished threads that
are not detached, nor waited for) are joined to reclaim their resources.

interactor
Create a new console and run the Prolog toplevel in this new console. See also
attach_console/0.
attach
c
If the current thread has no console attached yet, attach one and redirect the user streams (input, output, and error) to the new console window. The console is an xterm application. For this to work, you should be running X-windows and your xterm should know the -Sccn.

This predicate has a couple of useful applications. One is to separate (debugging) I/O of different threads. Another is to start debugging a thread that is running in the background. If thread 10 is running, the following sequence starts the tracer on this thread:

?- thread_signal(10, (attach_console, trace)).

4.39.4 Status of the thread implementation

It is assumed that the basic Prolog execution is thread-safe. Various problems are to be expected though, both dead-locks as well as not-thread-safe code in builtin-predicates.

4.40 User Toplevel Manipulation

break

Recursively start a new Prolog top level. This Prolog top level has its own stacks, but shares the heap with all break environments and the top level. Debugging is switched off on entering a break and restored on leaving one. The break environment is terminated by typing the system’s end-of-file character (control-D). If the -t toplevel command line option is given this goal is started instead of entering the default interactive top level (prolog/0).

abort

Abort the Prolog execution and restart the top level. If the -t toplevel command line options is given this goal is started instead of entering the default interactive top level.

There are two implementations of abort/0. The default one uses the exception mechanism (see throw/1), throwing the exception $aborted. The other one uses the C-construct longjmp() to discard the entire environment and rebuild a new one. Using exceptions allows for proper recovery of predicates exploiting exceptions. Rebuilding the environment is safer if the Prolog stacks are corrupt. Therefore the system will use the rebuild-strategy if the abort was generated by an internal consistency check and the exception mechanism otherwise. Prolog can be forced to use the rebuild-strategy setting the prolog flag abort_with_exception to false.

halt

Terminate Prolog execution. Open files are closed and if the command line option -tty is not active the terminal status (see Unix stty(1)) is restored. Hooks may be registered both in Prolog and in foreign code. Prolog hooks are registered using at.halt/1. halt/0 is equivalent to halt(0).

halt(+Status)

Terminate Prolog execution with given status. Status is an integer. See also halt/0.
4.41 Creating a Protocol of the User Interaction

SWI-Prolog offers the possibility to log the interaction with the user on a file. All Prolog interaction, including warnings and tracer output, are written on the protocol file.

\[\text{protocol}(+\text{File})\]
Start protocolling on file \text{File}. If there is already a protocol file open then close it first. If \text{File} exists it is truncated.

\[\text{protocola}(+\text{File})\]
Equivalent to \text{protocol}/1, but does not truncate the \text{File} if it exists.

\[\text{noprotoocol}\]
Stop making a protocol of the user interaction. Pending output is flushed on the file.

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

4.42 Debugging and Tracing Programs

This section is a reference to the debugger interaction predicates. A more use-oriented overview of the debugger is in section 2.9.

If you have installed XPCE, you can use the graphical frontend of the tracer. This frontend is installed using the predicate \text{guitracer}/0.

\[\text{noprotocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.

---

\[\text{protocolling}(-\text{File})\]
Succeeds if a protocol was started with \text{protocol}/1 or \text{protocola}/1 and unifies \text{File} with the current protocol output file.
trace
Start the tracer. trace/0 itself cannot be seen in the tracer. Note that the Prolog toplevel treats trace/0 special; it means ‘trace the next goal’.

tracing
Succeeds when the tracer is currently switched on. tracing/0 itself can not be seen in the tracer.

notrace
Stop the tracer. notrace/0 itself cannot be seen in the tracer.

guitracer
Installs hooks (see prolog_trace_interception/4) into the system that redirects tracing information to a GUI frontend providing structured access to variable-bindings, graphical overview of the stack and highlighting of relevant source-code.

noguitracer
Reverts back to the textual tracer.

trace(+Pred)
Equivalent to trace(Pred, +all).

trace(+Pred, +Ports)
Put a trace-point on all predicates satisfying the predicate specification Pred. Ports is a list of portnames (call, redo, exit, fail). The atom all refers to all ports. If the port is preceded by a − sign the trace-point is cleared for the port. If it is preceded by a + the trace-point is set.

The predicate trace/2 activates debug mode (see debug/0). Each time a port (of the 4-port model) is passed that has a trace-point set the goal is printed as with trace/0. Unlike trace/0 however, the execution is continued without asking for further information. Examples:

?- trace(hello).
Trace all ports of hello with any arity in any module.

?- trace(foo/2, +fail).
Trace failures of foo/2 in any module.

?- trace(bar/1, -all).
Stop tracing bar/1.

The predicate debugging/0 shows all currently defined trace-points.

notrace(+Goal)
Call Goal, but suspend the debugger while Goal is executing. The current implementation cuts the choicepoints of Goal after successful completion. See once/1. Later implementations may have the same semantics as call/1.

deploy
Start debugger. In debug mode, Prolog stops at spy- and trace-points, disables tail-recursion optimisation and aggressive destruction of choice-points to make debugging information accessible. Implemented by the Prolog flag debug.
nodebug
Stop debugger. Implemented by the prolog flag debug. See also debug/0.

debugging
Print debug status and spy points on current output stream. See also the prolog flag debug.

spy(+Pred)
Put a spy point on all predicates meeting the predicate specification Pred. See section 4.4.

nospy(+Pred)
Remove spy point from all predicates meeting the predicate specification Pred.

nospyall
Remove all spy points from the entire program.

leash(?Ports)
Set/query leashing (ports which allow for user interaction). Ports is one of +Name, -Name, ?Name or a list of these. +Name enables leashing on that port, -Name disables it and ?Name succeeds or fails according to the current setting. Recognised ports are: call, redo, exit, fail and unify. The special shorthand all refers to all ports, full refers to all ports except for the unify port (default). half refers to the call, redo and fail port.

visible(+Ports)
Set the ports shown by the debugger. See leash/1 for a description of the port specification. Default is full.

unknown(-Old, +New)
Edinburgh-prolog compatibility predicate, interfacing to the ISO prolog flag unknown. Values are trace (meaning error) and fail. If the unknown flag is set to warning, unknown/2 reports the value as trace.

style_check(+Spec)
Set style checking options. Spec is either +⟨option⟩, −⟨option⟩, ?⟨option⟩ or a list of such options. +⟨option⟩ sets a style checking option, −⟨option⟩ clears it and ?⟨option⟩ succeeds or fails according to the current setting. consult/1 and derivatives resets the style checking options to their value before loading the file. If—for example—a file containing long atoms should be loaded the user can start the file with:

:- style_check(-atom).

Currently available options are:
### 4.43 Obtaining Runtime Statistics

`statistics(+Key, -Value)`

Unify system statistics determined by `Key` with `Value`. The possible keys are given in the table 4.2. The last part of the table contains keys for compatibility to other Prolog implementations (Quintus) for improved portability. Note that the ISO standard does not define methods to collect system statistics.

`statistics`  
Display a table of system statistics on the current output stream.

`time(+Goal)`  
Execute `Goal` just like `once/1` (i.e., leaving no choice points), but print used time, number of logical inferences and the average number of `lips` (logical inferences per second). Note that SWI-Prolog counts the actual executed number of inferences rather than the number of passes through the call- and redo ports of the theoretical 4-port model.

### 4.44 Finding Performance Bottlenecks

SWI-Prolog offers a statistical program profiler similar to Unix prof(1) for C and some other languages. A profiler is used as an aid to find performance pigs in programs. It provides information on the time spent in the various Prolog predicates.

The profiler is based on the assumption that if we monitor the functions on the execution stack on time intervals not correlated to the program’s execution the number of times we find a procedure on the environment stack is a measure of the time spent in this procedure. It is implemented by calling a procedure each time slice Prolog is active. This procedure scans the local stack and either just counts the procedure on top of this stack (plain profiling) or all procedures on the stack (cumulative profiling). To get accurate results each procedure one is interested in should have a reasonable number of counts. Typically a minute runtime will suffice to get a rough overview of the most expensive procedures.

<table>
<thead>
<tr>
<th>Name</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>singleton</td>
<td>on</td>
<td><code>read_clause/1</code> (used by <code>consult/1</code>) warns on variables only appearing once in a term (clause) which have a name not starting with an underscore.</td>
</tr>
<tr>
<td>atom</td>
<td>on</td>
<td><code>read/1</code> and derivatives will produce an error message on quoted atoms or strings longer than 5 lines.</td>
</tr>
<tr>
<td>dollar</td>
<td>off</td>
<td>Accept dollar as a lower case character, thus avoiding the need for quoting atoms with dollar signs. System maintenance use only.</td>
</tr>
<tr>
<td>discontiguous</td>
<td>on</td>
<td>Warn if the clauses for a predicate are not together in the same source file.</td>
</tr>
</tbody>
</table>
| string        | off     | Backward compatibility. See the prolog-flag `double_quotes(current_prolog_flag/2)`.
### 4.4.4. FINDING PERFORMANCE BOTTLENECKS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>Number of atom garbage-collections performed</td>
</tr>
<tr>
<td>age_gained</td>
<td>Number of atoms removed</td>
</tr>
<tr>
<td>age_time</td>
<td>Time spent in atom garbage-collections (User)</td>
</tr>
<tr>
<td>cputime</td>
<td>CPU time since Prolog was started in seconds</td>
</tr>
<tr>
<td>inferences</td>
<td>Total number of passes via the call and redo ports since Prolog was started.</td>
</tr>
<tr>
<td>heap</td>
<td>Estimated total size of the heap (see section 2.16.1)</td>
</tr>
<tr>
<td>heapused</td>
<td>Bytes heap in use by Prolog.</td>
</tr>
<tr>
<td>heaplimit</td>
<td>Maximum size of the heap (see section 2.16.1)</td>
</tr>
<tr>
<td>local</td>
<td>Allocated size of the local stack in bytes.</td>
</tr>
<tr>
<td>localused</td>
<td>Number of bytes in use on the local stack.</td>
</tr>
<tr>
<td>locallimit</td>
<td>Size to which the local stack is allowed to grow</td>
</tr>
<tr>
<td>global</td>
<td>Allocated size of the global stack in bytes.</td>
</tr>
<tr>
<td>globalused</td>
<td>Number of bytes in use on the global stack.</td>
</tr>
<tr>
<td>globallimit</td>
<td>Size to which the global stack is allowed to grow</td>
</tr>
<tr>
<td>trail</td>
<td>Allocated size of the trail stack in bytes.</td>
</tr>
<tr>
<td>trailused</td>
<td>Number of bytes in use on the trail stack.</td>
</tr>
<tr>
<td>traillimit</td>
<td>Size to which the trail stack is allowed to grow</td>
</tr>
<tr>
<td>atoms</td>
<td>Total number of defined atoms.</td>
</tr>
<tr>
<td>functors</td>
<td>Total number of defined name/arity pairs.</td>
</tr>
<tr>
<td>predicates</td>
<td>Total number of predicate definitions.</td>
</tr>
<tr>
<td>modules</td>
<td>Total number of module definitions.</td>
</tr>
<tr>
<td>codes</td>
<td>Total amount of byte codes in all clauses.</td>
</tr>
<tr>
<td>threads</td>
<td>MT-version: number of active threads</td>
</tr>
<tr>
<td>threads_created</td>
<td>MT-version: number of created threads</td>
</tr>
<tr>
<td>threads_cputime</td>
<td>MT-version: seconds CPU time used by finished threads</td>
</tr>
</tbody>
</table>

#### Compatibility keys

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>runtime</td>
<td>[ CPU time, CPU time since last ] (milliseconds)</td>
</tr>
<tr>
<td>system_time</td>
<td>[ System CPU time, System CPU time since last ] (milliseconds)</td>
</tr>
<tr>
<td>real_time</td>
<td>[ Wall time, Wall time since last ] (seconds since 1970)</td>
</tr>
<tr>
<td>memory</td>
<td>[ Total unshared data, free memory ] (Uses getrusage() if available, otherwise incomplete own statistics.</td>
</tr>
<tr>
<td>stacks</td>
<td>[ global use, local use ]</td>
</tr>
<tr>
<td>program</td>
<td>[ heap, 0 ]</td>
</tr>
<tr>
<td>global_stack</td>
<td>[ global use, global free ]</td>
</tr>
<tr>
<td>local_stack</td>
<td>[ local use, local free ]</td>
</tr>
<tr>
<td>trail</td>
<td>[ trail use, 0 ]</td>
</tr>
<tr>
<td>garbage_collection</td>
<td>[ number of GC, bytes gained, time spent ]</td>
</tr>
<tr>
<td>stack_shifts</td>
<td>[ global shifts, local shifts, time spent ] (fails if no shifter in this version)</td>
</tr>
<tr>
<td>atoms</td>
<td>[ number, memory use, 0 ]</td>
</tr>
<tr>
<td>atom_garbage_collection</td>
<td>[ number of AGC, bytes gained, time spent ]</td>
</tr>
<tr>
<td>core</td>
<td>Same as memory</td>
</tr>
</tbody>
</table>

Table 4.2: Keys for statistics/2
profile(+Goal, +Style, +Number)
Execute Goal just like time/1. Collect profiling statistics according to style (see profiler/2) and show the top Number procedures on the current output stream (see show_profile/1). The results are kept in the database until reset_profiler/0 or profile/3 is called and can be displayed again with show_profile/1. profile/3 is the normal way to invoke the profiler. The predicates below are low-level predicates that can be used for special cases.

show_profile(+Number)
Show the collected results of the profiler. Stops the profiler first to avoid interference from show_profile/1. It shows the top Number predicates according the percentage CPU-time used.24

profiler(-Old, +New)
Query or change the status of the profiler. The status is one of off, plain or cumulative. plain implies the time used by children of a predicate is not added to the time of the predicate. For status cumulative the time of children is added (except for recursive calls). Cumulative profiling implies the stack is scanned up to the top on each time slice to find all active predicates. This implies the overhead grows with the number of active frames on the stack. Cumulative profiling starts debugging mode to disable tail recursion optimisation, which would otherwise remove the necessary parent environments. Switching status from plain to cumulative resets the profiler. Switching to and from status off does not reset the collected statistics, thus allowing to suspend profiling for certain parts of the program.

reset_profiler
Switches the profiler to off and clears all collected statistics.

profile_count(+Head, -Calls, -Promilage)
Obtain profile statistics of the predicate specified by Head. Head is an atom for predicates with arity 0 or a term with the same name and arity as the predicate required (see current_predicate/2). Calls is unified with the number of ‘calls’ and ‘redos’ while the profiler was active. Promilage is unified with the relative number of counts the predicate was active (cumulative) or on top of the stack (plain). Promilage is an integer between 0 and 1000.

4.45 Memory Management
Note: limit_stack/2 and trim_stacks/0 have no effect on machines that do not offer dynamic stack expansion. On these machines these predicates simply succeed to improve portability.

garbage_collect
Invoke the global- and trail stack garbage collector. Normally the garbage collector is invoked automatically if necessary. Explicit invocation might be useful to reduce the need for garbage collections in time critical segments of the code. After the garbage collection trim_stacks/0 is invoked to release the collected memory resources.

24 show_profile/1 is defined in Prolog and takes a considerable amount of memory.
garbage_collect_atoms
Reclaim unused atoms. Normally invoked after agc_margin (a prolog flag) atoms have been created.

limit_stack(+Key, +Kbytes)
Limit one of the stack areas to the specified value. Key is one of local, global or trail. The limit is an integer, expressing the desired stack limit in K bytes. If the desired limit is smaller than the currently used value, the limit is set to the nearest legal value above the currently used value. If the desired value is larger than the maximum, the maximum is taken. Finally, if the desired value is either 0 or the atom unlimited the limit is set to its maximum. The maximum and initial limit is determined by the command line options -L, -G and -T.

trim_stacks
Release stack memory resources that are not in use at this moment, returning them to the operating system. Trim stack is a relatively cheap call. It can be used to release memory resources in a backtracking loop, where the iterations require typically seconds of execution time and very different, potentially large, amounts of stack space. Such a loop should be written as follows:

```
loop :-
    generator,
    trim_stacks,
    potentially_expensive_operation,
    stop_condition, !.
```

The prolog top level loop is written this way, reclaiming memory resources after every user query.

stack_parameter(+Stack, +Key, -Old, +New)
Query/set a parameter for the runtime stacks. Stack is one of local, global, trail or argument. The table below describes the Key/Value pairs. Old is first unified with the current value.

<table>
<thead>
<tr>
<th>Key</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>limit</td>
<td>Maximum size of the stack in bytes</td>
</tr>
<tr>
<td>min_free</td>
<td>Minimum free space at entry of foreign predicate</td>
</tr>
</tbody>
</table>

This predicate is currently only available on versions that use the stack-shifter to enlarge the runtime stacks when necessary. It’s definition is subject to change.

4.46 Windows DDE interface

The predicates in this section deal with MS-Windows ‘Dynamic Data Exchange’ or DDE protocol. A Windows DDE conversation is a form of interprocess communication based on sending reserved window-events between the communicating processes. See also section 6.4 for loading Windows DLL’s into SWI-Prolog.

---

25This interface is contributed by Don Dwiggins.
4.46.1 DDE client interface

The DDE client interface allows Prolog to talk to DDE server programs. We will demonstrate the use of the DDE interface using the Windows PROGMAN (Program Manager) application:

1 ?- open_dde_conversation(progman, progman, C).
   C = 0
2 ?- dde_request(0, groups, X)
   --> Unifies X with description of groups
3 ?- dde_execute(0, 'CreateGroup("DDE Demo")').
   Yes
4 ?- close_dde_conversation(0).
   Yes

For details on interacting with progman, use the SDK online manual section on the Shell DDE interface. See also the Prolog library(progman), which may be used to write simple Windows setup scripts in Prolog.

open_dde_conversation(+Service, +Topic, -Handle)
   Open a conversation with a server supporting the given service name and topic (atoms). If successful, Handle may be used to send transactions to the server. If no willing server is found this predicate fails silently.

close_dde_conversation(+Handle)
   Close the conversation associated with Handle. All opened conversations should be closed when they’re no longer needed, although the system will close any that remain open on process termination.

dde_request(+Handle, +Item, -Value)
   Request a value from the server. Item is an atom that identifies the requested data, and Value will be a string (CF_TEXT data in DDE parlance) representing that data, if the request is successful. If unsuccessful, Value will be unified with a term of form error(⟨Reason⟩), identifying the problem. This call uses SWI-Prolog string objects to return the value rather then atoms to reduce the load on the atom-space. See section 4.23 for a discussion on this data type.

dde_execute(+Handle, +Command)
   Request the DDE server to execute the given command-string. Succeeds if the command could be executed and fails with error message otherwise.

dde_poke(+Handle, +Item, +Command)
   Issue a POKE command to the server on the specified Item. Command is passed as data of type CF_TEXT.
4.46. WINDOWS DDE INTERFACE

4.46.2 DDE server mode

The (autoload) library (dde) defines primitives to realise simple DDE server applications in SWI-Prolog. These features are provided as of version 2.0.6 and should be regarded prototypes. The C-part of the DDE server can handle some more primitives, so if you need features not provided by this interface, please study library (dde).

`dde_register_service(+Template, +Goal)`

Register a server to handle DDE request or DDE execute requests from other applications. To register a service for a DDE request, `Template` is of the form:

```
+Service(+Topic, +Item, +Value)
```

`Service` is the name of the DDE service provided (like `progmam` in the client example above). `Topic` is either an atom, indicating `Goal` only handles requests on this topic or a variable that also appears in `Goal`. `Item` and `Value` are variables that also appear in `Goal`. `Item` represents the request data as a Prolog atom.\(^{26}\)

The example below registers the Prolog `current_prolog_flag/2` predicate to be accessible from other applications. The request may be given from the same Prolog as well as from another application.

```
?- dde_register_service(prolog(current_prolog_flag, F, V),
                       current_prolog_flag(F, V)).
?- open_dde_conversation(prolog, current_prolog_flag, Handle),
   dde_request(Handle, home, Home),
   close_dde_conversation(Handle).
```

Home = `/usr/local/lib/pl-2.0.6/`

Handling DDE execute requests is very similar. In this case the template is of the form:

```
+Service(+Topic, +Item)
```

Passing a `Value` argument is not needed as execute requests either succeed or fail. If `Goal` fails, a ‘not processed’ is passed back to the caller of the DDE request.

`dde_unregister_service(+Service)`

Stop responding to `Service`. If Prolog is halted, it will automatically call this on all open services.

`dde_current_service(-Service, -Topic)`

Find currently registered services and the topics served on them.

`dde_current_connection(-Service, -Topic)`

Find currently open conversations.

\(^{26}\)Upto version 3.4.5 this was a list of character codes. As recent versions have atom garbage collection there is no need for this anymore.
4.47 Miscellaneous

**dwim_match(+Atom1, +Atom2)**
Succeeds if *Atom1* matches *Atom2* in ‘Do What I Mean’ sense. Both *Atom1* and *Atom2* may also be integers or floats. The two atoms match if:

- They are identical
- They differ by one character (spy ≡ spu)
- One character is inserted/deleted (debug ≡ deug)
- Two characters are transposed (trace ≡ tarce)
- ‘Sub-words’ are glued differently (existsfile ≡ existsFile ≡ exists_file)
- Two adjacent sub words are transposed (existsFile ≡ fileExists)

**dwim_match(+Atom1, +Atom2, -Difference)**
Equivalent to *dwim_match/2*, but unifies *Difference* with an atom identifying the difference between *Atom1* and *Atom2*. The return values are (in the same order as above): equal, mismatched_char, inserted_char, transposed_char, separated and transposed_word.

**wildcard_match(+Pattern, +String)**
Succeeds if *String* matches the wildcard pattern *Pattern*. *Pattern* is very similar the the Unix csh pattern matcher. The patterns are given below:

- `?` Matches one arbitrary character.
- `*` Matches any number of arbitrary characters.
- `[...]` Matches one of the characters specified between the brackets.
- `<char1>-<char2>` indicates a range.
- `{...}` Matches any of the patterns of the comma separated list between the braces.

Example:

```prolog
?- wildcard_match(’[a-z]*{pro,pl}[%˜]’, ’a_hello.pl%’).
Yes
```

**gensym(+Base, -Unique)**
Generate a unique atom from base *Base* and unify it with *Unique*. *Base* should be an atom. The first call will return `<base>1`, the next `<base>2`, etc. Note that this is no warrant that the atom is unique in the system.²⁷

**sleep(+Time)**
Suspend execution *Time* seconds. *Time* is either a floating point number or an integer. Granularity is dependent on the system’s timer granularity. A negative time causes the timer to return immediately. On most non-realtime operating systems we can only ensure execution is suspended for at least *Time* seconds.

---
²⁷BUG: I plan to supply a real *gensym/2* which does give this warrant for future versions.
5 Using Modules

5.1 Why Using Modules?

In traditional Prolog systems the predicate space was flat. This approach is not very suitable for the development of large applications, certainly not if these applications are developed by more than one programmer. In many cases, the definition of a Prolog predicate requires sub-predicates that are intended only to complete the definition of the main predicate. With a flat and global predicate space these support predicates will be visible from the entire program.

For this reason, it is desirable that each source module has its own predicate space. A module consists of a declaration for its name, its public predicates and the predicates themselves. This approach allows the programmer to use short (local) names for support predicates without worrying about name conflicts with the support predicates of other modules. The module declaration also makes explicit which predicates are meant for public usage and which for private purposes. Finally, using the module information, cross reference programs can indicate possible problems much better.

5.2 Name-based versus Predicate-based Modules

Two approaches to realize a module system are commonly used in Prolog and other languages. The first one is the name based module system. In these systems, each atom read is tagged (normally prefixed) with the module name, with the exception of those atoms that are defined public. In the second approach, each module actually implements its own predicate space.

A critical problem with using modules in Prolog is introduced by the meta-predicates that transform between Prolog data and Prolog predicates. Consider the case where we write:

```prolog
:- module(extend, [add_extension/3]).

add_extension(Extension, Plain, Extended) :-
    maplist(extend_atom(Extension), Plain, Extended).

extend_atom(Extension, Plain, Extended) :-
    concat(Plain, Extension, Extended).
```

In this case we would like maplist to call extend_atom/3 in the module extend. A name based module system will do this correctly. It will tag the atom extend_atom with the module and maplist will use this to construct the tagged term extend_atom/3. A name based module however, will not only tag the atoms that will eventually be used to refer to a predicate, but all atoms that are not declared public. So, with a name based module system also data is local to the module. This introduces another serious problem:
:- module(action, [action/3]).

action(Object, sleep, Arg) :- ....
action(Object, awake, Arg) :- ....

:- module(process, [awake_process/2]).

awake_process(Process, Arg) :-
    action(Process, awake, Arg).

This code uses a simple object-oriented implementation technique were atoms are used as method selectors. Using a name based module system, this code will not work, unless we declare the selectors public atoms in all modules that use them. Predicate based module systems do not require particular precautions for handling this case.

It appears we have to choose either to have local data, or to have trouble with meta-predicates. Probably it is best to choose for the predicate based approach as novice users will not often write generic meta-predicates that have to be used across multiple modules, but are likely to write programs that pass data around across modules. Experienced Prolog programmers should be able to deal with the complexities of meta-predicates in a predicate based module system.

5.3 Defining a Module

Modules normally are created by loading a module file. A module file is a file holding a module/2 directive as its first term. The module/2 directive declares the name and the public (i.e., externally visible) predicates of the module. The rest of the file is loaded into the module. Below is an example of a module file, defining reverse/2.

:- module(reverse, [reverse/2]).

reverse(List1, List2) :-
    rev(List1, [ ], List2).

rev([ ], List, List).
rev([Head|List1], List2, List3) :-
    rev(List1, [Head|List2], List3).

5.4 Importing Predicates into a Module

As explained before, in the predicate based approach adapted by SWI-Prolog, each module has its own predicate space. In SWI-Prolog, a module initially is completely empty. Predicates can be added to a module by loading a module file as demonstrated in the previous section, using assert or by importing them from another module.

Two mechanisms for importing predicates explicitly from another module exist. The use_module/[1,2] predicates load a module file and import (part of the) public predicates of the file. The import/1 predicate imports any predicate from any module.
5.5. USING THE MODULE SYSTEM

use_module(+File)
Load the file(s) specified with File just like ensure_loaded/1. The files should all be module files. All exported predicates from the loaded files are imported into the context module. The difference between this predicate and ensure_loaded/1 becomes apparent if the file is already loaded into another module. In this case ensure_loaded/1 does nothing; use_module will import all public predicates of the module into the current context module.

use_module(+File, +ImportList)
Load the file specified with File (only one file is accepted). File should be a module file. ImportList is a list of name/arity pairs specifying the predicates that should be imported from the loaded module. If a predicate is specified that is not exported from the loaded module a warning will be printed. The predicate will nevertheless be imported to simplify debugging.

import(+Head)
Import predicate Head into the current context module. Head should specify the source module using the ⟨module⟩:⟨term⟩ construct. Note that predicates are normally imported using one of the directives use_module/[1,2]. import/1 is meant for handling imports into dynamically created modules.

It would be rather inconvenient to have to import each predicate referred to by the module, including the system predicates. For this reason each module is assigned a default module. All predicates in the default module are available without extra declarations. Their definition however can be overruled in the local module. This schedule is implemented by the exception handling mechanism of SWI-Prolog: if an undefined predicate exception is raised for a predicate in some module, the exception handler first tries to import the predicate from the module’s default module. On success, normal execution is resumed.

5.4.1 Reserved Modules

SWI-Prolog contains two special modules. The first one is the module system. This module contains all built-in predicates described in this manual. Module system has no default module assigned to it. The second special module is the module user. This module forms the initial working space of the user. Initially it is empty. The default module of module user is system, making all built-in predicate definitions available as defaults. Built-in predicates thus can be overruled by defining them in module user before they are used.

All other modules default to module user. This implies they can use all predicates imported into user without explicitly importing them.

5.5 Using the Module System

The current structure of the module system has been designed with some specific organisations for large programs in mind. Many large programs define a basic library layer on top of which the actual program itself is defined. The module user, acting as the default module for all other modules of the program can be used to distribute these definitions over all program module without introducing the need to import this common layer each time explicitly. It can also be used to redefine built-in predicates if this is required to maintain compatibility to some other Prolog implementation. Typically, the loadfile of a large application looks like this:
The ‘use_module’ declarations will import the public predicates from the generic modules into the user module. The ‘ensure_loaded’ directive loads the modules that constitute the actual application. It is assumed these modules import predicates from each other using use_module/[1,2] as far as necessary.

In combination with the object-oriented schema described below it is possible to define a neat modular architecture. The generic code defines general utilities and the message passing predicates (invoke/3 in the example below). The application modules define classes that communicate using the message passing predicates.

### 5.5.1 Object Oriented Programming

Another typical way to use the module system is for defining classes within an object oriented paradigm. The class structure and the methods of a class can be defined in a module and the explicit module-boundary overruling describes in section 5.6.2 can by used by the message passing code to invoke the behaviour. An outline of this mechanism is given below.

% Define class point
:- module(point, []). % class point, no exports

% name type, default value
variable(x, integer, 0, both).
variable(y, integer, 0, both).

% method name predicate name arguments
behaviour(mirror, mirror, []).
mirror(P) :-
    fetch(P, x, X),
5.6. META-PREDICATES IN MODULES

fetch(P, y, Y),
store(P, y, X),
store(P, x, Y).

The predicates fetch/3 and store/3 are predicates that change instance variables of instances. The figure below indicates how message passing can easily be implemented:

% invoke(+Instance, +Selector, ?ArgumentList)
% send a message to an instance

invoke(I, S, Args) :-
    class_of_instance(I, Class),
    Class:behaviour(S, P, ArgCheck), !,
    convert_arguments(ArgCheck, Args, ConvArgs),
    Goal =.. [P|ConvArgs],
    Class:Goal.

The construct ⟨Module⟩:(Goal) explicitly calls Goal in module Module. It is discussed in more detail in section 4.8.

5.6 Meta-Predicates in Modules

As indicated in the introduction, the problem with a predicate based module system lies in the difficulty to find the correct predicate from a Prolog term. The predicate ‘solution(Solution)’ can exist in more than one module, but ‘assert(solution(4))’ in some module is supposed to refer to the correct version of solution/1.

Various approaches are possible to solve this problem. One is to add an extra argument to all predicates (e.g. ‘assert(Module, Term)’). Another is to tag the term somehow to indicate which module is desired (e.g. ‘assert(Module:Term)’). Both approaches are not very attractive as they make the user responsible for choosing the correct module, inviting unclear programming by asserting in other modules. The predicate assert/1 is supposed to assert in the module it is called from and should do so without being told explicitly. For this reason, the notion context module has been introduced.

5.6.1 Definition and Context Module

Each predicate of the program is assigned a module, called it’s definition module. The definition module of a predicate is always the module in which the predicate was originally defined. Each active goal in the Prolog system has a context module assigned to it.

The context module is used to find predicates from a Prolog term. By default, this module is the definition module of the predicate running the goal. For meta-predicates however, this is the context module of the goal that invoked them. We call this module transparent in SWI-Prolog. In the ‘using maplist’ example above, the predicate maplist/3 is declared module transparent. This implies the context module remains extend, the context module of add_extension/3. This way maplist/3 can decide to call extend_atom in module extend rather than in it’s own definition module.

All built-in predicates that refer to predicates via a Prolog term are declared module transparent. Below is the code defining maplist.
:- module(maplist, maplist/3).

:- module_transparent maplist/3.

% maplist(+Goal, +List1, ?List2)
% True if Goal can successfully be applied to all successive pairs
% of elements of List1 and List2.
maplist(_, [], []).  
maplist(Goal, [Elem1|Tail1], [Elem2|Tail2]) :-
    apply(Goal, [Elem1, Elem2]),
    maplist(Goal, Tail1, Tail2).

5.6.2 Overruling Module Boundaries

The mechanism above is sufficient to create an acceptable module system. There are however cases in which we would like to be able to overrule this schema and explicitly call a predicate in some module or assert explicitly in some module. The first is useful to invoke goals in some module from the user's toplevel or to implement a object-oriented system (see above). The latter is useful to create and modify dynamic modules (see section 5.7).

For this purpose, the reserved term :/2 has been introduced. All built-in predicates that transform a term into a predicate reference will check whether this term is of the form ‘⟨Module⟩:⟨Term⟩’. If so, the predicate is searched for in Module instead of the goal's context module. The : operator may be nested, in which case the inner-most module is used.

The special calling construct ⟨Module⟩:⟨Goal⟩ pretends Goal is called from Module instead of the context module. Examples:

?- assert(world:done).  % asserts done/0 into module world
?- world:assert(done).  % the same
?- world:done.          % calls done/0 in module world

5.7 Dynamic Modules

So far, we discussed modules that were created by loading a module-file. These modules have been introduced on facilitate the development of large applications. The modules are fully defined at load-time of the application and normally will not change during execution. Having the notion of a set of predicates as a self-contained world can be attractive for other purposes as well. For example, assume an application that can reason about multiple worlds. It is attractive to store the data of a particular world in a module, so we extract information from a world simply by invoking goals in this world.

Dynamic modules can easily be created. Any built-in predicate that tries to locate a predicate in a specific module will create this module as a side-effect if it did not yet exist. Example:

?- assert(world_a:consistent),
   world_a:unknown(_, fail).
These calls create a module called ‘world_a’ and make the call ‘world_a:consistent’ succeed. Undefined predicates will not start the tracer or autoloader for this module (see unknown/2).

Import and export from dynamically created world is arranged via the predicates import/1 and export/1:

?- world_b:export(solve(_,_)). % exports solve/2 from world_b
?- world_c:import(world_b:solve(_,_)). % and import it to world_c

5.8 Module Handling Predicates

This section gives the predicate definitions for the remaining built-in predicates that handle modules.

:- module(+Module, +PublicList)
This directive can only be used as the first term of a source file. It declares the file to be a module file, defining Module and exporting the predicates of PublicList. PublicList is a list of name/arity pairs.

module_transparent +Preds
Preds is a comma separated list of name/arity pairs (like dynamic/1). Each goal associated with a transparent declared predicate will inherit the context module from its parent goal.

meta_predicate +Heads
This predicate is defined in library(quintus) and provides a partial emulation of the Quintus predicate. See section 5.9.1 for details.

current_module(-Module)
Generates all currently known modules.

current_module(?Module, ?File)
Is true if File is the file from which Module was loaded. File is the internal canonical filename. See also source_file/[1,2].

context_module(-Module)
Unify Module with the context module of the current goal. context_module/1 itself is transparent.

export(+Head)
Add a predicate to the public list of the context module. This implies the predicate will be imported into another module if this module is imported with use_module/[1,2]. Note that predicates are normally exported using the directive module/2. export/1 is meant to handle export from dynamically created modules.

export_list(+Module, ?Exports)
Unifies Exports with a list of terms. Each term has the name and arity of a public predicate of Module. The order of the terms in Exports is not defined. See also predicate_property/2.
default_module(+Module, -Default)

Successively unifies Default with the module names from which a call in Module attempts to use the definition. For the module user, this will generate user and system. For any other module, this will generate the module itself, followed by user and system.

module(+Module)

The call module(Module) may be used to switch the default working module for the interactive toplevel (see prolog/0). This may be used to when debugging a module. The example below lists the clauses of file_of_label/2 in the module tex.

1  ?- module(tex).

Yes
tex: 2  ?- listing(file_of_label/2).
...

5.9 Compatibility of the Module System

The principles behind the module system of SWI-Prolog differ in a number of aspects from the Quintus Prolog module system.

- The SWI-Prolog module system allows the user to redefine system predicates.
- All predicates that are available in the system and user modules are visible in all other modules as well.
- Quintus has the ‘meta_predicate/1’ declaration were SWI-Prolog has the module_transparent/1 declaration.

The meta_predicate/1 declaration causes the compiler to tag arguments that pass module sensitive information with the module using the :/2 operator. This approach has some disadvantages:

- Changing a meta_predicate declaration implies all predicates calling the predicate need to be reloaded. This can cause serious consistency problems.
- It does not help for dynamically defined predicates calling module sensitive predicates.
- It slows down the compiler (at least in the SWI-Prolog architecture).
- At least within the SWI-Prolog architecture the run-time overhead is larger than the overhead introduced by the transparent mechanism.

Unfortunately the transparent predicate approach also has some disadvantages. If a predicate A passes module sensitive information to a predicate B, passing the same information to a module sensitive system predicate both A and B should be declared transparent. Using the Quintus approach only A needs to be treated special (i.e., declared with meta_predicate/1)\(^1\). A second problem arises if the body of a transparent predicate uses module sensitive predicates for which it wants to refer to its own module. Suppose we want to define findall/3 using assert/1 and retract/1\(^2\). The example in figure 5.1 gives the solution.

\(^1\)Although this would make it impossible to call B directly.
\(^2\)The system version uses recordz/2 and recorded/3.
5.9. COMPATIBILITY OF THE MODULE SYSTEM

:- module(findall, [findall/3]).

:- dynamic
    solution/1.

:- module_transparent
    findall/3,
    store/2.

findall(Var, Goal, Bag) :-
    assert(findall:solution('$mark')),
    store(Var, Goal),
    collect(Bag).

store(Var, Goal) :-
    % refers to context module of
    % caller of findall/3
    Goal,
    assert(findall:solution(Var)),
    fail.
store(_, _).

collect(Bag) :-
    ...,
5.9.1 Emulating meta_predicate/1

The Quintus meta_predicate/1 directive can in many cases be replaced by the transparent declaration. Below is the definition of meta_predicate/1 as available from library(quintus).

```prolog
:- op(1150, fx, (meta_predicate)).
meta_predicate((Head, More)) :- !,
    meta_predicate1(Head),
    meta_predicate(More).
meta_predicate(Head) :-
    meta_predicate1(Head).
meta_predicate1(Head) :-
    Head =.. [Name|Arguments],
    member(Arg, Arguments),
    module_expansion_argument(Arg), !,
    functor(Head, Name, Arity),
    module_transparent(Name/Arity).
meta_predicate1(_). % just a mode declaration
module_expansion_argument(:).
module_expansion_argument(N) :- integer(N).
```

The discussion above about the problems with the transparent mechanism show the two cases in which this simple transformation does not work.
Foreign Language Interface

SWI-Prolog offers a powerful interface to C [Kernighan & Ritchie, 1978]. The main design objectives of the foreign language interface are flexibility and performance. A foreign predicate is a C-function that has the same number of arguments as the predicate represented. C-functions are provided to analyse the passed terms, convert them to basic C-types as well as to instantiate arguments using unification. Non-deterministic foreign predicates are supported, providing the foreign function with a handle to control backtracking.

C can call Prolog predicates, providing both an query interface and an interface to extract multiple solutions from a non-deterministic Prolog predicate. There is no limit to the nesting of Prolog calling C, calling Prolog, etc. It is also possible to write the ‘main’ in C and use Prolog as an embedded logical engine.

6.1 Overview of the Interface

A special include file called SWI-Prolog.h should be included with each C-source file that is to be loaded via the foreign interface. The installation process installs this file in the directory include in the SWI-Prolog home directory (?- current_prolog_flag(home, Home).). This C-header file defines various data types, macros and functions that can be used to communicate with SWI-Prolog. Functions and macros can be divided into the following categories:

- Analysing Prolog terms
- Constructing new terms
- Unifying terms
- Returning control information to Prolog
- Registering foreign predicates with Prolog
- Calling Prolog from C
- Recorded database interactions
- Global actions on Prolog (halt, break, abort, etc.)

6.2 Linking Foreign Modules

Foreign modules may be linked to Prolog in three ways. Using static linking, the extensions, a small description file and the basic SWI-Prolog object file are linked together to form a new executable. Using dynamic linking, the extensions are linked to a shared library (.so file on most Unix systems)
or dynamic-link library (.DLL file on Microsoft platforms) and loaded into the the running Prolog process.\footnote{The system also contains code to load .o files directly for some operating systems, notably Unix systems using the BSD a.out executable format. As the number of Unix platforms supporting this gets quickly smaller and this interface is difficult to port and slow, it is no longer described in this manual. The best alternatively would be to use the dld package on machines do not have shared libraries.}

6.2.1 What linking is provided?

The \textit{static linking} schema can be used on all versions of SWI-Prolog. Whether or not dynamic linking is supported can be deduced from the prolog-flag \texttt{open_shared_object} (see \texttt{current_prolog_flag/2}). If this prolog-flag yields true, \texttt{open_shared_object/2} and related predicates are defined. See section 6.4 for a suitable high-level interface to these predicates.

6.2.2 What kind of loading should I be using?

All described approaches have their advantages and disadvantages. Static linking is portable and allows for debugging on all platforms. It is relatively cumbersome and the libraries you need to pass to the linker may vary from system to system, though the utility program \texttt{plld} described in section 6.7 often hides these problems from the user.

Loading shared objects (DLL files on Windows) provides sharing and protection and is generally the best choice. If a saved-state is created using \texttt{qsave_program/[1,2]}, an \texttt{initialization/1} directive may be used to load the appropriate library at startup.

Note that the definition of the foreign predicates is the same, regardless of the linking type used.

6.3 Dynamic Linking of shared libraries

The interface defined in this section allows the user to load shared libraries (.so files on most Unix systems, .dll files on Windows). This interface is portable to Windows as well as to Unix machines providing \texttt{dlopen(2)} (Solaris, Linux, FreeBSD, Irix and many more) or \texttt{shl_open(2)} (HP/UX). It is advised to use the predicates from section 6.4 in your application.

\textbf{open\_shared\_object(+File, -Handle)}

\textit{File} is the name of a .so file (see your C programmers documentation on how to create a .so file). This file is attached to the current process and \textit{Handle} is unified with a handle to the shared object. Equivalent to \texttt{open\_shared\_object(File, [global], Handle)}. See also \texttt{load\_foreign\_library/[1,2]}.

On errors, an exception \texttt{shared\_object(Action, Message)} is raised. \textit{Message} is the return value from \texttt{dlerror()}. 

\textbf{open\_shared\_object(+File, +Options, -Handle)}

As \texttt{open\_shared\_object/2}, but allows for additional flags to be passed. \textit{Options} is a list of atoms. \texttt{now} implies the symbols are resolved immediately rather than lazy (default). \texttt{global} implies symbols of the loaded object are visible while loading other shared objects (by default they are local). Note that these flags may not be supported by your operating system. Check the documentation of dlopen() or equivalent on your operating system. Unsupported flags are silently ignored.
close_shared_object(+Handle)
   Detach the shared object identified by Handle.

call_shared_object_function(+Handle, +Function)
   Call the named function in the loaded shared library. The function is called without arguments and the return-value is ignored. Normally this function installs foreign language predicates using calls to PL_register_foreign().

6.4 Using the library shlib for .DLL and .SO files

This section discusses the functionality of the (autoload) library shlib.pl, providing an interface to shared libraries. This library can only be used if the prolog-flag open_shared_object is enabled.

load_foreign_library(+Lib, +Entry)
   Search for the given foreign library and link it to the current SWI-Prolog instance. The library may be specified with or without the extension. First, absolute_file_name/3 is used to locate the file. If this succeeds, the full path is passed to the low-level function to open the library. Otherwise, the plain library name is passed, exploiting the operating-system defined search mechanism for the shared library. The file_search_path/2 alias mechanism defines the alias foreign, which refers to the directories ⟨plhome⟩/lib/⟨arch⟩ and ⟨plhome⟩/lib, in this order.

   If the library can be loaded, the function called Entry will be called without arguments. The return value of the function is ignored.

   The Entry function will normally call PL_register_foreign() to declare functions in the library as foreign predicates.

load_foreign_library(+Lib)
   Equivalent to load_foreign_library/2. For the entry-point, this function first identifies the ‘base-name’ of the library, which is defined to be the file-name with path nor extension. It will then try the entry-point install-⟨base⟩. On failure it will try to function install(). Otherwise no install function will be called.

unload_foreign_library(+Lib)
   If the foreign library defines the function uninstall_⟨base⟩() or uninstall(), this function will be called without arguments and its return value is ignored. Next, abolish/2 is used to remove all known foreign predicates defined in the library. Finally the library itself is detached from the process.

current_foreign_library(-Lib, -Predicates)
   Query the currently loaded foreign libraries and their predicates. Predicates is a list with elements of the form Module:Head, indicating the predicates installed with PL_register_foreign() when the entry-point of the library was called.

Figure 6.1 connects a Windows message-box using a foreign function. This example was tested using Windows NT and Microsoft Visual C++ 2.0.
#include <windows.h>
#include <SWI-Prolog.h>

static foreign_t
pl_say_hello(term_t to)
{
  char *a;

  if ( PL_get_atom_chars(to, &a) )
    MessageBox(NULL, a, "DLL test", MB_OK|MB_TASKMODAL);

  PL_succeed;
}

PL_fail;

install_t
install()
{
  PL_register_foreign("say_hello", 1, pl_say_hello, 0);
}

Figure 6.1: MessageBox() example in Windows NT

6.4.1 Static Linking

Below is an outline of the files structure required for statically linking SWI-Prolog with foreign extensions. \
ldots/pl refers to the SWI-Prolog home directory (see current_prolog_flag/2). \langle arch \rangle refers to the architecture identifier that may be obtained using current_prolog_flag/2.

\ldots/pl/runtime/\langle arch \rangle/libpl.a  SWI-Library
\ldots/pl/include/SWI-Prolog.h  Include file
\ldots/pl/include/SWI-Stream.h  Stream I/O include file
\ldots/pl/include/SWI-Exports  Export declarations (AIX only)
\ldots/pl/include/stub.c  Extension stub

The definition of the foreign predicates is the same as for dynamic linking. Unlike with dynamic linking however, there is no initialisation function. Instead, the file \ldots/pl/include/stub.c may be copied to your project and modified to define the foreign extensions. Below is stub.c, modified to link the lowercase example described later in this chapter:

/* Copyright (c) 1991 Jan Wielemaker. All rights reserved.
   jan@swi.psy.uva.nl

   Purpose: Skeleton for extensions
*/

#include <stdio.h>
#include <SWI-Prolog.h>

extern foreign_t pl_lowercase(term, term);

PL_extension predicates[] =
{
    /*{ "name", arity, function, PL_FA_<flags> },*/
    { "lowercase", 2 pl_lowercase, 0 },
    { NULL, 0, NULL, 0 } /* terminating line */
};

int
main(int argc, char **argv)
{
    PL_register_extensions(predicates);

    if ( !PL_initialise(argc, argv) )
        PL_halt(1);

    PL_install_readline(); /* delete if not required */

    PL_halt(PL_toplevel() ? 0 : 1);
}

Now, a new executable may be created by compiling this file and linking it to libpl.a from the runtime directory and the libraries required by both the extensions and the SWI-Prolog kernel. This may be done by hand, or using the plld utility described in secretplld.

6.5 Interface Data types

6.5.1 Type term_t: a reference to a Prolog term

The principal data-type is term_t. Type term_t is what Quintus calls QP_term_ref. This name indicates better what the type represents: it is a handle for a term rather than the term itself. Terms can only be represented and manipulated using this type, as this is the only safe way to ensure the Prolog kernel is aware of all terms referenced by foreign code and thus allows the kernel to perform garbage-collection and/or stack-shifts while foreign code is active, for example during a callback from C.

A term reference is a C unsigned long, representing the offset of a variable on the Prolog environment-stack. A foreign function is passed term references for the predicate-arguments, one for each argument. If references for intermediate results are needed, such references may be created using PL_new_term_ref() or PL_new_term_refs(). These references normally live till the foreign function returns control back to Prolog. Their scope can be explicitly limited using PL_open_foreign_frame() and
A term *t* always refers to a valid Prolog term (variable, atom, integer, float or compound term). A term lives either until backtracking takes us back to a point before the term was created, the garbage collector has collected the term or the term was created after a `PL_open_foreign_frame()` and `PL_discard_foreign_frame()` has been called.

The foreign-interface functions can either *read*, *unify* or *write* to term-references. In the this document we use the following notation for arguments of type term *t*:

- `term_t +t` Accessed in read-mode. The ‘+’ indicates the argument is ‘input’.
- `term_t -t` Accessed in write-mode.
- `term_t ?t` Accessed in unify-mode.

Term references are obtained in any of the following ways.

- **Passed as argument**
  The C-functions implementing foreign predicates are passed their arguments as term-references. These references may be read or unified. Writing to these variables causes undefined behaviour.

- **Created by `PL_new_term_ref()`**
  A term created by `PL_new_term_ref()` is normally used to build temporary terms or be written by one of the interface functions. For example, `PL_get_arg()` writes a reference to the term-argument in its last argument.

- **Created by `PL_new_term.refs(int n)`**
  This function returns a set of term refs with the same characteristics as `PL_new_term_ref()`. See `PL_open_query()`.

- **Created by `PL_copy_term_ref(term_t t)`**
  Creates a new term-reference to the same term as the argument. The term may be written to. See figure 6.3.

Term-references can safely be copied to other C-variables of type term *t*, but all copies will always refer to the same term.

### `term_t PL_new_term_ref()`
Return a fresh reference to a term. The reference is allocated on the *local* stack. Allocating a term-reference may trigger a stack-shift on machines that cannot use sparse-memory management for allocation the Prolog stacks. The returned reference describes a variable.

### `term_t PL_new_term.refs(int n)`
Return *n* new term references. The first term-reference is returned. The others are *t* + 1, *t* + 2, etc. There are two reasons for using this function. `PL_open_query()` expects the arguments as a set of consecutive term references and *very* time-critical code requiring a number of term-references can be written as:

```c
pl_mypredicate(term_t a0, term_t a1)
{ term_t t0 = PL_new_term.refs(2);
  term_t t1 = t0+1;
```
6.5. INTERFACE DATA TYPES

\[
\cdots
\]

\[
}\)

term_t \texttt{PL\_copy\_term\_ref}(term_t \text{ from})
Create a new term reference and make it point initially to the same term as \text{ from}. This function
is commonly used to copy a predicate argument to a term reference that may be written.

\textbf{void} \texttt{PL\_reset\_term\_refs}(term_t \text{ after})
Destroy all term references that have been created after \text{ after}, including \text{ after} itself. Any refer-
ence to the invalidated term references after this call results in undefined behaviour.

Note that returning from the foreign context to Prolog will reclaim all references used in the
foreign context. This call is only necessary if references are created inside a loop that never exits
back to Prolog. See also \texttt{PL\_open\_foreign\_frame()}, \texttt{PL\_close\_foreign\_frame()} and \texttt{PL\_discard\_foreign\_frame()}.

\section*{Interaction with the garbage collector and stack-shifter}

Prolog implements two mechanisms for avoiding stack overflow: garbage collection and stack ex-
pansion. On machines that allow for it, Prolog will use virtual memory management to detect stack
overflow and expand the runtime stacks. On other machines Prolog will reallocate the stacks and up-
date all pointers to them. To do so, Prolog needs to know which data is referenced by C-code. As all
Prolog data known by C is referenced through term references (\text{ term}_t), Prolog has all information
necessary to perform its memory management without special precautions from the C-programmer.

\subsection*{6.5.2 Other foreign interface types}

\textbf{atom}_t An atom in Prologs internal representation. Atoms are pointers to an opaque structure. They
are a unique representation for represented text, which implies that atom \text{ A} represents the same
text as atom \text{ B} if-and-only-if \text{ A} and \text{ B} are the same pointer.

Atoms are the central representation for textual constants in Prolog The transformation of C a
character string to an atom implies a hash-table lookup. If the same atom is needed often, it is
advised to store its reference in a global variable to avoid repeated lookup.

\textbf{functor}_t A functor is the internal representation of a name/arity pair. They are used to find the name
and arity of a compound term as well as to construct new compound terms. Like atoms they
live for the whole Prolog session and are unique.

\textbf{predicate}_t Handle to a Prolog predicate. Predicate handles live forever (although they can loose
their definition).

\textbf{qid}_t Query Identifier. Used by \texttt{PL\_open\_query()}/\texttt{PL\_next\_solution()}/\texttt{PL\_close\_query()} to handle backtracking from C.

\textbf{fid}_t Frame Identifier. Used by \texttt{PL\_open\_foreign\_frame()}/\texttt{PL\_close\_foreign\_frame()}.

\textbf{module}_t A module is a unique handle to a Prolog module. Modules are used only to call predicates
in a specific module.
foreign_t  Return type for a C-function implementing a Prolog predicate.

control_t  Passed as additional argument to non-deterministic foreign functions. See PL_retry*() and PL_foreign_context*().

install_t  Type for the install() and uninstall() functions of shared or dynamic link libraries. See se-crefshlib.

6.6  The Foreign Include File

6.6.1  Argument Passing and Control

If Prolog encounters a foreign predicate at run time it will call a function specified in the predicate
definition of the foreign predicate. The arguments 1, \ldots, \text{arity} pass the Prolog arguments to the goal
as Prolog terms. Foreign functions should be declared of type foreign_t. Deterministic foreign
functions have two alternatives to return control back to Prolog:

\begin{verbatim}
void PL_succeed()
  Succeed deterministically. PL_succeed is defined as return TRUE.
\end{verbatim}

\begin{verbatim}
void PL_fail()
  Fail and start Prolog backtracking. PL_fail is defined as return FALSE.
\end{verbatim}

Non-deterministic Foreign Predicates

By default foreign predicates are deterministic. Using the PL_FA_NONDETERMINISTIC attribute
(see PL_register_foreign()) it is possible to register a predicate as a non-deterministic predic-
ate. Writing non-deterministic foreign predicates is slightly more complicated as the foreign function
needs context information for generating the next solution. Note that the same foreign function should
be prepared to be simultaneously active in more than one goal. Suppose the natural_number_below_n/2
is a non-deterministic foreign predicate, backtracking over all natural numbers lower than the first ar-
gument. Now consider the following predicate:

\begin{verbatim}
quotient_below_n(Q, N) :-
  natural_number_below_n(N, N1),
  natural_number_below_n(N, N2),
  Q =:= N1 / N2, !.
\end{verbatim}

In this predicate the function natural_number_below_n/2 simultaneously generates solutions for both
its invocations.

Non-deterministic foreign functions should be prepared to handle three different calls from Prolog:

\begin{itemize}
  \item \textit{Initial call (PL_FIRST_CALL)}
    Prolog has just created a frame for the foreign function and asks it to produce the first answer.
  \item \textit{Redo call (PL_REDO)}
    The previous invocation of the foreign function associated with the current goal indicated it was
    possible to backtrack. The foreign function should produce the next solution.
\end{itemize}
• **Terminate call (PL\_CUTTED)**  
The choice point left by the foreign function has been destroyed by a cut. The foreign function is given the opportunity to clean the environment.

Both the context information and the type of call is provided by an argument of type `control_t` appended to the argument list for deterministic foreign functions. The macro `PL\_foreign\_control()` extracts the type of call from the control argument. The foreign function can pass a context handle using the `PL\_retry\_*()` macros and extract the handle from the extra argument using the `PL\_foreign\_context\_*()` macro.

```c
void PL\_retry(long)
```

The foreign function succeeds while leaving a choice point. On backtracking over this goal the foreign function will be called again, but the control argument now indicates it is a ‘Redo’ call and the macro `PL\_foreign\_context()` will return the handle passed via `PL\_retry()`. This handle is a 30 bits signed value (two bits are used for status indication).

```c
void PL\_retry\_address(void *)
```

As `PL\_retry()`, but ensures an address as returned by `malloc()` is correctly recovered by `PL\_foreign\_context\_address()`.

```c
int PL\_foreign\_control(control_t)
```

Extracts the type of call from the control argument. The return values are described above. Note that the function should be prepared to handle the `PL\_CUTTED` case and should be aware that the other arguments are not valid in this case.

```c
long PL\_foreign\_context(control_t)
```

Extracts the context from the context argument. In the call type is `PL\_FIRST\_CALL` the context value is 0L. Otherwise it is the value returned by the last `PL\_retry()` associated with this goal (both if the call type is `PL\_REDO` as `PL\_CUTTED`).

```c
void * PL\_foreign\_context\_address(control_t)
```

Extracts an address as passed in by `PL\_retry\_address()`.

Note: If a non-deterministic foreign function returns using `PL\_succeed` or `PL\_fail`, Prolog assumes the foreign function has cleaned its environment. No call with control argument `PL\_CUTTED` will follow.

The code of figure 6.2 shows a skeleton for a non-deterministic foreign predicate definition.

### 6.6.2 Atoms and functors

The following functions provide for communication using atoms and functors.

```c
atom_t PL\_new\_atom(const char *)
```

Return an atom handle for the given C-string. This function always succeeds. The returned handle is valid as long as the atom is referenced (see section 6.6.2).

```c
const char* PL\_atom\_chars(atom_t atom)
```

Return a C-string for the text represented by the given atom. The returned text will not be changed by Prolog. It is not allowed to modify the contents, not even ‘temporary’ as the string
typedef struct /* define a context structure */
{ ...
} context;

foreign_t
my_function(term_t a0, term_t a1, foreign_t handle)
{ struct context * ctxt;

    switch( PL_foreign_control(handle) )
    { case PL_FIRST_CALL:
        ctxt = malloc(sizeof(struct context));
        ...
        PL_retry_address(ctxt);
        case PL_REDO:
        ctxt = PL_foreign_context_address(handle);
        ...
        PL_retry_address(ctxt);
        case PL_CUTTED:
        free(ctxt);
        PL_succeed;
    }
}

Figure 6.2: Skeleton for non-deterministic foreign functions
may reside in read-only memory. The returned string becomes invalid if the atom is garbage-collected (see section 6.6.2). Foreign functions that require the text from an atom passed in a term_t normally use PL_get_atom_chars() or PL_get_atom_nchars().

functor_t PL_new_functor(atom_t name, int arity)
  Returns a functor identifier, a handle for the name/arity pair. The returned handle is valid for the entire Prolog session.

atom_t PL_functor_name(functor_t f)
  Return an atom representing the name of the given functor.

int PL_functor arity(functor_t f)
  Return the arity of the given functor.

Atoms and atom-garbage collection

With the introduction of atom-garbage collection in version 3.3.0, atoms no longer live as long as the process. Instead, their lifetime is guaranteed only as long as they are referenced. In the single-threaded version, atom garbage collections are only invoked at the call-port. In the multi-threaded version (see section 4.39), they appear asynchronously, except for the invoking thread.

For dealing with atom garbage collection, two additional functions are provided:

void PL_register_atom(atom_t atom)
  Increment the reference count of the atom by one. PL_new_atom() performs this automatically, returning an atom with a reference count of at least one.\(^2\)

void PL_unregister_atom(atom_t atom)
  Decrement the reference count of the atom. If the reference-count drops below zero, an assertion error is raised.

Please note that the following two calls are different with respect to atom garbage collection:

PL_unify_atom_chars(t, "text");
PL_unify_atom(t, PL_new_atom("text"));

The latter increments the reference count of the atom text, which effectively ensures the atom will never be collected. It is advised to use the *_chars() or *_nchars() functions whenever applicable.

6.6.3 Analysing Terms via the Foreign Interface

Each argument of a foreign function (except for the control argument) is of type term_t, an opaque handle to a Prolog term. Three groups of functions are available for the analysis of terms. The first just validates the type, like the Prolog predicates var/1, atom/1, etc and are called PL_is_*(). The second group attempts to translate the argument into a C primitive type. These predicates take a term_t and a pointer to the appropriate C-type and return TRUE or FALSE depending on successful or unsuccessful translation. If the translation fails, the pointed-to data is never modified.

\(^2\)Otherwise asynchronous atom garbage collection might destroy the atom before it is used.
Testing the type of a term

```c
int PL_term_type(term_t)
```

Obtain the type of a term, which should be a term returned by one of the other interface predicates or passed as an argument. The function returns the type of the Prolog term. The type identifiers are listed below. Note that the extraction functions `PL_ge_t*()` also validate the type and thus the two sections below are equivalent.

```c
if ( PL_is_atom(t) )
{
    char *s;
    PL_get_atom_chars(t, &s);
    ...
}
```

or

```c
char *s;
if ( PL_get_atom_chars(t, &s) )
{
    ...
}
```

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL_VARIABLE</td>
<td>An unbound variable. The value of term as such is a unique identifier for the variable.</td>
</tr>
<tr>
<td>PL_ATOM</td>
<td>A Prolog atom.</td>
</tr>
<tr>
<td>PL_STRING</td>
<td>A Prolog string.</td>
</tr>
<tr>
<td>PL_INTEGER</td>
<td>A Prolog integer.</td>
</tr>
<tr>
<td>PL_FLOAT</td>
<td>A Prolog floating point number.</td>
</tr>
<tr>
<td>PL_TERM</td>
<td>A compound term. Note that a list is a compound term ./2.</td>
</tr>
</tbody>
</table>

The functions `PL_is_{type}` are an alternative to `PL_term_type()`. The test `PL_is_variable(term)` is equivalent to `PL_term_type(term) == PL_VARIABLE`, but the first is considerably faster. On the other hand, using a switch over `PL_term_type()` is faster and more readable then using an if-then-else using the functions below. All these functions return either `TRUE` or `FALSE`.

```c
int PL_is_variable(term_t)
```

Returns non-zero if `term` is a variable.

```c
int PL_is_atom(term_t)
```

Returns non-zero if `term` is an atom.

```c
int PL_is_string(term_t)
```

Returns non-zero if `term` is a string.

```c
int PL_is_integer(term_t)
```

Returns non-zero if `term` is an integer.
int PL_is_float(term_t)
   Returns non-zero if term is a float.

int PL_is_compound(term_t)
   Returns non-zero if term is a compound term.

int PL_is_functor(term_t, functor_t)
   Returns non-zero if term is a compound term and its functor is functor. This test is equivalent to
   PL_get_functor(), followed by testing the functor, but easier to write and faster.

int PL_is_list(term_t)
   Returns non-zero if term is a compound term with functor ./2 or the atom [].

int PL_is_atomic(term_t)
   Returns non-zero if term is atomic (not variable or compound).

int PL_is_number(term_t)
   Returns non-zero if term is an integer or float.

Reading data from a term

The functions PL_get_*() read information from a Prolog term. Most of them take two arguments.
   The first is the input term and the second is a pointer to the output value or a term-reference.

int PL_get_atom(term_t +t, atom_t *a)
   If t is an atom, store the unique atom identifier over a. See also PL_atom_chars() and
   PL_new_atom(). If there is no need to access the data (characters) of an atom, it is ad-
   vised to manipulate atoms using their handle. As the atom is referenced by t, it will live
   at least as long as t does. If longer live-time is required, the atom should be locked using
   PL_register_atom().

int PL_get_atom_chars(term_t +t, char **s)
   If t is an atom, store a pointer to a 0-terminated C-string in s. It is explicitly not allowed to
   modify the contents of this string. Some built-in atoms may have the string allocated in read-
   only memory, so ‘temporary manipulation’ can cause an error.

int PL_get_string_chars(term_t +t, char **s, int *len)
   If t is a string object, store a pointer to a 0-terminated C-string in s and the length of the string
   in len. Note that this pointer is invalidated by backtracking, garbage-collection and stack-shifts,
   so generally the only save operations are to pass it immediately to a C-function that doesn’t
   involve Prolog.

int PL_get_chars(term_t +t, char **s, unsigned flags)
   Convert the argument term t to a 0-terminated C-string. flags is a bitwise disjunction from two
   groups of constants. The first specifies which term-types should converted and the second how
   the argument is stored. Below is a specification of these constants. BUF_RING implies, if the
   data is not static (as from an atom), the data is copied to the next buffer from a ring of 16 buffers.
   This is a convenient way of converting multiple arguments passed to a foreign predicate to C-
   strings. If BUF_MALLOC is used, the data must be freed using free() when not needed any
   longer.
### Chapter 6. Foreign Language Interface

<table>
<thead>
<tr>
<th>CVT_ATOM</th>
<th>Convert if term is an atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVT_STRING</td>
<td>Convert if term is a string</td>
</tr>
<tr>
<td>CVT_LIST</td>
<td>Convert if term is a list of integers between 1 and 255</td>
</tr>
<tr>
<td>CVT_INTEGER</td>
<td>Convert if term is an integer (using %d)</td>
</tr>
<tr>
<td>CVT_FLOAT</td>
<td>Convert if term is a float (using %f)</td>
</tr>
<tr>
<td>CVT_NUMBER</td>
<td>Convert if term is an integer or float</td>
</tr>
<tr>
<td>CVT_ATOMIC</td>
<td>Convert term is atomic</td>
</tr>
<tr>
<td>CVT_VARIABLE</td>
<td>Convert variable to print-name</td>
</tr>
<tr>
<td>CVT_WRITE</td>
<td>Convert any term that is not converted by any of the</td>
</tr>
<tr>
<td></td>
<td>other flags using write/1. If no BUF_* is provided,</td>
</tr>
<tr>
<td></td>
<td>BUF_RING is implied.</td>
</tr>
<tr>
<td>CVT_ALL</td>
<td>Convert if term is any of the above, except for</td>
</tr>
<tr>
<td></td>
<td>CVT_VARIABLE and CVT_WRITE</td>
</tr>
<tr>
<td>BUF_DISCARDABLE</td>
<td>Data must copied immediately</td>
</tr>
<tr>
<td>BUF_RING</td>
<td>Data is stored in a ring of buffers</td>
</tr>
<tr>
<td>BUF_MALLOC</td>
<td>Data is copied to a new buffer returned by malloc(3)</td>
</tr>
</tbody>
</table>

```c
int PL_get_list_chars(+term_t t, char **s, unsigned flags)
Same as PL_get_chars(l, s, CVT_LIST—flags), provided flags contains no of the CVT_* flags.
```

```c
int PL_get_integer(+term_t t, int *i)
If t is a Prolog integer, assign its value over i. On 32-bit machines, this is the same as PL_get_long(), but avoids a warning from the compiler. See also PL_get_long().
```

```c
int PL_get_long(term_t +t, long *i)
If t is a Prolog integer, assign its value over i. Note that Prolog integers have limited value-range. If t is a floating point number that can be represented as a long, this function succeeds as well.
```

```c
int PL_get_pointer(term_t +t, void **ptr)
In the current system, pointers are represented by Prolog integers, but need some manipulation to make sure they do not get truncated due to the limited Prolog integer range. PL_put_pointer() / PL_get_pointer() guarantees pointers in the range of malloc() are handled without truncating.
```

```c
int PL_get_float(term_t +t, double *f)
If t is a float or integer, its value is assigned over f.
```

```c
int PL_get_functor(term_t +t, functor_t *f)
If t is compound or an atom, the Prolog representation of the name-arity pair will be assigned over f. See also PL_get_name arity() and PL_is_functor().
```

```c
int PL_get_name arity(term_t +t, atom_t *name, int *arity)
If t is compound or an atom, the functor-name will be assigned over name and the arity over arity. See also PL_get_functor() and PL_is_functor().
```

```c
int PL_get_module(term_t +t, module_t *module)
If t is an atom, the system will lookup or create the corresponding module and assign an opaque pointer to it over module.
```
int PL_get_arg(int index, term t +t, term t -a)
   If t is compound and index is between 1 and arity (including), assign a with a term-reference to the argument.

int PL_get_arg(int index, term t +t, term t -a)
   Same as PL_get_arg(), but no checking is performed, nor whether t is actually a term, nor whether index is a valid argument-index.

Exchanging text using length and string

All internal text-representation of SWI-Prolog is represented using char * plus length and allow for 0-bytes in them. The foreign library supports this by implementing a *_nchars() function for each applicable *_chars() function. Below we briefly present the signatures of these functions. For full documentation consult the *_chars() function.

int PL_get_atom_nchars(term t, unsigned int len, char **s)

int PL_get_list_nchars(term t, unsigned int len, char **s)

int PL_get_nchars(term t, unsigned int len, char **s, unsigned int flags)

int PL_put_atom_nchars(term t, unsigned int len, const char *s)

int PL_put_string_nchars(term t, unsigned int len, const char *s)

int PL_put_list_ncodes(term t, unsigned int len, const char *s)

int PL_put_list_nchars(term t, unsigned int len, const char *s)

int PL_unify_atom_nchars(term t, unsigned int len, const char *s)

int PL_unify_string_nchars(term t, unsigned int len, const char *s)

int PL_unify_list_ncodes(term t, unsigned int len, const char *s)

int PL_unify_list_nchars(term t, unsigned int len, const char *s)

In addition, the following functions are available for creating and inspecting atoms:

atom t PL_new_atom_nchars(unsigned int len, const char *s)
   Create a new atom as PL_new_atom(), but from length and characters.
const char * PL_atom_nchars(atom_t a, unsigned int *len)
    Extract text and length of an atom.

Reading a list

The functions from this section are intended to read a Prolog list from C. Suppose we expect a list of atoms, the following code will print the atoms, each on a line:

```c
foreign_t
pl_write_atoms(term_t l)
{ term_t head = PL_new_term_ref(); /* variable for the elements */
    term_t list = PL_copy_term_ref(l); /* copy as we need to write */

    while( PL_get_list(list, head, list) )
    { char *s;

        if ( PL_get_atom_chars(head, &s) )
            Sprintf("%s\n", s);
        else
            PL_fail;
    }

    return PL_get_nil(list); /* test end for [] */
}
```

```c
int PL_get_list(term_t +l, term_t -h, term_t -t)
    If l is a list and not [] assign a term-reference to the head to h and to the tail to t.

int PL_get_head(term_t +l, term_t -h)
    If l is a list and not [] assign a term-reference to the head to h.

int PL_get_tail(term_t +l, term_t -t)
    If l is a list and not [] assign a term-reference to the tail to t.

int PL_get_nil(term_t +l)
    Succeeds if represents the atom [].
```

An example: defining write/1 in C

Figure 6.3 shows a simplified definition of write/1 to illustrate the described functions. This simplified version does not deal with operators. It is called display/1, because it mimics closely the behaviour of this Edinburgh predicate.

6.6.4 Constructing Terms

Terms can be constructed using functions from the PL_put_*() and PL_cons_*() families. This approach builds the term ‘inside-out’, starting at the leaves and subsequently creating compound
6.6. THE FOREIGN INCLUDE FILE

foreign_t
pl_display(term_t t)
{ functor_t functor;
  int arity, len, n;
  char *s;

  switch( PL_term_type(t) )
  { case PL_VARIABLE:
    case PL_ATOM:
    case PL_INTEGER:
    case PL_FLOAT:
      PL_get_chars(t, &s, CVT_ALL);
      Sprintf("%s", s);
      break;
    case PL_STRING:
      PL_get_string_chars(t, &s, &len);
      Sprintf("\"%s\"", s);
      break;
    case PL_TERM:
      { term_t a = PL_new_term_ref();

        PL_get_name arity(t, &name, &arity);
        Sprintf("%s", PL_atom_chars(name));
        for(n=1; n<=arity; n++)
          { PL_get_arg(n, t, a);
            if ( n > 1 )
              Sprintf("",");
            pl_display(a);
          }
        Sprintf(")");
        break;
      }
      default: /* should not happen */
      }

  PL_succeed;
}

Figure 6.3: A Foreign definition of display/1
This section discusses functions for the first approach. This approach is generally used for creating arguments for \texttt{PL_call()} and \texttt{PL_open_query}.

\begin{verbatim}
void \texttt{PL\_put\_variable}(term t -t)
    Put a fresh variable in the term. The new variable lives on the global stack. Note that the initial variable lives on the local stack and is lost after a write to the term-references. After using this function, the variable will continue to live.

void \texttt{PL\_put\_atom}(term t -t, atom t a)
    Put an atom in the term reference from a handle. See also \texttt{PL\_new\_atom()} and \texttt{PL\_atom\_chars()}.

void \texttt{PL\_put\_atom\_chars}(term t -t, const char *chars)
    Put an atom in the term-reference constructed from the 0-terminated string. The string itself will never be references by Prolog after this function.

void \texttt{PL\_put\_string\_chars}(term t -t, const char *chars)
    Put a zero-terminated string in the term-reference. The data will be copied. See also \texttt{PL\_put\_string\_nchars()}.

void \texttt{PL\_put\_string\_nchars}(term t -t, unsigned int len, const char *chars)
    Put a string, represented by a length/start pointer pair in the term-reference. The data will be copied. This interface can deal with 0-bytes in the string. See also section 6.6.18.

void \texttt{PL\_put\_list\_chars}(term t -t, const char *chars)
    Put a list of ASCII values in the term-reference.

void \texttt{PL\_put\_integer}(term t -t, long i)
    Put a Prolog integer in the term reference.

void \texttt{PL\_put\_pointer}(term t -t, void *ptr)
    Put a Prolog integer in the term-reference. Provided ptr is in the 'malloc()-area', \texttt{PL\_get\_pointer()} will get the pointer back.

void \texttt{PL\_put\_float}(term t -t, double f)
    Put a floating-point value in the term-reference.

void \texttt{PL\_put\_functor}(term t -t, functor t functor)
    Create a new compound term from functor and bind t to this term. All arguments of the term will be variables. To create a term with instantiated arguments, either instantiate the arguments using the \texttt{PL\_unify\_*()} functions or use \texttt{PL\_cons\_functor()}.

void \texttt{PL\_put\_list}(term t -l)
    Same as \texttt{PL\_put\_functor(l, PL\_new\_functor(PL\_new\_atom("."), 2))}.

void \texttt{PL\_put\_nil}(term t -l)
    Same as \texttt{PL\_put\_atom\_chars("[]")}.
\end{verbatim}
6.6. THE FOREIGN INCLUDE FILE

void **PL_put_term(term_t t1, term_t t2)
Make t1 point to the same term as t2.

void **PL_cons_functor(term_t h, functor_t f, ...)
Create a term, whose arguments are filled from variable argument list holding the same number
of term_t objects as the arity of the functor. To create the term animal(gnu, 50), use:

{ term_t a1 = PL_new_term_ref();
  term_t a2 = PL_new_term_ref();
  term_t t = PL_new_term_ref();
  functor_t animal2;

  /* animal2 is a constant that may be bound to a global
     variable and re-used */
  animal2 = PL_new_functor(PL_new_atom("animal"), 2);

  PL_put_atom_chars(a1, "gnu");
  PL_put_integer(a2, 50);
  PL_cons_functor(t, animal2, a1, a2);
}

After this sequence, the term-references a1 and a2 may be used for other purposes.

void **PL_cons_functor_v(term_t h, functor_t f, term_t a0)
Creates a compound term like **PL_cons_functor(), but a0 is an array of term references
as returned by **PL_new_term_refs(). The length of this array should match the number
of arguments required by the functor.

void **PL_cons_list(term_t l, term_t h, term_t t)
Create a list (cons-) cell in l from the head and tail. The code below creates a list of atoms from
a char **. The list is built tail-to-head. The **PL_unify_*() functions can be used to build
a list head-to-tail.

void
put_list(term_t l, int n, char **words)
{ term_t a = PL_new_term_ref();

  PL_put_nil(l);
  while( --n >= 0 )
  { PL_put_atom_chars(a, words[n]);
    PL_cons_list(l, a, l);
  }
}

Note that l can be redefined within a **PL_cons_list call as shown here because operationally
its old value is consumed before its new value is set.
6.6.5 Unifying data

The functions of this section unify terms with other terms or translated C-data structures. Except for PL_unify(), the functions of this section are specific to SWI-Prolog. They have been introduced to make translation of old code easier, but also because they provide for a faster mechanism for returning data to Prolog that requires less term-references. Consider the case where we want a foreign function to return the host name of the machine Prolog is running on. Using the PL_get_*() and PL_put_*( ) functions, the code becomes:

```c
foreign_t
pl_hostname(term_t name)
{ char buf[100];

    if ( gethostname(buf, sizeof(buf)) )
    { term_t tmp = PL_new_term_ref();

        PL_put_atom_chars(tmp, buf);
        return PL_unify(name, buf);
    }

    PL_fail;
}
```

Using PL_unify_atom_chars( ), this becomes:

```c
foreign_t
pl_hostname(term_t name)
{ char buf[100];

    if ( gethostname(buf, sizeof(buf)) )
        return PL_unify_atom_chars(name, buf);

    PL_fail;
}
```

int PL_unify(term_t ?t1, term_t ?t2)
Unify two Prolog terms and return non-zero on success.

int PL_unify_atom(term_t ?t, atom_t a)
Unify t with the atom a and return non-zero on success.

int PL_unify_atom_chars(term_t ?t, const char *chars)
Unify t with an atom created from chars and return non-zero on success.

int PL_unify_list_chars(term_t ?t, const char *chars)
Unify t with a list of ASCII characters constructed from chars.

void PL_unify_string_chars(term_t ?t, const char *chars)
Unify t with a Prolog string object created from the zero-terminated string chars. The data will be copied. See also PL_unify_string_nchars().
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void PL_unify_string_nchars(term_t ?t, unsigned int len, const char *chars)
    Unify t with a Prolog string object created from the string created from the len/chars pair. The data will be copied. This interface can deal with 0-bytes in the string. See also section 6.6.18.

int PL_unify_integer(term_t ?t, long n)
    Unify t with a Prolog integer from n.

int PL_unify_float(term_t ?t, double f)
    Unify t with a Prolog float from f.

int PL_unify_pointer(term_t ?t, void *ptr)
    Unify t with a Prolog integer describing the pointer. See also PL_put_pointer() and PL_get_pointer().

int PL_unify_functor(term_t ?t, functor_t f)
    If t is a compound term with the given functor, just succeed. If it is unbound, create a term and bind the variable, else fails. Not that this function does not create a term if the argument is already instantiated.

int PL_unify_list(term_t ?l, term_t -h, term_t -t)
    Unify l with a list-cell (/2). If successful, write a reference to the head of the list to h and a reference to the tail of the list in t. This reference may be used for subsequent calls to this function. Suppose we want to return a list of atoms from a char **. We could use the example described by PL_put_list(), followed by a call to PL_unify(), or we can use the code below. If the predicate argument is unbound, the difference is minimal (the code based on PL_put_list() is probably slightly faster). If the argument is bound, the code below may fail before reaching the end of the word-list, but even if the unification succeeds, this code avoids a duplicate (garbage) list and a deep unification.

foreign_t
pl_get_environ(term_t env)
{ term_t l = PL_copy_term_ref(env);
  term_t a = PL_new_term_ref();
  extern char **environ;
  char **e;

  for(e = environ; *e; e++)
  { if ( !PL_unify_list(l, a, l) ||
          !PL_unify_atom_chars(a, *e) )
      PL_fail;
  }

  return PL_unify_nil(l);
}

int PL_unify_nil(term_t ?l)
    Unify l with the atom [].

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int PL_unify_arg(int index, term \*t, term \*a)
    Unifies the index-th argument (1-based) of t with a.

int PL_unify_term(term \*t, ...
    Unify t with a (normally) compound term. The remaining arguments is a sequence of a type identifier, followed by the required arguments. This predicate is an extension to the Quintus and SICStus foreign interface from which the SWI-Prolog foreign interface has been derived, but has proved to be a powerful and comfortable way to create compound terms from C. Due to the vararg packing/unpacking and the required type-switching this interface is slightly slower than using the primitives. Please note that some bad C-compilers have fairly low limits on the number of arguments that may be passed to a function.

Special attention is required when passing numbers. C ‘promotes’ any integral smaller than int to int. I.e. the types char, short and int are all passed as int. In addition, on most 32-bit platforms int and long are the same. Upto version 4.0.5, only PL_INTEGER could be specified which was taken from the stack as long. Such code fails when passing small integral types on machines where int is smaller than long. It is advised to use PL_SHORT, PL_INT or PL_LONG as appropriate. Similar, C compilers promote float to double and therefore PL_FLOAT and PL_DOUBLE are synonyms.

The type identifiers are:

**PL_VARIABLE none**
    No op. Used in arguments of PL_FUNCTOR.

**PL_ATOM atom**
    Unify the argument with an atom, as in PL_unify_atom().

**PL_SHORT short**
    Unify the argument with an integer, as in PL_unify_integer(). As short is promoted to int, PL_SHORT is a synonym for PL_INT.

**PL_INT int**
    Unify the argument with an integer, as in PL_unify_integer().

**PL_LONG long**
    Unify the argument with an integer, as in PL_unify_integer().

**PL_INTEGER long**
    Unify the argument with an integer, as in PL_unify_integer().

**PL_DOUBLE double**
    Unify the argument with a float, as in PL_unify_float(). Note that, as the argument is passed using the C vararg conventions, a float must be casted to a double explicitly.

**PL_FLOAT double**
    Unify the argument with a float, as in PL_unify_float().

**PL_POINTER void**
    Unify the argument with a pointer, as in PL_unify_pointer().

**PL_STRING const char**
    Unify the argument with a string object, as in PL_unify_string_chars().

**PL_TERM term**
    Unify a subterm. Note this may the return value of a PL_new_term_ref() call to get access to a variable.
PL_CHARS *const char *
    Unify the argument with an atom, constructed from the C char *, as in
    PL_unify_atom_chars().

PL_FUNCTOR functor f, . . .
    Unify the argument with a compound term. This specification should be followed by
    exactly as many specifications as the number of arguments of the compound term.

PL_FUNCTOR_CHARS const char *name, int arity, . . .
    Create a functor from the given name and arity and then behave as PL_FUNCTOR.

PL_LIST int length, . . .
    Create a list of the indicated length. The following arguments contain the elements of the
    list.

For example, to unify an argument with the term language(dutch), the following skeleton
may be used:

    static functor_t FUNCTOR_language1;

    static void
    init_constants()
    { FUNCTOR_language1 = PL_new_functor(PL_new_atom("language"), 1);
    }

    foreign_t
    pl_get_lang(term_t r)
    { return PL_unify_term(r,
        PL_FUNCTOR, FUNCTOR_language1,
        PL_CHARS, "dutch");
    }

    install_t
    install()
    { PL_register_foreign("get_lang", 1, pl_get_lang, 0);
        init_constants();
    }

int PL_chars_to_term(const char *chars, term t - t)
    Parse the string chars and put the resulting Prolog term into t. chars may or may not be closed
    using a Prolog full-stop (i.e., a dot followed by a blank). Returns FALSE if a syntax error
    was encountered and TRUE after successful completion. In addition to returning FALSE, the
    exception-term is returned in t on a syntax error. See also term_to_atom/2.

    The following example build a goal-term from a string and calls it.

    int
    call_chars(const char *goal)
    { fid_t fid = PL_open_foreign_frame();
    }
term_t g = PL_new_term_ref();
BOOL rval;
if ( PL_string_to_term(goal, g) )
    rval = PL_call(goal, NULL);
else
    rval = FALSE;

PL_discard_foreign_frame(fid);
return rval;
}

... call_chars("consult(load)"); ...

char * PL_quote(int chr, const char *string)
Return a quoted version of string. If chr is '\\', the result is a quoted atom. If chr is '"',
the result is a string. The result string is stored in the same ring of buffers as described with the
BUF_RING argument of PL_get_chars();

In the current implementation, the string is surrounded by chr and any occurrence of chr is
doubled. In the future the behaviour will depend on the character_escape prolog-flag.
See current_prolog_flag/2.

6.6.6 Calling Prolog from C

The Prolog engine can be called from C. There are two interfaces for this. For the first, a term is
created that could be used as an argument to call/1 and next PL_call() is used to call Prolog.
This system is simple, but does not allow to inspect the different answers to a non-deterministic goal
and is relatively slow as the runtime system needs to find the predicate. The other interface is based on
PL_open_query(), PL_next_solution() and PL_cut_query() or PL_close_query().
This mechanism is more powerful, but also more complicated to use.

Predicate references

This section discusses the functions used to communicate about predicates. Though a Prolog predicate
may defined or not, redefined, etc., a Prolog predicate has a handle that is not destroyed, nor moved.
This handle is known by the type predicate_t.

predicate_t PL_pred(functor_t f, module_t m)
Return a handle to a predicate for the specified name/arity in the given module. This function
always succeeds, creating a handle for an undefined predicate if no handle was available.

predicate_t PL_predicate(const char *name, int arity, const char* module)
Same a PL_pred(), but provides a more convenient interface to the C-programmer.
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```c
void PL_predicate_info(predicate_t p, atom_t *n, int *a, module_t *m)
```

Return information on the predicate `p`. The name is stored over `n`, the arity over `a`, while `m` receives the definition module. Note that the latter need not be the same as specified with `PL_predicate()`. If the predicate was imported into the module given to `PL_predicate()`, this function will return the module where the predicate was defined.

**Initiating a query from C**

This section discusses the functions for creating and manipulating queries from C. Note that a foreign context can have at most one active query. This implies it is allowed to make strictly nested calls between C and Prolog (Prolog calls C, calls Prolog, calls C, etc., but it is **not** allowed to open multiple queries and start generating solutions for each of them by calling `PL_next_solution()`). Be sure to call `PL_cut_query()` or `PL_close_query()` on any query you opened before opening the next or returning control back to Prolog.

```c
qid_t PL_open_query(module_t ctx, int flags, predicate_t p, term_t +t0)
```

Opens a query and returns an identifier for it. This function always succeeds, regardless whether the predicate is defined or not. `ctx` is the context module of the goal. When `NULL`, the context module of the calling context will be used, or `user` if there is no calling context (as may happen in embedded systems). Note that the context module only matters for `module_transparent` predicates. See `context_module/1` and `module_transparent/1`. The `p` argument specifies the predicate, and should be the result of a call to `PL_pred()` or `PL_predicate()`. Note that it is allowed to store this handle as global data and reuse it for future queries. The term-reference `t0` is the first of a vector of term-references as returned by `PL_new_term_refs(n)`.

The `flags` arguments provides some additional options concerning debugging and exception handling. It is a bitwise or of the following values:

- **PL_Q_NORMAL**
  Normal operation. The debugger inherits its settings from the environment. If an exception occurs that is not handled in Prolog, a message is printed and the tracer is started to debug the error.\(^3\)

- **PL_Q_NODEBUG**
  Switch off the debugger while executing the goal. This option is used by many calls to hook-predicates to avoid tracing the hooks. An example is `print/1` calling `portray/1` from foreign code.

- **PL_Q_CATCH_EXCEPTION**
  If an exception is raised while executing the goal, do not report it, but make it available for `PL_exception()`.

- **PL_Q_PASS_EXCEPTION**
  As **PL_Q_CATCH_EXCEPTION**, but do not invalidate the exception-term while calling `PL_close_query()`. This option is experimental.

The example below opens a query to the predicate `is_a/2` to find the ancestor of for some name.

---

\(^3\)Do not pass the integer 0 for normal operation, as this is interpreted as **PL_Q_NODEBUG** for backward compatibility reasons.
char *
ancestor(const char *me)
{
    term_t a0 = PL_new_term_refs(2);
    static predicate_t p;

    if ( !p )
        p = PL_predicate("is_a", 2, "database");

    PL_put_atom_chars(a0, me);
    PL_open_query(NULL, PL_Q_NORMAL, p, a0);
    ...
}

int PL_next_solution(qid_t qid)
Generate the first (next) solution for the given query. The return value is TRUE if a solution was found, or FALSE to indicate the query could not be proven. This function may be called repeatedly until it fails to generate all solutions to the query.

void PL_cut_query(qid)
Discards the query, but does not delete any of the data created by the query. It just invalidate qid, allowing for a new call to PL_open_query() in this context.

void PL_close_query(qid)
As PL_cut_query(), but all data and bindings created by the query are destroyed.

int PL_call_predicate(module_t m, int flags, predicate_t pred, term_t +t0)
Shorthand for PL_open_query(), PL_next_solution(), PL_cut_query(), generating a single solution. The arguments are the same as for PL_open_query(), the return value is the same as PL_next_solution().

int PL_call(term_t, module_t)
Call term just like the Prolog predicate once/1. Term is called in the specified module, or in the context module if module_t = NULL. Returns TRUE if the call succeeds, FALSE otherwise. Figure 6.4 shows an example to obtain the number of defined atoms. All checks are omitted to improve readability.

6.6.7 Discarding Data
The Prolog data created and term-references needed to setup the call and/or analyse the result can in most cases be discarded right after the call. PL_close_query() allows for destructing the data, while leaving the term-references. The calls below may be used to destroy term-references and data. See figure 6.4 for an example.

fid_t PL_open_foreign_frame()
Created a foreign frame, holding a mark that allows the system to undo bindings and destroy data created after it as well as providing the environment for creating term-references. This function is called by the kernel before calling a foreign predicate.
int count_atoms()
{
    fid_t fid = PL_open_foreign_frame();
    term_t goal = PL_new_term_ref();
    term_t a1 = PL_new_term_ref();
    term_t a2 = PL_new_term_ref();
    functor_t s2 = PL_new_functor(PL_new_atom("statistics"), 2);
    int atoms;

    PL_put_atom_chars(a1, "atoms");
    PL_cons_functor(goal, s2, a1, a2);
    PL_call(goal, NULL); /* call it in current module */

    PL_get_integer(a2, &atoms);
    PL_discard_foreign_frame(fid);

    return atoms;
}

Figure 6.4: Calling Prolog

void PL_close_foreign_frame(fid_t id)
Discard all term-references created after the frame was opened. All other Prolog data is retained.
This function is called by the kernel whenever a foreign function returns control back to Prolog.

void PL_discard_foreign_frame(fid_t id)
Same as PL_close_foreign_frame(), but also undo all bindings made since the open and
destroy all Prolog data.

void PL_rewind_foreign_frame(fid_t id)
Undo all bindings and discard all term-references created since the frame was created, but does
not pop the frame. I.e. the same frame can be rewinded multiple times, and must eventually be
closed or discarded.

It is obligatory to call either of the two closing functions to discard a foreign frame. Foreign
frames may be nested.

6.6.8 Foreign Code and Modules

Modules are identified via a unique handle. The following functions are available to query and ma-
nipulate modules.

module_t PL_context()
    Return the module identifier of the context module of the currently active foreign predicate.

int PL_strip_module(term_t *raw, module_t *m, term_t -plain)
    Utility function. If raw is a term, possibly holding the module construct ⟨module⟩:⟨rest⟩ this
    function will make plain a reference to ⟨rest⟩ and fill module * with ⟨module⟩. For further
nested module constructs the inner most module is returned via module *. If raw is not a module construct arg will simply be put in plain. If module * is NULL it will be set to the context module. Otherwise it will be left untouched. The following example shows how to obtain the plain term and module if the default module is the user module:

```c
{ module m = PL_new_module(PL_new_atom("user"));
    term_t plain = PL_new_term_ref();

    PL_strip_module(term, &m, plain);
    ...
```

atom_t `PL_module_name(module_t)`
Return the name of module as an atom.

module_t `PL_new_module(atom_t name)`
Find an existing or create a new module with name specified by the atom name.

### 6.6.9 Prolog exceptions in foreign code

This section discusses `PL_exception()`, `PL_throw()` and `PL_raise_exception()`, the interface functions to detect and generate Prolog exceptions from C-code. `PL_throw()` and `PL_raise_exception()` from the C-interface to raise an exception from foreign code. `PL_throw()` exploits the C-function `longjmp()` to return immediately to the innermost `PL_next_solution()`. `PL_raise_exception()` registers the exception term and returns FALSE. If a foreign predicate returns FALSE, while an exception-term is registered a Prolog exception will be raised by the virtual machine.

Calling these functions outside the context of a function implementing a foreign predicate results in undefined behaviour.

`PL_exception()` may be used after a call to `PL_next_solution()` fails, and returns a term reference to an exception term if an exception was raised, and 0 otherwise.

If a C-function, implementing a predicate calls Prolog and detects an exception using `PL_exception()`, it can handle this exception, or return with the exception. Some caution is required though. It is **not** allowed to call `PL_close_query()` or `PL_discard_foreign_frame()` afterwards, as this will invalidate the exception term. Below is the code that calls a Prolog defined arithmetic function (see `arithmetic_function/1`).

If `PL_next_solution()` succeeds, the result is analysed and translated to a number, after which the query is closed and all Prolog data created after `PL_open_foreign_frame()` is destroyed. On the other hand, if `PL_next_solution()` fails and if an exception was raised, just pass it. Otherwise generate an exception (`PL_error()` is an internal call for building the standard error terms and calling `PL_raise_exception()`). After this, the Prolog environment should be discarded using `PL_cut_query()` and `PL_close_foreign_frame()` to avoid invalidating the exception term.

```c
static int prologFunction(ArithFunction f, term_t av, Number r)
{ int arity = f->proc->definition->functor->arity;
    fid_t fid = PL_open_foreign_frame();
```
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qid_t qid;
int rval;

qid = PL_open_query(NULL, PL_Q_NORMAL, f->proc, av);

if ( PL_next_solution(qid) )
{
  rval = valueExpression(av+arity-1, r);
  PL_close_query(qid);
  PL_discard_foreign_frame(fid);
} else
{
  term_t except;
  if ( (except = PL_exception(qid)) )
  {
    rval = PL_throw(except); /* pass exception */
  } else
  {
    char *name = stringAtom(f->proc->definition->functor->name);
    /* generate exception */
    rval = PL_error(name, arity-1, NULL, ERR_FAILED, f->proc);
  }

  PL_cut_query(qid); /* dont destroy data */
  PL_close_foreign_frame(fid); /* same */
}

return rval;
}

int PL_raise_exception(term_t exception)
Generate an exception (as throw/1) and return FALSE. Below is an example returning an
exception from foreign predicate:

foreign_t
pl_hello(term_t to)
{
  char *s;

  if ( PL_get_atom_chars(to, &s) )
  {
    Sprintf("Hello \"%s\"\n", s);
    PL_succeed;
  } else
  {
     term_t except = PL_new_term_ref();

     PL_unify_term(except,
                   PL_FUNCTOR_CHARS, "type_error", 2,
                   PL_CHARS, "atom",}
PL_TERM, to);

    return PL_raise_exception(except);
  }
}

int PL_throw(term t exception)
Similar to PL_raise_exception(), but returns using the C longjmp() function to the innermost PL_next_solution().

term t PL_exception(qid t qid)
If PL_next_solution() fails, this can be due to normal failure of the Prolog call, or because an exception was raised using throw/1. This function returns a handle to the exception term if an exception was raised, or 0 if the Prolog goal simply failed.4.

6.6.10 Foreign code and Prolog threads

If SWI-Prolog has been build to support multi-threading (see section 4.39), all foreign-code linked to Prolog should be thread-safe (reentrant) or guarded in Prolog using with_mutex/2 from simultaneous access from multiple Prolog threads. On Unix systems, this generally implies the code should be compiled with the -D_REENTRANT flag passed to the compiler. Please note that on many Unix systems not all systemcalls and library-functions are thread-safe. Consult your manual for details.

If you are using SWI-Prolog as an embedded engine in a multi-threaded application you can access the Prolog engine from multiple threads by creating an engine in each thread from which you call Prolog. Without creating an engine, a thread can only use functions that do not use the term_t type (for example PL_new_atom()).

Please note that the interface below will only work if threading in your application is based on the same thread-library as used to compile SWI-Prolog.

int PL_thread_self()
Returns the integer Prolog identifier of the engine or -1 if the calling thread has no Prolog engine. This function is also provided in the single-threaded version of SWI-Prolog, where it returns -2.

int PL_thread_attach_engine(PL_thread_attr_t *attr)
Creates a new Prolog engine in the calling thread. If the calling thread already has an engine the reference count of the engine is incremented. The attr argument can be NULL to create a thread with default attributes. Otherwise it is a pointer to a structure with the definition below. For any field with value ‘0’, the default is used.

typedef struct
{ unsigned long local_size; /* Stack sizes (K-bytes) */
  unsigned long global_size;
  unsigned long trail_size;

4This interface differs in two ways from Quintus. The calling predicates simp,y signal failure if an exception was raised, and a term referenced is returned, rather passed and filled with the error term. Exceptions can only be handled using the PL_next_solution() interface, as a handle to the query is required

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unsigned long argument_size;
char * alias; /* alias name */
} PL_thread_attr_t;

The structure may be destroyed after PL_thread_attach_engine() has returned. If an error occurs, -1 is returned. If this Prolog is not compiled for multi-threading, -2 is returned.

int PL_thread_destroy_engine()
Destroy the Prolog engine in the calling thread. Only takes effect if PL_thread_destroy_engine() is called as many times as PL_thread_attach_engine() in this thread. Returns TRUE on success and FALSE if the calling thread has no engine or this Prolog does not support threads.

Please note that construction and destruction of engines are relatively expensive operations. Only destroy an engine if performance is not critical and memory is a critical resource. The engine is automatically destroyed if the thread finishes, regardless how many times PL_thread_attach_engine() has been called.

6.6.11 Miscellaneous

Term Comparison

int PL_compare(term_t t1, term_t t2)
Compares two terms using the standard order of terms and returns -1, 0 or 1. See also compare/3.

int PL_same_compound(term_t t1, term_t t2)
Yields TRUE if t1 and t2 refer to physically the same compound term and FALSE otherwise.

Recorded database

In some applications it is useful to store and retrieve Prolog terms from C-code. For example, the XPCE graphical environment does this for storing arbitrary Prolog data as slot-data of XPCE objects.

Please note that the returned handles have no meaning at the Prolog level and the recorded terms are not visible from Prolog. The functions PL_recorded() and PL_erase() are the only functions that can operate on the stored term.

Two groups of functions are provided. The first group (PL_record() and friends) store Prolog terms on the Prolog heap for retrieval during the same session. These functions are also used by recorda/3 and friends. The recorded database may be used to communicate Prolog terms between threads.

record_t PL_record(term_t t +t)
Record the term t into the Prolog database as recorda/3 and return an opaque handle to the term. The returned handle remains valid until PL_erase() is called on it. PL_recorded() is used to copy recorded terms back to the Prolog stack.

void PL_recorded(record_t record, term_t +t)
Copy a recorded term back to the Prolog stack. The same record may be used to copy multiple instances at any time to the Prolog stack. See also PL_record() and PL_erase().

---

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void PL_erase(record_t record)

Remove the recorded term from the Prolog database, reclaiming all associated memory resources.

The second group (headed by PL_record_external()) provides the same functionality, but the returned data has properties that enable storing the data on an external device. It has been designed to make it possible to store Prolog terms fast and compact in an external database. Here are the main features:

- **Independent of session**
  Records can be communicated to another Prolog session and made visible using PL_recorded_external().

- **Binary**
  The representation is binary for maximum performance. The returned data may contain 0-bytes.

- **Byte-order independent**
  The representation can be transferred between machines with different byte-order.

- **No alignment restrictions**
  There are no memory alignment restrictions and copies of the record can thus be moved freely. For example, it is possible to use this representation to exchange terms using shared memory between different Prolog processes.

- **Compact**
  It is assumed that a smaller memory footprint will eventually outperform slightly faster representations.

- **Stable**
  The format is designed for future enhancements without breaking compatibility with older records.

char * PL_record_external(term_t +t, unsigned int *len)

Record the term $t$ into the Prolog database as recorda/3 and return an opaque handle to the term. The returned handle remains valid until PL_erase() is called on it.

It is allowed to copy the data and use PL_recorded_external() on the copy. The user is responsible for the memory management of the copy. After copying, the original may be discarded using PL_erase_external().

PL_recorded_external() is used to copy such recorded terms back to the Prolog stack.

int PL_recorded_external(const char *record, term_t -t)

Copy a recorded term back to the Prolog stack. The same record may be used to copy multiple instances at any time to the Prolog stack. See also PL_record_external() and PL_erase_external().

int PL_erase_external(char *record)

Remove the recorded term from the Prolog database, reclaiming all associated memory resources.
6.6.12 Catching Signals (Software Interrupts)

SWI-Prolog offers both a C and Prolog interface to deal with software interrupts (signals). The Prolog mapping is defined in section 4.10. This subsection deals with handling signals from C.

If a signal is not used by Prolog and the handler does not call Prolog in any way, the native signal interface routines may be used.

Some versions of SWI-Prolog, notably running on popular Unix platforms, handle **SIG_SEGV** for guarding the Prolog stacks. If the application wishes to handle this signal too, it should use **PL_signal()** to install its handler after initialising Prolog. SWI-Prolog will pass **SIG_SEGV** to the user code if it detected the signal is not related to a Prolog stack overflow.

Any handler that wishes to call one of the Prolog interface functions should call **PL_signal()** for its installation.

```c
void (*)(*) PL_signal(sig, func)
```
This function is equivalent to the BSD-Unix signal() function, regardless of the platform used. The signal handler is blocked while the signal routine is active, and automatically reactivated after the handler returns.

After a signal handler is registered using this function, the native signal interface redirects the signal to a generic signal handler inside SWI-Prolog. This generic handler validates the environment, creates a suitable environment for calling the interface functions described in this chapter and finally calls the registered user-handler.

By default, signals are handled asynchronously (i.e. at the time they arrive). It is inherently dangerous to call extensive code fragments, and especially exception related code from asynchronous handlers. The interface allows for **synchronous** handling of signals. In this case the native OS handler just schedules the signal using **PL_raise()**, which is checked by **PL_handle_signals()** at the call- and redo-port. This behaviour is realised by or-ing sig with the constant **PL_SIGSYNC**.

Signal handling routines may raise exceptions using **PL_raise_exception()**. The use of **PL_throw()** is not safe. If a synchronous handler raises an exception, the exception is delayed to the next call to **PL_handle_signals()**;

```c
int PLHandle_signals( void )
```

Handle any signals pending from **PL_raise()**. **PLHandle_signals()** is called at each pass through the call- and redo-port at a safe point. Exceptions raised by the handler using **PL_raise_exception()** are properly passed to the environment.

The user may call this function inside long-running foreign functions to handle scheduled interrupts. This routine returns the number of signals handled. If a handler raises an exception, the return value is -1 and the calling routine should return with **FALSE** as soon as possible.

6.6.13 Errors and warnings

**PL_warning()** prints a standard Prolog warning message to the standard error (**user_error**) stream. Please note that new code should consider using **PL_raise_exception()** to raise a Prolog exception. See also section 4.9.

---

5 A better default would be to use synchronous handling, but this interface preserves backward compatibility.
PL_ACTION_TRACE  Start Prolog tracer (trace/0). Requires no arguments.
PL_ACTION_DEBUG   Switch on Prolog debug mode (debug/0). Requires no arguments.
PL_ACTION_BACKTRACE Print backtrace on current output stream. The argument (an int) is the number of frames printed.
PL_ACTION_HALT     Halt Prolog execution. This action should be called rather than Unix exit() to give Prolog the opportunity to clean up. This call does not return. The argument (an int) is the exit code. See halt/1.
PL_ACTION_ABORT    Generate a Prolog abort (abort/0). This call does not return. Requires no arguments.
PL_ACTION_BREAK    Create a standard Prolog break environment (break/0). Returns after the user types the end-of-file character. Requires no arguments.
PL_ACTION_GUIAPP   Win32: Used to indicate the kernel that the application is a GUI application if the argument is not 0 and a console application if the argument is 0. If a fatal error occurs, the system uses a windows messagebox to report this on a GUI application and simply prints the error and exits otherwise.
PL_ACTION_WRITE    Write the argument, a char * to the current output stream.
PL_ACTION_FLUSH    Flush the current output stream. Requires no arguments.

<table>
<thead>
<tr>
<th>PL_ACTION_TRACE</th>
<th>Start Prolog tracer (trace/0). Requires no arguments.</th>
</tr>
</thead>
<tbody>
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</tr>
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<td>Write the argument, a char * to the current output stream.</td>
</tr>
<tr>
<td>PL_ACTION_FLUSH</td>
<td>Flush the current output stream. Requires no arguments.</td>
</tr>
</tbody>
</table>

Table 6.1: PL_action() options

int PL_warning(format, a1, ...)
Print an error message starting with ‘[WARNING: ’, followed by the output from format, followed by a ‘]’ and a newline. Then start the tracer. format and the arguments are the same as for printf(2). Always returns FALSE.

6.6.14 Environment Control from Foreign Code

int PL_action(int, ...)
Perform some action on the Prolog system. int describes the action, Remaining arguments depend on the requested action. The actions are listed in table 6.1.

6.6.15 Querying Prolog

C_type PL_query(int)
Obtain status information on the Prolog system. The actual argument type depends on the information required. int describes what information is wanted. The options are given in table 6.2.

6.6.16 Registering Foreign Predicates

int PL_register_foreign(const char *name, int arity, foreign_t (*function)(), int flags)
Register a C-function to implement a Prolog predicate. After this call returns successfully a
6.6. THE FOREIGN INCLUDE FILE

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL_QUERY_ARGC</td>
<td>Return an integer holding the number of arguments given to Prolog from Unix.</td>
</tr>
<tr>
<td>PL_QUERY_ARGV</td>
<td>Return a char ** holding the argument vector given to Prolog from Unix.</td>
</tr>
<tr>
<td>PL_QUERY_SYMBOLFILE</td>
<td>Return a char * holding the current symbol file of the running process.</td>
</tr>
<tr>
<td>PL_MAX_INTEGER</td>
<td>Return a long, representing the maximal integer value represented by a Prolog integer.</td>
</tr>
<tr>
<td>PL_MIN_INTEGER</td>
<td>Return a long, representing the minimal integer value.</td>
</tr>
<tr>
<td>PL_QUERY_VERSION</td>
<td>Return a long, representing the version as $10,000 \times M + 100 \times m + p$, where $M$ is the major, $m$ the minor version number and $p$ the patch-level. For example, 20717 means 2.7.17.</td>
</tr>
</tbody>
</table>

Table 6.2: PL_query() options

A predicate with name name (a char *) and arity arity (a C int) is created. As a special case, name may consist of a sequence of alpha-numerical characters followed by the colon (:). In this case the name up till the colon is taken to be the destination module and the rest of the name the predicate name.

When called in Prolog, Prolog will call function. flags forms bitwise or'ed list of options for the installation. These are:

<table>
<thead>
<tr>
<th>Options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL_FA_NOTRACE</td>
<td>Predicate cannot be seen in the tracer</td>
</tr>
<tr>
<td>PL_FA_TRANSPARENT</td>
<td>Predicate is module transparent</td>
</tr>
<tr>
<td>PL_FA_NONDETERMINISTIC</td>
<td>Predicate is non-deterministic. See also PL_retry().</td>
</tr>
<tr>
<td>PL_FA_VARARGS</td>
<td>Use alternative calling convention.</td>
</tr>
</tbody>
</table>

void PL_load_extensions(PL_extension *e)

Register foreign predicates from a table of structures. This is an alternative to multiple calls to PL_register_foreign() and simplifies code that wishes to use PL_register_extensions() as an alternative. The type PL_extension is defined as:

```c
typedef struct _PL_extension
{ char *predicate_name; /* Name of the predicate */
  short arity; /* Arity of the predicate */
  pl_function_t function; /* Implementing functions */
  short flags; /* Or of PL_FA_... */
} PL_extension;
```

void PL_register_extensions(PL_extension *e)

The function PL_register_extensions() behaves as PL_load_extensions(), but is the only PL_* function that may be called before PL_initialise(). The predicates are registered into the module user after registration of the SWI-Prolog builtin foreign predicates and before loading the initial saved state. This implies that initialization/1 directives can refer to them.

Here is an example of its usage:
static PL_extension predicates[] = {
{ "foo", 1, pl_foo, 0 },
{ "bar", 2, pl_bar, PL_FA_NONDETERMINISTIC },
{ NULL, 0, NULL, 0 }
};

main(int argc, char **argv)
{ PL_register_extensions(predicates);

  if ( !PL_initialise(argc, argv) )
    PL_halt(1);

  ...
}

6.6.17 Foreign Code Hooks

For various specific applications some hooks re provided.

PL_dispatch_hook_t PL_dispatch_hook(PL_dispatch_hook_t)
If this hook is not NULL, this function is called when reading from the terminal. It is sup-
posed to dispatch events when SWI-Prolog is connected to a window environment. It can re-
turn two values: PL_DISPATCH_INPUT indicates Prolog input is available on file descriptor
0 or PL_DISPATCH_TIMEOUT to indicate a timeout. The old hook is returned. The type
PL_dispatch_hook_t is defined as:

typedef int (*PL_dispatch_hook_t)(void);

void PL_abort_hook(PL_abort_hook_t)
Install a hook when abort/0 is executed. SWI-Prolog abort/0 is implemented using C
setjmp()/longjmp() construct. The hooks are executed in the reverse order of their registra-
tion after the longjmp() took place and before the Prolog toplevel is reinvoked. The type
PL_abort_hook_t is defined as:

typedef void (*PL_abort_hook_t)(void);

int PL_abort_unhook(PL_abort_hook_t)
Remove a hook installed with PL_abort_hook(). Returns FALSE if no such hook is found,
TRUE otherwise.

void PL_on_halt(void (*)(int, void *), void *closure)
Register the function f to be called if SWI-Prolog is halted. The function is called with two
arguments: the exit code of the process (0 if this cannot be determined on your operating system)
and the closure argument passed to the PL_on_halt() call. See also at_halt/1.
PL_agc_hook_t PL_agc_hook(PL_agc_hook_t new)

Register a hook with the atom-garbage collector (see garbage.collect.atoms/0 that is called on any atom that is reclaimed. The old hook is returned. If no hook is currently defined, NULL is returned. The argument of the called hook is the atom that is to be garbage collected. The return value is an int. If the return value is zero, the atom is not reclaimed. The hook may invoke any Prolog predicate.

The example below defines a foreign library for printing the garbage collected atoms for debugging purposes.

```c
#include <SWI-Stream.h>
#include <SWI-Prolog.h>

static int
atom_hook(atom_t a)
{ Sdprintf("AGC: deleting %s\n", PL_atom_chars(a));

    return TRUE;
}

static PL_agc_hook_t old;

install_t
install()
{ old = PL_agc_hook(atom_hook);
}

install_t
uninstall()
{ PL_agc_hook(old);
}
```

### 6.6.18 Storing foreign data

This section provides some hints for handling foreign data in Prolog. With foreign data, we refer to data that is used by foreign language predicates and needs to be passed around in Prolog. Excluding combinations, there are three principal options for storing such data

- **Natural Prolog data**
  E.i. using the representation one would choose if there was no foreign interface required.

- **Opaque packed Prolog data**
  Data can also be represented in a foreign structure and stored on the Prolog stacks using `PL_put_string_nchars()` and retrieved using `PL_get_string_chars()`. It is generally good practice to wrap the string in a compound term with arity 1, so Prolog can identify the type. `portray/1` rules may be used to streamline printing such terms during development.
• Natural foreign data, passing a pointer
  An alternative is to pass a pointer to the foreign data. Again, this functor may be wrapped in a compound term.

The choice may be guided using the following distinctions

• Is the data opaque to Prolog
  With ‘opaque’ data, we refer to data handled in foreign functions, passed around in Prolog, but of which Prolog never examines the contents of the data itself. If the data is opaque to Prolog, the chosen representation does not depend on simple analysis by Prolog, and the selection will be driven solely by simplicity of the interface and performance (both in time and space).

• How big is the data
  Is efficient encoding required? For example, a boolean array may be expressed as a compound term, holding integers each of which contains a number of bits, or as a list of true and false.

• What is the nature of the data
  For examples in C, constants are often expressed using ‘enum’ or #define’d integer values. If prolog needs to handle this data, atoms are a more logical choice. Whether or not this mapping is used depends on whether Prolog needs to interpret the data, how important debugging is and how important performance is.

• What is the lifetime of the data
  We can distinguish three cases.

  1. The lifetime is dictated by the accessibility of the data on the Prolog stacks. Their is no way by which the foreign code when the data becomes ‘garbage’, and the data thus needs to be represented on the Prolog stacks using Prolog data-types. (2).

  2. The data lives on the ‘heap’ and is explicitly allocated and deallocated. In this case, representing the data using native foreign representation and passing a pointer to it is a sensible choice.

  3. The data lives as during the lifetime of a foreign predicate. If the predicate is deterministic, foreign automatic variables are suitable. If the predicate is non-deterministic, the data may be allocated using malloc() and a pointer may be passed. See section 6.6.1.

Examples for storing foreign data

In this section, we will outline some examples, covering typical cases. In the first example, we will deal with extending Prolog’s data representation with integer-sets, represented as bit-vectors. In the second example, we look at handling a ‘netmask’. Finally, we discuss the outline of the DDE interface.

Integer sets  with not-to-far-apart upper- and lower-bounds can be represented using bit-vectors. Common set operations, such as union, intersection, etc. are reduced to simple and’ing and or’ing the bitvectors. This can be done in Prolog, using a compound term holding integer arguments. Especially if the integers are kept below the maximum tagged integer value (see current_prolog_flag/2), this representation is fairly space-efficient (wasting 1 word for the functor and and 7 bits per integer for the tags). Arithmetic can all be performed in Prolog too.
For really demanding applications, foreign representation will perform better, especially time-wise. Bit-vectors are naturally expressed using string objects. If the string is wrapped in bitvector/1, lower-bound of the vector is 0, and the upperbound is not defined, an implementation for getting and putting the sets as well as the union predicate for it is below.

```c
#include <SWI-Prolog.h>
#define max(a, b) ((a) > (b) ? (a) : (b))
#define min(a, b) ((a) < (b) ? (a) : (b))

static functor_t FUNCTOR_bitvector1;

static int get_bitvector(term_t in, int *len, unsigned char **data)
{ if (PL_is_functor(in, FUNCTOR_bitvector1))
    { term_t a = PL_new_term_ref();
      PL_get_arg(1, in, a);
      return PL_get_string(a, (char **)data, len);
    }
  PL_fail;
}

static int unify_bitvector(term_t out, int len, const unsigned char *data)
{ if (PL_unify_functor(out, FUNCTOR_bitvector1))
    { term_t a = PL_new_term_ref();
      PL_get_arg(1, out, a);
      return PL_unify_string_nchars(a, len, (const char *)data);
    }
  PL_fail;
}

static foreign_t pl_bitvector_union(term_t t1, term_t t2, term_t u)
{ unsigned char *s1, *s2;
  int l1, l2;

  if (get_bitvector(t1, &l1, &s1) &&
      get_bitvector(t2, &l2, &s2))
  { int l = max(l1, l2);
    unsigned char *s3 = alloca(l);
```
if ( s3 )
{
    int n;
    int ml = min(l1, l2);

    for(n=0; n<ml; n++)
        s3[n] = s1[n] | s2[n];
    for( ; n < l1; n++)
        s3[n] = s1[n];
    for( ; n < l2; n++)
        s3[n] = s2[n];

    return unify_bitvector(u, l, s3);
}

return PL_warning("Not enough memory");
}

PL_fail;
}

install_t
install()
{
    PL_register_foreign("bitvector_union", 3, pl_bitvector_union, 0);

    FUNCTOR_bitvector1 = PL_new_functor(PL_new_atom("bitvector"), 1);
}

Netmask’s are used with TCP/IP configuration. Suppose we have an application dealing with reasoning about a network configuration. Such an application requires communicating netmask structures from the operating system, reasoning about them and possibly communicate them to the user. A netmask consists of 4 bitmasks between 0 and 255. C-application normally see them as an 4-byte wide unsigned integer. SWI-Prolog cannot do that, as integers are always signed.

We could use the string approach outlined above, but this makes it hard to handle these terms in Prolog. A better choice is a compound term netmask/4, holding the 4 submasks as integer arguments.

As the implementation is trivial, we will omit this here.

The DDE interface (see section 4.46) represents another common usage of the foreign interface: providing communication to new operating system features. The DDE interface requires knowledge about active DDE server and client channels. These channels contains various foreign data-types. Such an interface is normally achieved using an open/close protocol that creates and destroys a handle. The handle is a reference to a foreign data-structure containing the relevant information.

There are a couple of possibilities for representing the handle. The choice depends on responsibilities and debugging facilities. The simplest aproach is to using PL_unify_pointer() and
PL_get_pointer(). This approach is fast and easy, but has the drawbacks of (untyped) point-
ers: there is no reliable way to detect the validity of the pointer, not to verify it is pointing to a
structure of the desired type. The pointer may be wrapped into a compound term with arity 1 (i.e.,
dde_channel((Pointer)), making the type-problem less serious.

Alternatively (used in the DDE interface), the interface code can maintain a (preferably variable
length) array of pointers and return the index in this array. This provides better protection. Especially
for debugging purposes, wrapping the handle in a compound is a good suggestion.

6.6.19 Embedding SWI-Prolog in a C-program

As of version 2.1.0, SWI-Prolog may be embedded in a C-program. To reach at a compiled C-program
with SWI-Prolog as an embedded application is very similar to creating a statically linked SWI-Prolog
executable as described in section 6.4.1.

The file \ldots/pl/include/stub.c defines SWI-Prolog’s default main program:

```c
int main(int argc, char **argv)
{ if ( !PL_initialise(argc, argv) )
    PL_halt(1);

    PL_install_readline(); /* delete if you don’t want readline */

    PL_halt(PL_toplevel() ? 0 : 1);
}
```

This may be replaced with your own main C-program. The interface function PL_initialise() must
be called before any of the other SWI-Prolog foreign language functions described in this chap-
ner. PL_initialise() interprets all the command-line arguments, except for the -t toplevel
flag that is interpreted by PL_toplevel().

```c
int PL_initialise(int argc, char **argv)
Initialises the SWI-Prolog heap and stacks, restores the boot QLF file, loads the system and
personal initialisation files, runs the at_initialization/1 hooks and finally runs the
-g goal hook.

Special consideration is required for argv[0]. On Unix, this argument passes the part of the
commandline that is used to locate the executable. Prolog uses this to find the file holding the
running executable. The Windows version uses this to find a module of the running executable.
If the specified module cannot be found, it tries the module libpl.dll, containing the Prolog
runtime kernel. In all these cases, the resulting file is used for two purposes

• See whether a Prolog saved-state is appended to the file. If this is the case, this state will
  be loaded instead of the default boot.prc file from the SWI-Prolog home directory. See
  also qsave_program/[1,2] and section 6.7.

• Find the Prolog home directory. This process is described in detail in section 6.8.
```
PL_initialise() returns 1 if all initialisation succeeded and 0 otherwise.\footnote{BUG: Various fatal errors may cause PL_initialise to call PL_halt(1), preventing it from returning at all.}

In most cases, argc and argv will be passed from the main program. It is allowed to create your own argument vector, provided argv[0] is constructed according to the rules above. For example:

```c
int
main(int argc, char **argv)
{
    char *av[10];
    int ac = 0;

    av[ac++] = argv[0];
    av[ac++] = "-x";
    av[ac++] = "mystate";
    av[ac] = NULL;

    if ( !PL_initialise(ac, av) )
        PL_halt(1);
    ...
}
```

Please note that the passed argument vector may be referred from Prolog at any time and should therefore be valid as long as the Prolog engine is used.

A good setup in Windows is to add SWI-Prolog’s bin directory to your PATH and either pass a module holding a saved-state, or "libpl.dll" as argv[0].

```
int PL_is_initialised(int *argc, char ***argv)
    Test whether the Prolog engine is already initialised. Returns FALSE if Prolog is not initialised and TRUE otherwise. If the engine is initialised and argc is not NULL, the argument count used with PL_initialise() is stored in argc. Same for the argument vector argv.

void PL_install_readline()
    Installs the GNU-readline line-editor. Embedded applications that do not use the Prolog toplevel should normally delete this line, shrinking the Prolog kernel significantly.

int PL_toplevel()
    Runs the goal of the \(-t\) toplevel switch (default prolog/0) and returns 1 if successful, 0 otherwise.

void PL_cleanup(int status)
    This function performs the reverse of PL_initialise(). It runs the PL_on_halt() and at_halt/1 handlers, closes all streams (except for the ‘standard I/O’ streams which are flushed only), deallocates all memory and restores all signal handlers. The status argument is passed to the various termination hooks and indicates the exit-status.

    This function allows deleting and restarting the Prolog system in the same process. Use it with care, as PL_initialise() is a costly function. Unix users should consider using exec() (available as part of the clib package.).
```
void PL_hal(int status)
    Cleanup the Prolog environment using PL_cleanups() and calls exit() with the status argument.

6.7 Linking embedded applications using plld

The utility program plld (Win32: plld.exe) may be used to link a combination of C-files and Prolog files into a stand-alone executable. plld automates most of what is described in the previous sections.

In the normal usage, a copy is made of the default embedding template \ldots/pl/include/stub.c. The main() routine is modified to suit your application. PL_initialise() must be passed the program-name (argv[0]) (Win32: the executing program can be obtained using GetModuleFileName()). The other elements of the command-line may be modified. Next, plld is typically invoked as:

    plld -o output stubfile.c [other-c-or-o-files] [plfiles]

plld will first split the options into various groups for both the C-compiler and the Prolog compiler. Next, it will add various default options to the C-compiler and call it to create an executable holding the user’s C-code and the Prolog kernel. Then, it will call the SWI-Prolog compiler to create a saved state from the provided Prolog files and finally, it will attach this saved state to the created emulator to create the requested executable.

Below, it is described how the options are split and which additional options are passed.

-**help**
    Print brief synopsis.

-**pl prolog**
    Select the prolog to use. This prolog is used for two purposes: get the home-directory as well as the compiler/linker options and create a saved state of the Prolog code.

-**ld linker**
    Linker used to link the raw executable. Default is to use the C-compiler (Win32: link.exe).

-**cc C-compiler**
    Compiler for .c files found on the commandline. Default is the compiler used to build SWI-Prolog (see current_prolog_flag/2) (Win32: cl.exe).

-**c++ C++-compiler**
    Compiler for C++ sources (extensions .cpp, .cxx, .cc or .C) files found on the commandline. Default is c++ or g++ if the C-compiler is gcc (Win32: cl.exe).

-**nostate**
    Just relink the kernel, do not add any Prolog code to the new kernel. This is used to create a new kernel holding additional foreign predicates on machines that do not support the shared-library (DLL) interface, or if building the state cannot be handled by the default procedure used by plld. In the latter case the state is created seperately and appended to the kernel using cat {kernel} {state} > {out} (Win32: copy /b {kernel}+{state} {out})
-pl-options ...
Additional options passed to Prolog when creating the saved state. The first character immediately following pl-options is used as separator and translated to spaces when the argument is built. Example: -pl-options,-F,xpce passed -F xpce as additional flags to Prolog.

-ld-options ...
Passes options to the linker, similar to -pl-options.

-cc-options ...
Passes options to the C/C++ compiler, similar to -pl-options.

-v
Select verbose operation, showing the various programs and their options.

-o outfile
Reserved to specify the final output file.

-Llibrary
Specifies a library for the C-compiler. By default, -lpl (Win32: libpl.lib) and the libraries needed by the Prolog kernel are given.

-Llibrary-directory
Specifies a library directory for the C-compiler. By default the directory containing the Prolog C-library for the current architecture is passed.

-g | -Iinclude-directory | -Ddefinition
These options are passed to the C-compiler. By default, the include directory containing SWI-Prolog.h is passed. plld adds two additional * -Ddef flags:

-D__SWI_PROLOG__
Indicates the code is to be connected to SWI-Prolog.

-D__SWI_EMBEDDED__
Indicates the creation of an embedded program.

*.o | *.c | *.C |*.cxx | *.cpp
Passed as input files to the C-compiler

*.pl |*.qlf
Passed as input files to the Prolog compiler to create the saved-state.

* I.e. all other options. These are passed as linker options to the C-compiler.

6.7.1 A simple example

The following is a very simple example going through all the steps outlined above. It provides an arithmetic expression evaluator. We will call the application calc and define it in the files calc.c and calc.pl. The Prolog file is simple:
calc(Atom) :-
    term_to_atom(Expr, Atom),
    A is Expr,
    write(A),
    nl.

The C-part of the application parses the command-line options, initialises the Prolog engine, locates
the calc/1 predicate and calls it. The coder is in figure 6.5.
The application is now created using the following command-line:

% plld -o calc calc.c calc.pl

The following indicates the usage of the application:

% calc pi/2
1.5708

6.8 The Prolog ‘home’ directory

Executables embedding SWI-Prolog should be able to find the ‘home’ directory of the develop-
ment environment unless a self-contained saved-state has been added to the executable (see qsave
program/[1,2] and section 6.7).

If Prolog starts up, it will try to locate the development environment. To do so, it will try the
following steps until one succeeds.

1. If the environment variable SWI_HOME_DIR is defined and points to an existing directory, use
   this.

2. If the environment variable SWIPL is defined and points to an existing directory, use this.

3. Locate the primary executable or (Windows only) a component (module) thereof and check
   whether the parent directory of the directory holding this file contains the file swipl. If so,
   this file contains the (relative) path to the home directory. If this directory exists, use this. This
   is the normal mechanism used by the binary distribution.

4. If the precompiled path exists, use it. This is only useful for a source installation.

If all fails and there is no state attached to the executable or provided Windows module (see
PL_initialise()), SWI-Prolog gives up. If a state is attached, the current working directory is
used.

The file_search_path/2 alias swi is set to point to the home directory located.

6.9 Example of Using the Foreign Interface

Below is an example showing all stages of the declaration of a foreign predicate that transforms atoms
possibly holding uppercase letters into an atom only holding lower case letters. Figure 6.6 shows the
C-source file, figure 6.7 illustrates compiling and loading of foreign code.
#include <stdio.h>
#include <SWI-Prolog.h>

#define MAXLINE 1024

int main(int argc, char **argv)
{
    char expression[MAXLINE];
    char *e = expression;
    char *program = argv[0];
    char *plav[2];
    int n;

    /* combine all the arguments in a single string */
    for(n=1; n<argc; n++)
    {
        if ( n != 1 )
            *e++ = ' ';
        strcpy(e, argv[n]);
        e += strlen(e);
    }

    /* make the argument vector for Prolog */
    plav[0] = program;
    plav[1] = NULL;

    /* initialise Prolog */
    if ( !PL_initialise(1, plav) )
        PL_halt(1);

    /* Lookup calc/1 and make the arguments and call */
    { predicate_t pred = PL_predicate("calc", 1, "user");
      term_t h0 = PL_new_term_refs(1);
      int rval;

      PL_put_atom_chars(h0, expression);
      rval = PL_call_predicate(NULL, PL_Q_NORMAL, pred, h0);

      PL_halt(rval ? 0 : 1);
    }

    return 0;
}
/* Include file depends on local installation */
#include <SWI-Prolog.h>
#include <stdlib.h>
#include <ctype.h>

foreign_t
pl_lowercase(term_t u, term_t l)
{
    char *copy;
    char *s, *q;
    int rval;

    if ( !PL_get_atom_chars(u, &s) )
        return PL_warning("lowercase/2: instantiation fault");
    copy = malloc(strlen(s)+1);

    for( q=copy; *s; q++, s++)
        *q = (isupper(*s) ? tolower(*s) : *s);
    *q = '0';

    rval = PL_unify_atom_chars(l, copy);
    free(copy);

    return rval;
}

install_t
install()
{
    PL_register_foreign("lowercase", 2, pl_lowercase, 0);
}

Figure 6.6: Lowercase source file
% gcc -I/usr/local/lib/pl-\plversion/include -fpic -c lowercase.c
% gcc -shared -o lowercase.so lowercase.o
% pl
Welcome to SWI-Prolog (Version \plversion)
Copyright (c) 1993-1996 University of Amsterdam. All rights reserved.

For help, use ?- help(Topic). or ?- apropos(Word).

1 ?- load_foreign_library(lowercase).
   Yes
2 ?- lowercase(’Hello World!’, L).
   L = ’hello world!’
   Yes

Figure 6.7: Compiling the C-source and loading the object file
6.10 Notes on Using Foreign Code

6.10.1 Memory Allocation

SWI-Prolog’s memory allocation is based on the `malloc(3)` library routines. Foreign applications can safely use `malloc(3), realloc(3)` and `free(3)`. Memory allocation using `brk(2)` or `sbrk(2)` is not allowed as these calls conflict with `malloc(3)`.

6.10.2 Debugging Foreign Code

Statically linked foreign code or embedded systems can be debugged normally. Most modern environments provide debugging tools for dynamically loaded shared objects or dynamic load libraries. The following example traces the code of lowercase using `gdb(1)` in a Unix environment.

```
% gcc -I/usr/local/lib/pl-2.2.0/include -fpic -c -g lowercase.c
% gcc -shared -o lowercase.so lowercase.o
% gdb pl
(gdb) r
Welcome to SWI-Prolog (Version \plversion)
Copyright (c) 1993-1996 University of Amsterdam. All rights reserved.

For help, use ?- help(Topic). or ?- apropos(Word).

?- load_foreign_library(lowercase).
<type Control-C>
(gdb) shared % loads symbols for shared objects
(gdb) break pl_lowercase
(gdb) continue
?- lowercase('HELLO', X).
```

6.10.3 Name Conflicts in C modules

In the current version of the system all public C functions of SWI-Prolog are in the symbol table. This can lead to name clashes with foreign code. Someday I should write a program to strip all these symbols from the symbol table (why does Unix not have that?). For now I can only suggest to give your function another name. You can do this using the C preprocessor. If—for example—your foreign package uses a function `warning()`, which happens to exist in SWI-Prolog as well, the following macro should fix the problem.

```
#define warning warning_
```

Note that shared libraries do not have this problem as the shared library loader will only look for symbols in the main executable for symbols that are not defined in the library itself.

6.10.4 Compatibility of the Foreign Interface

The term-reference mechanism was first used by Quintus Prolog version 3. SICStus Prolog version 3 is strongly based on the Quintus interface. The described SWI-Prolog interface is similar to using the
Quintus or SICStus interfaces, defining all foreign-predicate arguments of type +term. SWI-Prolog explicitly uses type functor.t, while Quintus and SICStus uses \langle name \rangle and \langle arity \rangle. As the names of the functions differ from Prolog to Prolog, a simple macro layer dealing with the names can also deal with this detail. For example:

```
#define QP_put_functor(t, n, a) PL_put_functor(t, PL_new_functor(n, a))
```

The PL\_unify\_\*() functions are lacking from the Quintus and SICStus interface. They can easily be emulated or the put/unify approach should be used to write compatible code.

The PL\_open\_foreign\_frame()/PL\_close\_foreign\_frame() combination is lacking from both other Prologs. SICStus has PL\_new\_term\_refs(0), followed by PL\_reset\_term\_refs() that allows for discarding term references.

The Prolog interface for the graphical user interface package XPCE shares about 90% of the code using a simple macro layer to deal with different naming and calling conventions of the interfaces.
This chapter describes the features of SWI-Prolog for delivering applications that can run without the development version of the system installed.

A SWI-Prolog runtime executable is a file consisting of two parts. The first part is the emulator, which is machine dependent. The second part is the resource archive, which contains the compiled program in a machine-independent format, startup options and possibly user-defined resources, see `resource/3` and `open_resource/3`.

These two parts can be connected in various different ways. The most common way for distributed runtime applications is to concatenate the two parts. This can be achieved using external commands (Unix: `cat`, Windows: `copy`), or using the `stand-alone` option to `qsave_program/2`. The second option is to attach a startup script in front of the resource that starts the emulator with the proper options. This is the default under Unix. Finally, an emulator can be told to use a specified resource file using the `-x` commandline switch.

```
qsave_program(+File, +ListOfOptions)
```

Saves the current state of the program to the file `File`. The result is a resource archive containing a saved-state that expresses all Prolog data from the running program and all user-defined resources. Depending on the `stand-alone` option, the resource is headed by the emulator, a Unix shell-script or nothing.

`ListOfOptions` is a list of `<Key> = <Value>` or `<Key>(<Value>)` pairs. The available keys are described in table 7.1.

Before writing the data to file, `qsave_program/2` will run `autoload/0` to all required autoloading the system can discover. See `autoload/0`.

Provided the application does not require any of the Prolog libraries to be loaded at runtime, the only file from the SWI-Prolog development environment required is the emulator itself. The emulator may be built in two flavours. The default is the development emulator. The runtime emulator is similar, but lacks the tracer.

If the option `stand-alone(on)` is present, the emulator is the first part of the state. If the emulator is started it will test whether a boot-file (state) is attached to the emulator itself and load this state. Provided the application has all libraries loaded, the resulting executable is completely independent of the runtime environment or location where it was build.

See also section 5.

```
qsave_program(+File)
```

Equivalent to `qsave_program(File, [])`.

```
autoload
```

Check the current Prolog program for predicates that are referred to, are undefined and have a definition in the Prolog library. Load the appropriate libraries.
<table>
<thead>
<tr>
<th>Key</th>
<th>Option</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>-L</td>
<td>K-bytes</td>
<td>Size (Limit) of local stack</td>
</tr>
<tr>
<td>global</td>
<td>-G</td>
<td>K-bytes</td>
<td>Size (Limit) of global stack</td>
</tr>
<tr>
<td>trail</td>
<td>-T</td>
<td>K-bytes</td>
<td>Size (Limit) of trail stack</td>
</tr>
<tr>
<td>argument</td>
<td>-A</td>
<td>K-bytes</td>
<td>Size (Limit) of argument stack</td>
</tr>
<tr>
<td>goal</td>
<td>-g</td>
<td>atom</td>
<td>Initialisation goal</td>
</tr>
<tr>
<td>toplevel</td>
<td>-t</td>
<td>atom</td>
<td>Prolog toplevel goal</td>
</tr>
<tr>
<td>init_file</td>
<td>-f</td>
<td>atom</td>
<td>Personal initialisation file</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key</th>
<th>Option</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>class</td>
<td></td>
<td>atom</td>
<td>If runtime, only read resources from the state (default). If kernel, lock all predicates as system predicates If development, save the predicates in their current state and keep reading resources from their source (if present). See also resource/3.</td>
</tr>
<tr>
<td>autoload</td>
<td></td>
<td>bool</td>
<td>If true, run autoload/0 first</td>
</tr>
<tr>
<td>map</td>
<td></td>
<td>file</td>
<td>File to write info on dump</td>
</tr>
<tr>
<td>op</td>
<td></td>
<td>save/standard</td>
<td>Save operator declarations?</td>
</tr>
<tr>
<td>stand-alone</td>
<td></td>
<td>bool</td>
<td>Include the emulator in the state</td>
</tr>
<tr>
<td>emulator</td>
<td></td>
<td>file</td>
<td>Emulator attached to the (stand-alone) executable. Default is the running emulator.</td>
</tr>
</tbody>
</table>

Table 7.1: \((\text{Key}) = (\text{Value})\) pairs for \text{qsave_program/2}

This predicate is used by \text{qsave_program/[1,2]} to ensure the saved state will not depend on one of the libraries. The predicate \text{autoload/0} will find all \textbf{direct} references to predicates. It does not find predicates referenced via meta-predicates. The predicate \text{log/2} is defined in the library(q quintus) to provide a quintus compatible means to compute the natural logarithm of a number. The following program will behave correctly if its state is executed in an environment where the library(q quintus) is not available:

\begin{verbatim}
logtable(From, To) :-
   From > To, !.
logtable(From, To) :-
   log(From, Value),
   format(’
     ^d"t'8"2f"-n’, [From, Value]),
   F is From + 1,
   logtable(F, To).
\end{verbatim}

However, the following implementation refers to \text{log/2} through the meta-predicate \text{maplist/3}. Autoload will not be able to find the reference. This problem may be fixed either by loading the module \text{library(q quintus)} explicitly or use \text{require/1} to tell the system that the predicate \text{log/2} is required by this module.

\begin{verbatim}
logtable(From, To) :-
   findall(X, between(From, To, X), Xlist),
\end{verbatim}
7.1 LIMITATIONS OF QSAVE_PROGRAM

maplist(log, Xlist, SineList),
write_table(Xlist, SineList).

write_table([], []).  
write_table([I|IT], [V|VT]) :-
  format('˜d˜8|˜2f˜n', [I, V]),
  write_table(IT, VT).

volatile +Name/Arity, . . .

Declare that the clauses of specified predicates should not be saved to the program. The volatile declaration is normally used to avoid that the clauses of dynamic predicates that represent data for the current session is saved in the state file.

7.1 Limitations of qsave_program

There are three areas that require special attention when using qsave_program/[1,2].

- If the program is an embedded Prolog application or uses the foreign language interface, care has to be taken to restore the appropriate foreign context. See section 7.2 for details.

- If the program uses directives (:− goal. lines) that perform other actions then setting predicate attributes (dynamic, volatile, etc.) or loading files (consult, etc.), the directive may need to be prefixed with initialization/1.

- Database references as returned by clause/3, recorded/3, etc. are not preserved and may thus not be part of the database when saved.

7.2 Runtimes and Foreign Code

Some applications may need to use the foreign language interface. Object code is by definition machine-dependent and thus cannot be part of the saved program file.

To complicate the matter even further there are various ways of loading foreign code:

- Using the library(shlib) predicates
  This is the preferred way of dealing with foreign code. It loads quickly and ensures an acceptable level of independence between the versions of the emulator and the foreign code loaded. It works on Unix machines supporting shared libraries and library functions to load them. Most modern Unixes, as well as Win32 (Windows 95/NT) satisfy this constraint.

- Static linking
  This mechanism works on all machines, but generally requires the same C-compiler and linker to be used for the external code as is used to build SWI-Prolog itself.

To make a runtime executable that can run on multiple platforms one must make runtime checks to find the correct way of linking. Suppose we have a source-file myextension defining the installation function install().

If this file is compiled into a shared library, load_foreign_library/1 will load this library and call the installation function to initialise the foreign code. If it is loaded as a static extension, define install() as the predicate install/0:
static foreign_t
pl_install()
{
    install();

    PL_succeed;
}

PL_extension PL_extensions[] =
{
    /*{ "name", arity, function, PL_FA_<flags> },*/,
    { "install", 0, pl_install, 0 },
    { NULL, 0, NULL, 0 } /* terminating line */
};

Now, use the following Prolog code to load the foreign library:

load_foreign_extensions :-
    current_predicate(install, install), !, % static loaded
    install.
load_foreign_extensions :- % shared library
    load_foreign_library(foreign(myextension)).

:- initialization load_foreign_extensions.

The path alias foreign is defined by file_search_path/2. By default it searches the directories ⟨home⟩/lib/⟨arch⟩ and ⟨home⟩/lib. The application can specify additional rules for file_search_path/2.

7.3 Using program resources

A resource is very similar to a file. Resources however can be represented in two different formats: on files, as well as part of the resource archive of a saved-state (see qsave_program/2).

A resource has a name and a class. The source data of the resource is a file. Resources are declared by declaring the predicate resource/3. They are accessed using the predicate open_resource/3.

Before going into details, let us start with an example. Short texts can easily be expressed in Prolog source code, but long texts are cumbersome. Assume our application defines a command ‘help’ that prints a help text to the screen. We put the content of the help text into a file called help.txt. The following code implements our help command such that help.txt is incorporated into the runtime executable.

resource(help, text, 'help.txt').

help :-
    open_resource(help, text, In),
7.3. USING PROGRAM RESOURCES

    copy_stream(In, user_output),
    close(In).

copy_stream(In, Out) :-
    get0(In, C),
    copy_stream(C, In, Out).

copy_stream(-1, _, _) :- !.

copy_stream(C, In, Out) :-
    put(Out, C),
    get0(In, C2),
    copy_stream(C2, In, Out).

The predicate `help/0` opens the resource as a Prolog stream. If we are executing this from the development environment, this will actually return a stream to the `gelp.txt` itself. When executed from the saved-state, the stream will actually be a stream opened on the program resource file, taking care of the offset and length of the resource.

7.3.1 Predicates Definitions

`resource(+Name, +Class, +FileSpec)`

This predicate is defined as a dynamic predicate in the module `user`. Clauses for it may be defined in any module, including the user module. `Name` is the name of the resource (an atom). A resource name may contain any character, except for $ and :, which are reserved for internal usage by the resource library. `Class` describes what kind of object is stored in the resource. In the current implementation, it is just an atom. `FileSpec` is a file specification that may exploit `file_search_path/2` (see `absolute_file_name/2`).

Normally, resources are defined as unit clauses (facts), but the definition of this predicate also allows for rules. For proper generation of the saved state, it must be possible to enumerate the available resources by calling this predicate with all its arguments unbound.

Dynamic rules are useful to turn all files in a certain directory into resources, without specifying a resources for each file. For example, assume the `file_search_path/2 icons` refers to the resource directory containing icon-files. The following definition makes all these images available as resources:

```prolog
resource(Name, image, icons(XpmName)) :-
    atom(Name), !,
    file_name_extension(Name, xpm, XpmName).
resource(Name, image, XpmFile) :-
    var(Name),
    absolute_file_name(icons(./), [type(directory)], Dir)
    concat(Dir, '/.*.xpm', Pattern),
    expand_file_name(Pattern, XpmFiles),
    member(XpmFile, XpmFiles).
```
open_resource(+Name, ?Class, -Stream)

Opens the resource specified by Name and Class. If the latter is a variable, it will be unified to the class of the first resource found that has the specified Name. If successful, Stream becomes a handle to a binary input stream, providing access to the content of the resource.

The predicate open_resource/3 first checks resource/3. When successful it will open the returned resource source-file. Otherwise it will look in the programs resource database. When creating a saved-state, the system normally saves the resource contents into the resource archive, but does not save the resource clauses.

This way, the development environment uses the files (and modifications to the resource/3 declarations and/or files containing resource info thus immediately affect the running environment, while the runtime system quickly accesses the system resources.

7.3.2 The plrc program

The utility program plrc can be used to examine and manipulate the contents of a SWI-Prolog resource file. The options are inspired by the Unix ar program. The basic command is:

% plrc option resource-file member ...

The options are described below.

l
List contents of the archive.

x
Extract named (or all) members of the archive into the current directory.

a
Add files to the archive. If the archive already contains a member with the same name, the contents is replaced. Anywhere in the sequence of members, the options --class=class and --encoding=encoding may appear. They affect the class and encoding of subsequent files. The initial class is data and encoding none.

d
Delete named members from the archive.

This command is also described in the pl(1) Unix manual page.

7.4 Finding Application files

If your application uses files that are not part of the saved program such as database files, configuration files, etc., the runtime version has to be able to locate these files. The file_search_path/2 mechanism in combination with the -palias command-line argument is the preferred way to locate runtime files. The first step is to define an alias for the toplevel directory of your application. We will call this directory gnatdir in our examples.

A good place for storing data associated with SWI-Prolog runtime systems is below the emulator’s home-directory. swi is a predefined alias for this directory. The following is a useful default definition for the search path.
user:file_search_path(gnatdir, swi(gnat)).

The application should locate all files using absolute_file_name. Suppose gnatdir contains a file config.pl to define local configuration. Then use the code below to load this file:

```prolog
configure_gnat :-
    ( absolute_file_name(gnatdir('config.pl'), ConfigFile)
    -> consult(ConfigFile)
    ; format(user_error, 'gnat: Cannot locate config.pl\n'),
     halt(1)
    ).
```

### 7.4.1 Passing a path to the application

Suppose the system administrator has installed the SWI-Prolog runtime environment in /usr/local/lib/rt-pl-3.2.0. A user wants to install gnat, but gnat will look for its configuration in /usr/local/lib/rt-pl-3.2.0/gnat where the user cannot write.

The user decides to install the gnat runtime files in /users/bob/lib/gnat. For one-time usage, the user may decide to start gnat using the command:

% gnat -p gnatdir=/users/bob/lib/gnat

### 7.5 The Runtime Environment

#### 7.5.1 The Runtime Emulator

The sources may be used to built two versions of the emulator. By default, the development emulator is built. This emulator contains all features for interactive development of Prolog applications. If the system is configured using --enable-runtime, make(1) will create a runtime version of the emulator. This emulator is equivalent to the development version, except for the following features:

- **No input editing**
  The GNU library -lreadline that provides EMACS compatible editing of input lines will not be linked to the system.

- **No tracer**
  The tracer and all its options are removed, making the system a little faster too.

- **No profiler**
  profile/3 and friends are not supported. This saves some space and provides better performance.

- **No interrupt**
  Keyboard interrupt (Control-C normally) is not rebound and will normally terminate the application.
• current_prolog_flag(runtime, true) succeeds
  This may be used to verify your application is running in the runtime environment rather than
  the development environment.

• clause/[2,3] do not work on static predicates
  This prolog-flag inhibits listing your program. It is only a very limited protection however.

The following fragment is an example for building the runtime environment in `\env(HOME)/
lib/rt-pl-3.2.0`. If possible, the shared-library interface should be configured to ensure it can
serve a large number of applications.

% cd pl-3.2.0
% mkdir runtime
% cd runtime
% ../src/configure --enable-runtime --prefix=$HOME
% make
% make rt-install

The runtime directory contains the components listed below. This directory may be tar’ed and shipped
with your application.

<table>
<thead>
<tr>
<th>Directory</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>README.RT</td>
<td>Info on the runtime environment</td>
</tr>
<tr>
<td>bin/(arch)/pl</td>
<td>The emulator itself</td>
</tr>
<tr>
<td>man/pl.1</td>
<td>Manual page for pl</td>
</tr>
<tr>
<td>swipl</td>
<td>pointer to the home directory (.)</td>
</tr>
<tr>
<td>lib/</td>
<td>directory for shared libraries</td>
</tr>
<tr>
<td>lib/(arch)/</td>
<td>machine-specific shared libraries</td>
</tr>
</tbody>
</table>
The SWI-Prolog library

This chapter documents the SWI-Prolog library. As SWI-Prolog provides auto-loading, there is little difference between library predicates and built-in predicates. Part of the library is therefore documented in the rest of the manual. Library predicates differ from built-in predicates in the following ways.

- User-definition of a built-in leads to a permission-error, while using the name of a library predicate is allowed.
- If autoloading is disabled explicitly or because trapping unknown predicates is disabled (see `unknown/2` and `current_prolog_flag/2`), library predicates must be loaded explicitly.
- Using libraries reduced the footprint of applications that don’t need them.

The documentation of the library is just started. Material from the standard packages should be moved here, some material from other parts of the manual should be moved too and various libraries are not documented at all.

A.1 library(check): Elementary completeness checks

This library defines the predicate `check/0` and a few friends that allow for a quick-and-dirty cross-referencing.

check
Performs the three checking passes implemented by `list.undefined/0`, `list.autoload/0` and `list.redefined/0`. Please check the definition of these predicates for details.

The typical usage of this predicate is right after loading your program to get a quick overview on the completeness and possible conflicts in your program.

list.undefined
Scans the database for predicates that have no definition. A predicate is considered defined if it has clauses, is declared using `dynamic/1` or `multifile/1`. As a program is compiled calls are translated to predicates. If the called predicate is not yet defined it is created as a predicate without definition. The same happens with runtime generated calls. This predicate lists all such undefined predicates that are not defined in the library. See also `list.autoload/0`.

Note: undefined predicates are never removed from the database. For proper results it is therefore advised to run `check/0` right after loading your program.
list_autoload

Lists all undefined (see list_undefined/0) predicates that have a definition in the library along with the file from which they will be autoloaded when accessed. See also autoload/0.

list_redefined

Lists predicates that are defined in the global module user as well as in a normal module. I.e. predicates for which the local definition overrules the global default definition.

A.2 library(readutil): Reading lines, streams and files

This library contains primitives to read lines, files, multiple terms, etc.

read_line_to_codes(+Stream, -Codes)

Read the next line of input from Stream and unify the result with Codes after the line has been read. A line is ended by a newline character or end-of-file. Unlike read_line_to_codes/3, this predicate removes trailing newline character.

read_line_to_codes(+Stream, -Codes, ?Tail)

Difference-list version to read an input line to a list of character codes. Reading stops at the newline or end-of-file character, but unlike read_line_to_codes/2, the newline is retained in the output. This predicate is especially useful for reading a block of lines upto some delimiter. The following example reads an HTTP header ended by a blank line:

read_header_data(Stream, Header) :-
    read_line_to_codes(Stream, Header, Tail),
    read_header_data(Header, Stream, Tail).

read_header_data("\r\n", _, _) :- !.
read_header_data("\n", _, _) :- !.
read_header_data("", _, _) :- !.
read_header_data(_, Stream, Tail) :-
    read_line_to_codes(Stream, Tail, NewTail),
    read_header_data(Tail, Stream, NewTail).

read_stream_to_codes(+Stream, -Codes)

Read all input until end-of-file and unify the result to Codes.

read_stream_to_codes(+Stream, -Codes, ?Tail)

Difference-list version of read_stream_to_codes/2.

read_file_to_codes(+Spec, -Codes, +Options)

Read a file to a list of character codes. Spec is a file-specification for absolute_file_name/3. Codes is the resulting code-list. Options is a list of options for absolute_file_name/3 and open/4. In addition, the option tail(Tail) is defined, forming a difference-list.
### A.3 library(netscape): Activating your Web-browser

This library deals with the very system dependent task of opening a web-browser. See also library(url).

`www.open_url(+URL)`

Open URL in an external web-browser. The reason to place this in the library is to centralise the maintenance on this highly platform and browser specific task. It distinguishes between the following cases:

- **MS-Windows**
  
  If it detects MS-Windows it uses `win_shell/2` to open the URL. The behaviour and browser started depends on the Window and Windows-shell configuration, but in general it should be the behaviour expected by the user.

- **Other platforms**
  
  On other platforms it assumes the browser is `netscape`. It first tries to tell a running netscape to open the page and only after this fails it starts a new browser.

---

### A.4 library(registry): Manipulating the Windows registry

The library(registry) is only available on the MS-Windows version of SWI-Prolog. It loads the foreign extension `plregtry.dll`, providing the predicates described below. This library only makes the most common operations on the registry available through the Prolog user. The underlying DLL provides a more complete coverage of the Windows registry API. Please consult the sources in `pl/src/win32/foreign/plregtry.c` for further details.

In all these predicates, *Path* refers to a ‘/’ separated path into the registry. This is *not* an atom containing ‘/’-characters as used for filenames, but a term using the functor `//2`. Windows defines the following roots for the registry: `classes_root`, `current_user`, `local_machine` and `users`

#### registry_get_key(+Path, -Value)

Get the principal (default) value associated to this key. Fails silently of the key does not exist.

#### registry_get_key(+Path, +Name, -Value)

Get a named value associated to this key.

#### registry_set_key(+Path, +Value)

Set the principal (default) value of this key. Creates (a path to) the key if this does not already exist.

#### registry_set_key(+Path, +Name, +Value)

Associated a named value to this key. Creates (a path to) the key if this does not already exist.
registry_delete_key(+Path)
   Delete the indicated key.

shell_register_file_type(+Ext, +Type, +Name, +OpenAction)
   Register a file-type. Ext is the extension to associate. Type is the type name, often something
   link prolog.type. Name is the name visible in the Windows file-type browser. Finally, Open-
   nAction defines the action to execute when a file with this extension is opened in the Windows
   explorer.

shell_register_dde(+Type, +Action, +Service, +Topic, +Command, +IfNotRunning)
   Associate DDE actions to a type. Type is the same type as used for the 2nd argument of
   shell_register_file_type/4. Action is the a action to perform, Service and Topic specify
   the DDE topic to address and Command is the command to execute on this topic. Finally, If-
   NotRunning defines the command to execute if the required DDE server is not present.

shell_register_prolog(+Ext)
   Default registration of SWI-Prolog, which is invoked as part of the initialisation process on
   Windows systems. As the source also explains the above predicates, it is given as an example:

   shell_register_prolog(Ext) :-
   current_prolog_flag(argv, [Me|_]),
   concat_atom(['"', Me, '" "%1"'], OpenCommand),
   shell_register_file_type(Ext, 'prolog.type', 'Pro-
   log Source', OpenCommand),
   shell_register_dde('prolog.type', consult,
   prolog, control, 'con-
   sult(''%1''), Me),
   shell_register_dde('prolog.type', edit,
   prolog, control, 'edit(''%1''), Me).

A.5 library(url): Analysing and constructing URL

This library deals with the analysis and construction of a URL, Universal Resource Locator. URL is
the basis for communicating locations of resources (data) on the web. A URL consists of a protocol
identifier (e.g. HTTP, FTP), and a protocol-specific syntax further defining the location. URLs are
standardized in RFC-1738.

The implementation in this library covers only a small portion of the defined protocols. Though the
initial implementation followed RFC-1738 strictly, the current is more relaxed to deal with frequent
violations of the standard encountered in practical use.

This library contains code by Jan Wielemaker who wrote the initial version and Lukas Faulstich
who added various extensions.

parse_url(?URL, ?Parts)
   Construct or analyse a URL. URL is an atom holding a URL or a variable. Parts is a list of
   components. Each component is of the format Name(Value). Defined components are:
A.5. LIBRARY(URL): ANALYSING AND CONSTRUCTING URL

**protocol(Protocol)**
The used protocol. This is, after the optional url:, an identifier separated from the remainder of the URL using :. `parse_url/2` assumes the http protocol if no protocol is specified and the URL can be parsed as a valid HTTP url. In addition to the RFC-1738 specified protocols, the file: protocol is supported as well.

**host(Host)**
Host-name or IP-address on which the resource is located. Supported by all network-based protocols.

**port(Port)**
Integer port-number to access on the Host. This only appears if the port is explicitly specified in the URL. Implicit default ports (e.g. 80 for HTTP) do not appear in the part-list.

**path(Path)**
(File-) path addressed by the URL. This is supported for the ftp, http and file protocols. If no path appears, the library generates the path /.

**search(ListOfNameValue)**
Search-specification of HTTP URL. This is the part after the ?, normally used to transfer data from HTML forms that use the ‘GET’ protocol. In the URL it consists of a www-form-encoded list of Name=Value pairs. This is mapped to a list of Prolog Name=Value terms with decoded names and values.

**fragment(Fragment)**
Fragment specification of HTTP URL. This is the part after the # character.

The example below illustrates the all this for an HTTP UTL.

P = [ protocol(http),
    host('swi.psy.uva.nl'),
    fragment(x),
    search([ msg = 'Hello World!'] ),
    path('/message.cgi') ].

By instantiating the parts-list this predicate can be used to create a URL.

**parse_url(?url, +BaseUrl, ?Parts)**
Same as `parse_url/2`, but dealing a url that is relative to the given BaseUrl. This is used to analyse or construct a URI found in the document behind BaseUrl.

**global_url(+URL, +BaseUrl, -AbsoluteUrl)**
Transform a (possibly) relative URL into a global one.

**http_location(?url, ?Location)**
Similar to `parse_url/2`, but only deals with the location part of an HTTP URL. That is, the path, search and fragment specifiers. In the HTTP protocol, the first line of a message is
Action Location [HTTP/HttpVersion]

Location is either an atom or a code-list.

www_form_encode(?Value, ?WwwFormEncoded)
Translate between a string-literal and the x-www-form-encoded representation used in path and search specifications of the HTTP protocol.

Encoding implies mapping space to +, preserving alpha-numercial characters, map newlines to %0D%0A and anything else to %XX. When decoding, newlines appear as a single newline (10) character.
This appendix describes a number of predicates which enable the Prolog user to inspect the Prolog environment and manipulate (or even redefine) the debugger. They can be used as entry points for experiments with debugging tools for Prolog. The predicates described here should be handled with some care as it is easy to corrupt the consistency of the Prolog system by misusing them.

B.1 Examining the Environment Stack

prolog_current_frame(-Frame)

Unify Frame with an integer providing a reference to the parent of the current local stack frame. A pointer to the current local frame cannot be provided as the predicate succeeds deterministically and therefore its frame is destroyed immediately after succeeding.

prolog_frame_attribute(+Frame, +Key, -Value)

Obtain information about the local stack frame Frame. Frame is a frame reference as obtained through prolog_current_frame/1, prolog_trace_interception/4 or this predicate. The key values are described below.

alternative

Value is unified with an integer reference to the local stack frame in which execution is resumed if the goal associated with Frame fails. Fails if the frame has no alternative frame.

has_alternatives

Value is unified with true if Frame still is a candidate for backtracking. false otherwise.

goal

Value is unified with the goal associated with Frame. If the definition module of the active predicate is not user the goal is represented as ⟨module⟩:⟨goal⟩. Do not instantiate variables in this goal unless you know what you are doing!

clause

Value is unified with a reference to the currently running clause. Fails if the current goal is associated with a foreign (C) defined predicate. See also nth_clause/3 and clause_property/2.

level

Value is unified with the recursion level of Frame. The top level frame is at level ‘0’.

parent

Value is unified with an integer reference to the parent local stack frame of Frame. Fails if Frame is the top frame.
context_module
Value is unified with the name of the context module of the environment.

top
Value is unified with true if Frame is the top Prolog goal from a recursive call back from
the foreign language. false otherwise.

hidden
Value is unified with true if the frame is hidden from the user, either because a parent has
the hide-children attribute (all system predicates), or the system has no trace-me attribute.

pc
Value is unified with the program-pointer saved on behalf of the parent-goal if the parent-
goal is not owned by a foreign predicate.

argument(N)
Value is unified with the N-th slot of the frame. Argument 1 is the first argument of the
goal. Arguments above the arity refer to local variables. Fails silently if N is out of range.

deterministic
Succeeds if there are no choicepoints that are more recent than the parent frame.

B.2 Intercepting the Tracer

prolog_trace_interception(+Port, +Frame, +PC, -Action)
Dynamic predicate, normally not defined. This predicate is called from the SWI-Prolog debug-
ger just before it would show a port. If this predicate succeeds the debugger assumes the trace
action has been taken care of and continues execution as described by Action. Otherwise the
normal Prolog debugger actions are performed.

Port denotes the reason to activate the tracer (‘port’ in the 4/5-port, but with some additions:

call
Normal entry through the call-port of the 4-port debugger.

redo
Normal entry through the call-port of the 4-port debugger. The redo port signals resum-
ing a predicate to generate alternative solutions.

unify
The unify-port represents the neck instruction, signalling the end of the head-matching
process. This port is normally invisible. See leash/1 and visible/1.

exit
The exit-port signals the goal is proved. It is possible for the goal to have alternative. See
prolog_frame_attribute/3 to examine the goal-stack.

fail
The fail-port signals final failure of the goal.

exception(Except)
An exception is raised and still pending. This port is activated on each parent frame of
the frame generating the exception until the exception is caught or the user restarts normal
computation using retry. Except is the pending exception-term.
B.3 Hooks using the exception/3 predicate

This section describes the predicate exception/3, which may be defined by the user in the module user as a multifile predicate. Unlike the name suggests, this is actually a hook predicate. Exceptions are handled by the ISO predicates catch/3 and throw/1. They all frames created after the matching catch/3 to be discarded immediately.

The predicate exception/3 is called by the kernel on a couple of events, allowing the user to alter the behaviour on some predefined events.
exception(+Exception, +Context, -Action)

Dynamic predicate, normally not defined. Called by the Prolog system on run-time exceptions. Currently exception/3 is only used for trapping undefined predicates. Future versions might handle signal handling, floating exceptions and other runtime errors via this mechanism. The values for Exception are described below.

undefined_predicate

If Exception is undefined_predicate Context is instantiated to a term Name/Arity. Name refers to the name and Arity to the arity of the undefined predicate. If the definition module of the predicate is not user, Context will be of the form ⟨Module⟩:⟨Name⟩/⟨Arity⟩. If the predicate fails Prolog will generate an existence_error exception. If the predicate succeeds it should instantiate the last argument either to the atom fail to tell Prolog to fail the predicate, the atom retry to tell Prolog to retry the predicate or error to make the system generate an exception. The action retry only makes sense if the exception handler has defined the predicate.

B.4 Hooks for integrating libraries

Some libraries realise an entirely new programming paradigm on top of Prolog. An example is XPCE which adds an object-system to Prolog as well as an extensive set of graphical primitives. SWI-Prolog provides several hooks to improve the integration of such libraries. See also section 4.4 for editing hooks and section 4.9.3 for hooking into the message system.

prolog_list_goal(:Goal)

Hook, normally not defined. This hook is called by the ‘L’ command of the tracer in the module user to list the currently called predicate. This hook may be defined to list only relevant clauses of the indicated Goal and/or show the actual source-code in an editor. See also portray/1 and multifile/1.

prolog:debug_control_hook(:Action)

Hook for the debugger-control predicates that allows the creator of more high-level programming languages to use the common front-end predicates to control de debugger. For example, XPCE uses these hooks to allow for spying methods rather then predicates. Action is one of:

spy(Spec)

Hook in spy/1. If the hook succeeds spy/1 takes no further action.

nospy(Spec)

Hook in nospy/1. If the hook succeeds spy/1 takes no further action. If spy/1 is hooked, it is advised to place a complementary hook for nospy/1.

nospyall

Hook in nospyall/0. Should remove all spy-points. This hook is called in a failure-driven loop.

debugging

Hook in debugging/0. It can be used in two ways. It can report the status of the additional debug-points controlled by the above hooks and fail to let the system report the others or it succeed, overruling the entire behaviour of debugging/0.
prolog:help_hook(+Action)
    Hook into help/0 and help/1. If the hook succeeds, the built-in actions are not executed.
    For example, ?- help(picture). is caught by the XPCE help-hook to give help on the
class picture. Defined actions are:

    help
        User entered plain help/0 to give default help. The default performs help(help/1),
giving help on help.

    help(What)
        Hook in help/1 on the topic What.

    apropos(What)
        Hook in apropos/1 on the topic What.

B.5   Readline Interaction

The following predicates are available if current_prolog_flag(readline, true) suc-
ceeds. They allow for direct interaction with the GNU readline library. See also readline(3)

rl_read_init_file(+File)
    Read a readline initialisation file. Readline by default reads ~/.inputrc. This predicate may
be used to read alternative readline initialisation files.

rl_add_history(+Line)
    Add a line to the Control-P/Control-N history system of the readline library.
anonymous [variable]

The variable _ is called the anonymous variable. Multiple occurrences of _ in a single term are not shared.

arguments

Arguments are terms that appear in a compound term. A1 and a2 are the first and second argument of the term myterm(A1, a2).

arity

Argument count (is number of arguments) of a compound term.

assert

Add a clause to a predicate. Clauses can be added at either end of the clause-list of a predicate. See assert/1 and assertz/1.

atom

Textual constant. Used as name for compound terms, to represent constants or text.

backtracking

Searching process used by Prolog. If a predicate offers multiple clauses to solve a goal, they are tried one-by-one until one succeeds. If a subsequent part of the prove is not satisfied with the resulting variable binding, it may ask for an alternative solution (= binding of the variables), causing Prolog to reject the previously chosen clause and try the next one.

binding [of a variable]

Current value of the variable. See also backtracking and query.

built-in [predicate]

Predicate that is part of the Prolog system. Built in predicates cannot be redefined by the user, unless this is overruled using redefine_system_predicate/1.

body

Part of a clause behind the neck operator (:-).

clause

‘Sentence’ of a Prolog program. A clause consists of a head and body separated by the neck operator (:-) or it is a fact. For example:

\[
\begin{align*}
\text{parent}(X) & : - \\
\text{father}(X, _) & .
\end{align*}
\]
Expressed “X is a parent if X is a father of someone”. See also variable and predicate.

**compile**
Process where a Prolog program is translated to a sequence of instructions. See also interpreted. SWI-Prolog always compiles your program before executing it.

**compound [term]**
Also called structure. It consists of a name followed by $N$ arguments, each of which are terms. $N$ is called the arity of the term.

**context module**
If a term is referring to a predicate in a module, the context module is used to find the target module. The context module of a goal is the module in which the predicate is defined, unless this predicate is module transparent, in which case the context module is inherited from the parent goal. See also module\_transparent/1.

**dynamic [predicate]**
A dynamic predicate is a predicate to which clauses may be asserted and from which clauses may be retracted while the program is running. See also update view.

**exported [predicate]**
A predicate is said to be exported from a module if it appears in the public list. This implies that the predicate can be imported into another module to make it visible there. See also use\_module/[1,2].

**fact**
Clause without a body. This is called a fact because interpreted as logic, there is no condition to be satisfied. The example below states john is a person.

```
person(john). 
```

**fail**
A goal is said to have failed if it could not be proven.

**float**
Computers crippled representation of a real number. Represented as ‘IEEE double’.

**foreign**
Computer code expressed in other languages than Prolog. SWI-Prolog can only cooperate directly with the C and C++ computer languages.

**functor**
Combination of name and arity of a compound term. The term $\text{foo}(a, b, c)$ is said to be a term belonging to the functor $\text{foo}/3$. $\text{foo}/0$ is used to refer to the atom $\text{foo}$.

**goal**
Question stated to the Prolog engine. A goal is either an atom or a compound term. A goal succeeds, in which case the variables in the compound terms have a binding or fails if Prolog fails to prove the goal.
hashing

Indexing technique used for quick lookup.

head

Part of a clause before the neck instruction. This is an atom or compound term.

imported [predicate]

A predicate is said to be imported into a module if it is defined in another module and made available in this module. See also chapter 5.

indexing

Indexing is a technique used to quickly select candidate clauses of a predicate for a specific goal. In most Prolog systems, including SWI-Prolog, indexing is done on the first argument of the head. If this argument is instantiated to an atom, integer, float or compound term with functor, hashing is used quickly select all clauses of which the first argument may unify with the first argument of the goal.

integer

Whole number. On most current machines, SWI-Prolog integers are represented as ‘32-bit signed values’, ranging from -2147483648 to 2147483647. See also current_prolog_flag/2.

interpreted

As opposed to compiled, interpreted means the Prolog system attempts to prove a goal by directly reading the clauses rather than executing instructions from an (abstract) instruction set that is not or only indirectly related to Prolog.

meta predicate

A predicate that reasons about other predicates, either by calling them, (re)defining them or querying properties.

module

Collection of predicates. Each module defines a name-space for predicates. built-in predicates are accessible from all modules. Predicates can be published (exported) and imported to make their definition available to other modules.

module transparent [predicate]

A predicate that does not change the context module. Sometimes also called a meta predicate.

multifile [predicate]

Predicate for which the definition is distributed over multiple source-files. See multi_file/1.

neck

Operator (:-) separating head from body in a clause.

operator

Symbol (atom) that may be placed before its operant (prefix), after its operant (postfix) or between its two operants (infix).

In Prolog, the expression a+b is exactly the same as the canonical term + (a, b).
**operand**

*Argument of an operator.*

**precedence**

The *priority* of an operator. Operator precedence is used to interpret \( a+b*c \) as \(+((a, *(b,c)))\).

**predicate**

Collection of *clauses* with the same *functor* (name/arity). If a *goal* is proved, the system looks for a *predicate* with the same functor, then used *indexing* to select candidate *clauses* and then tries these *clauses* one-by-one. See also *backtracking*.

**priority**

In the context of *operators* a synonym for *precedence*.

**program**

Collection of *predicates*.

**property**

Attribute of an object. SWI-Prolog defines various *property* predicates to query the status of predicates, clauses, etc.

**prove**

Process where Prolog attempts to prove a *query* using the available *predicates*.

**public list**

List of *predicates* exported from a *module*.

**query**

See *goal*.

**retract**

Remove a *clause* from a *predicate*. See also *dynamic*, *update view* and *assert*.

**shared**

Two *variables* are called *shared* after they are *unified*. This implies if either of them is *bound*, the other is bound to the same value:

\[
\text{?- A = B, A = a.}
\]

\[
A = a, \\
B = a
\]

**singleton [variable]**

*Variable* appearing only one time in a *clause*. SWI-Prolog normally warns for this to avoid you making spelling mistakes. If a variable appears on purpose only once in a clause, write it as _ (see *anonymous*) or make sure the first character is a _. See also the *style_check/1* option *singletons*.

**solution**

*Bindings* resulting from a successfully *proven goal*. 
structure
   Synonym for compound term.

string
   Used for the following representations of text: a packed array (see section 4.23, SWI-Prolog specific), a list of character codes or a list of one-character atoms.

succeed
   A goal is said to have succeeded if it has been proven.

term
   Value in Prolog. A term is either a variable, atom, integer, float or compound term. In addition, SWI-Prolog also defines the type string

transparent
   See module transparent.

unify
   Prolog process to make two terms equal by assigning variables in one term to values at the corresponding location of the other term. For example:

   ?- foo(a, B) = foo(A, b).

   A = a,
   B = b

   Unlike assignment (which does not exist in Prolog), unification is not directed.

update view
   How Prolog behaves when a dynamic predicate is changed while it is running. There are two models. In most older Prolog systems the change becomes immediately visible to the goal, in modern systems including SWI-Prolog, the running goal is not affected. Only new goals ‘see’ the new definition.

variable
   A Prolog variable is a value that ‘is not yet bound’. After binding a variable, it cannot be modified. Backtracking to a point in the execution before the variable was bound will turn it back into a variable:

   ?- A = b, A = c.
   No
   ?- (A = b; true; A = c).
   A = b ;
   A = _G283 ;
   A = c ;
   No

   See also unify.
SWI-Prolog licensing aims at a large audience, combining ideas from the Free Software Foundation and the less principal Open Source Initiative. The license aims at:

- Make SWI-Prolog itself and its libraries are ‘As free as possible’.
- Allow for easy integration of contributions. See section D.2.
- Free software can build on SWI-Prolog without limitations.
- Non-free (open or proprietary) software can be produced using SWI-Prolog, although contributed pure GPL-ed components cannot be used.

To achieve this, different parts of the system have different licenses. SWI-Prolog programs consists of a mixture of ‘native’ code (source compiled to machine instructions) and ‘virtual machine’ code (Prolog source compiled to SWI-Prolog virtual machine instructions, covering both compiled SWI-Prolog libraries and your compiled application).

For maximal coherence between free licenses, we start with the two prime licenses from the Free Software Foundation, the GNU General Public License (GPL) and the Lesser GNU General Public License (LGPL), after which we add a proven (used by the GNU-C compiler runtime library as well as the GNU ClassPath project) exception to deal with the specific nature of compiled virtual machine code in a saved state.

D.1 The SWI-Prolog kernel and foreign libraries

The SWI-Prolog kernel and our foreign libraries are distributed under the LGPL. A Prolog executable consists of the combination of these ‘native’ code components and Prolog virtual machine code. The SWI-Prolog plrc utility allows for disassembling and re-assembling these parts, a process satisfying article 6b of the LGPL.

Under the LGPL SWI-Prolog can be linked to code distributed under arbitrary licenses, provided a number of requirements are fullfilled. The most important requirement is that, if an application replies on a modified version of SWI-Prolog, the modified sources must be made available.

D.1.1 The SWI-Prolog Prolog libraries

Lacking a satisfactory technical solution to handle article 6 of the LGPL, this license cannot be used for the Prolog source code that is part of the SWI-Prolog system (both libraries and kernel code). This situation is comparable to libgcc, the runtime library used with the GNU C-compiler. Therefore, we use the same proven license terms as this library. The libgcc license is the with a special exception. Below we rephrased this exception adjusted to our needs:
As a special exception, if you link this library with other files, compiled with a Free Software compiler, to produce an executable, this library does not by itself cause the resulting executable to be covered by the GNU General Public License. This exception does not however invalidate any other reasons why the executable file might be covered by the GNU General Public License.

D.2 Contributing to the SWI-Prolog project

To achieve maximal coherence using SWI-Prolog for Free and Non-Free software we advice the use of the LGPL for contributed foreign code and the use of the GPL with SWI-Prolog exception for Prolog code for contributed modules.

As a rule of thumb it is advised to use the above licenses whenever possible and only use a strict GPL compliant license only if the module contains other code under strict GPL compliant licenses.

D.3 Software support to keep track of license conditions

Given the above, it is possible that SWI-Prolog packages and extensions will rely on the GPL. The predicates below allow for registering license requirements for Prolog files and foreign modules. The predicate eval_license/0 reports which components from the currently configured system are distributed under copy-left and open source enforcing licenses (the GPL) and therefore must be replaced before distributing linked applications under non-free license conditions.

\[ \text{eval_license} \]

Evaluate the license conditions of all loaded components. If the system contains one or more components that are licenced under GPL-like restrictions the system indicates this program may only be distributed under the GPL license as well as which components prohibit the use of other license conditions.

\[ \text{license(+LicenseId, +Component)} \]

Register the fact that Component is distributed under a license identified by LicenseId. The most important LicenseId’s are:

\[ \text{swipl} \]

Indicates this module is distributed under the GNU General Public License (GPL) with the SWI-Prolog exception:

As a special exception, if you link this library with other files, compiled with SWI-Prolog, to produce an executable, this library does not by itself cause the resulting executable to be covered by the GNU General Public License. This exception does not however invalidate any other reasons why the executable file might be covered by the GNU General Public License.

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1. On the Unix version, the default toplevel uses the GNU readline library for command-line editing. This library is distributed under the GPL. In practice this problem is small as most final applications have Prolog embedded, without direct access to the commandline and therefore without need for libreadline.
2. This exception is a straight re-phrasing of the license used for libgcc, the GNU-C runtime library facing similar technical issues.
D.3. SOFTWARE SUPPORT TO KEEP TRACK OF LICENSE CONDITIONS

This should be the default for software contributed to the SWI-Prolog project as it allows the community to prosper both in the free and non-free world. Still, people using SWI-Prolog to create non-free applications must contribute sources to improvements they make to the community.

lgpl
This is the default license for foreign-libraries linked with SWI-Prolog. Use PL_license() to register the condition from foreign code.

gpl
Indicates this module is strictly Free Software, which implies it cannot be used together with any module that is incompatible to the GPL. Please only use these conditions when forced by other code used in the component.

license(+LicenseId)
Intended as a directive in Prolog source files. It takes the current filename and calls license/2.

void PL_license(const char *LicenseId, const char *Component)
Intended for the install() procedure of foreign libraries. This call can be made before PL_initialise().
Summary

E.1 Predicates

The predicate summary is used by the Prolog predicate `apropos/1` to suggest predicates from a keyword.

```prolog
!/0  Cut (discard choicepoints)
!/1  Cut block. See `block/3`
, /2  Conjunction of goals
->/2  If-then-else
*->/2  Soft-cut
./2  Consult. Also list constructor
;/2  Disjunction of goals. Same as `|/2`
</2  Arithmetic smaller
=/2  Unification
=../2  “Univ.” Term to list conversion
=:=/2  Arithmetic equal
=</2  Arithmetic smaller or equal
==/2  Identical
=@=/2  Structural identical
=\=/2  Arithmetic not equal
>/2  Arithmetic larger
>=/2  Arithmetic larger or equal
@</2  Standard order smaller
@=/2  Standard order equal
@=</2  Standard order smaller or equal
@>/2  Standard order larger
@>/2  Standard order larger or equal
+/1  Negation by failure. Same as `not/1`
\=/2  Not unifiable
\==/2  Not identical
\=@=/2  Not structural identical
^/2  Existential quantification (`bagof/3, setof/3`)
|/2  Disjunction of goals. Same as `;/2`
abolish/1 Remove predicate definition from the database
abolish/2 Remove predicate definition from the database
abort/0  Abort execution, return to top level
absolute_file_name/2  Get absolute path name
absolute_file_name/3  Get absolute path name with options
access_file/2  Check access permissions of a file
```
E.1. PREDICATES

append/1 Append to a file
append/3 Concatenate lists
apply/2 Call goal with additional arguments
apropos/1 library(online_help) Search manual
arg/3 Access argument of a term
arithmetic_function/1 Register an evaluable function
assert/1 Add a clause to the database
assert/2 Add a clause to the database, give reference
asserta/1 Add a clause to the database (first)
asserta/2 Add a clause to the database (first)
assertz/1 Add a clause to the database (last)
assertz/2 Add a clause to the database (last)
attach_console/0 Attach I/O console to thread
at_end_of_stream/0 Test for end of file on input
at_end_of_stream/1 Test for end of file on stream
at_halt/1 Register goal to run at halt/1
at_initialization/1 Register goal to run at start-up
atom/1 Type check for an atom
atom_chars/2 Convert between atom and list of characters
atom_codes/2 Convert between atom and list of ASCII values
atom_length/2 Determine length of an atom
atom_prefix/2 Test for start of atom
atom_to_term/3 Convert between atom and term
atomic/1 Type check for primitive
autoload/0 Autoload all predicates now
bagof/3 Find all solutions to a goal
between/3 Integer range checking/generating
block/3 Start a block (‘catch’/’throw’)
brack/0 Start interactive toplevel
call/1 Call a goal
call/[2...] Call with additional arguments
call_cleanup/3 Guard a goal with a cleanup-handler
call_cleanup/2 Guard a goal with a cleanup-handler
call_shared_object_function/2 UNIX: Call C-function in shared (.so) file
call_with_depth_limit/3 Prove goal with bounded depth
callable/1 Test for atom or compound term
catch/3 Call goal, watching for exceptions
char_code/2 Convert between atom and ASCII value
char_conversion/2 Provide mapping of input characters
char_type/2 Classify characters
character_count/2 Get character index on a stream
chdir/1 Compatibility: change working directory
checklist/2 Invoke goal on all members of a list
clause/2 Get clauses of a predicate
clause/3 Get clauses of a predicate
clause_property/2 Get properties of a clause
close/1 Close stream
close/2  Close stream (forced)
close_dde_conversation/1  Win32: Close DDE channel
close_shared_object/1  UNIX: Close shared library (.so file)
compare/3  Compare, using a predicate to determine the order
compiling/0  Is this a compilation run?
compound/1  Test for compound term
atom_concat/3  Append two atoms
code_type/2  Classify a character-code
concat_atom/2  Append a list of atoms
concat_atom/3  Append a list of atoms with separator
consult/1  Read (compile) a Prolog source file
context_module/1  Get context module of current goal
convert_time/8  Break time stamp into fields
convert_time/2  Convert time stamp to string
copy_stream_data/2  Copy all data from stream to stream
copy_stream_data/3  Copy n bytes from stream to stream
copy_term/2  Make a copy of a term
current_arithmetic_function/1  Examine evaluable functions
current_atom/1  Examine existing atoms
current_char_conversion/2  Query input character mapping
current_flag/1  Examine existing flags
current_foreign_library/2  library(shlib) Examine loaded shared libraries (.so files)
current_format_predicate/2  Enumerate user-defined format codes
current Functor/2  Examine existing name/arity pairs
current_input/1  Get current input stream
current_key/1  Examine existing database keys
current_module/1  Examine existing modules
current_module/2  Examine existing modules
current_mutex/3  Examine existing mutexes
current_op/3  Examine current operator declarations
current_output/1  Get the current output stream
current_predicate/1  Examine existing predicates (ISO)
current_predicate/2  Examine existing predicates
current_signal/3  Current software signal mapping
current_stream/3  Examine open streams
current_thread/2  Examine Prolog threads
dde_current_connection/2  Win32: Examine open DDE connections
dde_current_service/2  Win32: Examine DDE services provided
dde_execute/2  Win32: Execute command on DDE server
dde_register_service/2  Win32: Become a DDE server
dde_request/3  Win32: Make a DDE request
dde_poke/3  Win32: POKE operation on DDE server
dde_unregister_service/1  Win32: Terminate a DDE service
debug/0  Test for debugging mode
debug_control_hook/1  (hook) Extend spy/1, etc.
debugging/0  Show debugger status
default_module/2  Get the default modules of a module
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<td>--------------------------------------------------------------</td>
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<td>get/2</td>
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<td>get0/1</td>
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<td>get0/2</td>
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<tr>
<td>get_code/1</td>
<td>Read next character (ISO)</td>
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<tr>
<td>get_code/2</td>
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<tr>
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<tr>
<td>import/1</td>
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<td>include/1</td>
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<tr>
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<td>initialization/1</td>
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<tr>
<td>int_to_atom/2</td>
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<td>Convert from integer to atom (non-decimal)</td>
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<tr>
<td>integer/1</td>
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<td>intersection/3</td>
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<td>is_list/1</td>
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<td>keysort/2</td>
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<td>last/2</td>
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<tr>
<td>leash/1</td>
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<tr>
<td>length/2</td>
<td>Length of a list</td>
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<td>library_directory/1</td>
<td>(hook) Directories holding Prolog libraries</td>
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<tr>
<td>license/1</td>
<td>Define license for current file</td>
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<tr>
<td>license/2</td>
<td>Define license for named module</td>
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</tbody>
</table>
E.1. PREDICATES

limit_stack/2  Limit stack expansion
line_count/2  Line number on stream
line_position/2  Character position in line on stream
list_to_set/2  Remove duplicates
listing/0  List program in current module
listing/1  List predicate
load_files/2  Load source files with options
load_foreign_library/1  library(shlib) Load shared library (.so file)
load_foreign_library/2  library(shlib) Load shared library (.so file)
make/0  Reconsult all changed source files
make_directory/1  Create a folder on the file system
make_fat_filemap/1  Win32: Create file containing non-FAT filenames
make_library_index/1  Create autoload file INDEX.pl
make_library_index/2  Create selective autoload file INDEX.pl
maplist/3  Transform all elements of a list
member/2  Element is member of a list
memberchk/2  Deterministic member/2
merge/3  Merge two sorted lists
merge_set/3  Merge two sorted sets
message_hook/3  Intercept print_message/2
message_to_string/2  Translate message-term to string
meta_predicate/1  Quintus compatibility
module/1  Query/set current type-in module
module/2  Declare a module
module_transparent/1  Indicate module based meta predicate
msort/2  Sort, do not remove duplicates
multifile/1  Indicate distributed definition of predicate
mutex_create/1  Create a thread-synchronisation device
mutex_destroy/1  Destroy a mutex
mutex_lock/1  Become owner of a mutex
mutex_trylock/1  Become owner of a mutex (non-blocking)
mutex_unlock/1  Release ownership of mutex
mutex_unlock_all/0  Release ownership of all mutexes
name/2  Convert between atom and list of ASCII characters
nl/0  Generate a newline
nl/1  Generate a newline on a stream
nodebug/0  Disable debugging
noguitracer/0  Disable the graphical debugger
nonvar/1  Type check for bound term
noprotocol/0  Disable logging of user interaction
nospy/1  Remove spy point
nospyall/0  Remove all spy points
not/1  Negation by failure (argument not provable). Same as \+/1
notrace/0  Stop tracing
notrace/1  Do not debug argument goal
nth0/3  N-th element of a list (0-based)
nth1/3  N-th element of a list (1-based)
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<thead>
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<th>Symbol</th>
<th>Description</th>
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### E.1. PREDICATES

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</table>
E.2 Library predicates

E.2.1 library(check)

check/0  Program completeness and consistency
list_undefined/0  List undefined predicates
listautoload/0  List predicates that require autoload
list_redefined/0  List locally redefined predicates

E.2.2 library(readutil)

read_line_to_codes/2  Read line from a stream
read_line_to_codes/3  Read line from a stream
read_stream_to_codes/2  Read contents of stream
read_stream_to_codes/3  Read contents of stream
read_file_to_codes/3  Read contents of file
read_file_to_terms/3  Read contents of file to Prolog terms

E.2.3 library(netscape)

www_open_url/1  Open a web-page in a browser

E.2.4 library(registry)

registry_get_key/2  Get principal value of key
registry_get_key/3  Get associated value of key
registry_set_key/2  Set principal value of key
registry_set_key/3  Set associated value of key
registry_delete_key/1  Remove a key
shell_register_file_type/4  Register a file-type
shell_register_dde/6  Register DDE action
shell_register_prolog/1  Register Prolog

E.2.5 library(url)

parse_url/2  Analyse or construct a URL
parse_url/3  Analyse or construct a relative URL
global_url/3  Make relative URL global
http_location/2  Analyse or construct location
www_form_encode/2  Encode or decode form-data
E.3 Arithmetic Functions

* /2 Multiplication
** * /2 Power function
+ /2 Addition
− /1 Unary minus
− /2 Subtraction
/ /2 Division
// /2 Integer division
/ \ /2 Bitwise and
<< /2 Bitwise left shift
>> /2 Bitwise right shift
. /2 List of one character: character code
\ /1 Bitwise negation
\ / /2 Bitwise or
^ /2 Power function
abs /1 Absolute value
acos /1 Inverse (arc) cosine
asin /1 Inverse (arc) sine
atan /1 Inverse (arc) tangent
atan/2 Rectangular to polar conversion
ceil /1 Smallest integer larger than arg
ceiling /1 Smallest integer larger than arg
cos /1 Cosine
cputime /0 Get CPU time
e /0 Mathematical constant
exp /1 Exponent (base $e$)
float /1 Explicitly convert to float
float_fractional_part /1 Fractional part of a float
float_integer_part /1 Integer part of a float
floor /1 Largest integer below argument
integer /1 Round to nearest integer
log /1 Natural logarithm
log10 /1 10 base logarithm
max /2 Maximum of two numbers
min /2 Minimum of two numbers
mod /2 Remainder of division
random /1 Generate random number
rem /2 Remainder of division
round /1 Round to nearest integer
truncate /1 Truncate float to integer
pi /0 Mathematical constant
sign /1 Extract sign of value
sin /1 Sine
sqrt /1 Square root
tan /1 Tangent
xor/2  Bitwise exclusive or
E.4 Operators

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<td>$200xfy$</td>
<td>Predicate</td>
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<td>^</td>
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<td>mod</td>
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