ALS Prolog User Guide

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The ALS Prolog Language: Standard Part

1 The Syntax of ALS Prolog

This chapter describes the syntax of ALS Prolog, which is for the most part the syntax of the ISO Prolog standard . Prolog syntax is quite simple and regular, which is a great strength.

1.1 Constants

The simplest Prolog data type is a constant, which comes in two flavors:

- atoms (sometimes called ***symbols***)
- numbers

The notion of a *constant* corresponds roughly to the notion of a *name* in a natural language. Names in natural languages refer to things (which covers a lot of ground), and constants in Prolog are be used to refer to things when the language is interpreted.

1.1.1 Numbers

Prolog uses two representations for numbers:

- integer
- floating point

When it is impossible to use an integer representation due to the size of a nominal integer , a floating point representation can be used instead. This means that extremely large integers may actually require the extended precision of a floating point value. Any operation involving integers, such as a call to `is/2`, will first attempt to usean integer representation for the result, and will use a floating point value only when necessary.   This type *coercion* is carried out consistently within the Prolog system.

There is no automatic conversion of floating point numbers into integers[1].

Integers

The textual representation of an integer consists of a sequence of one or more digits

(`0` through `9`) optionally preceeded by a '`-`' to signify a negative number. The parser assumes that all integers are written using base ten, unless the special binary, octal, or hexadecimal notation is used.

The hexadecimal notation is a `0x` followed by a sequence of valid hexadecimal digits. The following are valid hexadecimal digits:

```
0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F
```

The octal notation is a 0o followed by a sequence of valid octal digits. The octal digits are:

```
0 1 2 3 4 5 6 7
```

The binary notation is a 0b follwed by a sequence of 0's and 1's.

Here are some examples of integers:

```
0   4532   -273  0000001  0x1fff  0b1001 0o123
```

It is important to note that a term of the form `+5` is not an integer, but rather a structured term.

Floating point numbers

Floating point numbers are slightly more complex than integers in that they may have either a fractional part, an exponent, or both. A ***fractional floating point number*** consists of a sequence of one or more numeric characters, followed by a dot ('`.`'), in turn followed by another sequence of one or more numeric characters; the entire expression may optionally be preceded by a '-'. Here are some examples of floating point numbers:

```
0.0   3.1415927  -3.4  000023.540000
```

You can also specify an exponent using ***scientific notation***. An exponent is either an `e` or an `E` followed by an optional '`-`', signifying a negative exponent, followed by a sequence of one or more numeric characters. Here are examples of floating point numbers with exponents:

1. In earlier versions of ALS Prolog, if a floating point number had no fractional part, and was within the range of an ALS Prolog integer, it would be represented internally as an integer. However, the ISO Prolog standard now forbids this.

```
0.1e-3   10E99  -44.66e-88  0E-0
```

ASCII Codes

ASCII (American Standard Code for Information Interchange) codes are small integers between `0` and `255` inclusive that represent characters. The parser will translate any printable character into its corresponding ASCII integer. In order to get the ASCII code for a character, preceed the character by the characters `0’`. For example, the code for the characters ‘A’, ‘8’, and ‘%’ would be given by:

```
0’A   0’8   0’%
```

In addition, the ANSI C-style octal and hex forms expression can be used. Thus, all of the expressions below denote the number 65:

```
0’A   0’\101   0’\x41
```

Table 1 (*Example ASCI Code Sequences.*) below contains some example ASCII code specifications.

Expression	Octal Expression	Hex Expression	ASCI Code (Decimal)	Character
0’A	0’\101	0’\x41	65	Upper case A
0’c	0’\143	0’\x63	99	Lower case c
0’~	0’\176	0’\x7e	126	Tilde character

Table 1. Example ASCI Code Sequences.

There also exists a small collection of symbolic control characters which can be thought of as synonyms for certain of the ASCI control character codes. These are presented in Table 3 (*Symbolic Control Characters.*)

Table 2:

Expression	Octal Expression	Hex Expression	ASCI Code (Decimal)	Character
0’\a	0’\007	0’\x7	7	alert (‘bell’)
0’\b	0’\010	0’x\8	8	backspace

Table 2:

Expression	Octal Expression	Hex Expression	ASCI Code (Decimal)	Character
0’\f	0’\014	0’\xC	12	form feed
0’\n	0’\012	0’\xA	10	new line
0’\r	0’\015	0’\xD	13	return
0’\t	0’\011	0’\x9	9	horizontal tab
0’\v	0’\147	0’\x77	119	vertical tab

Table 3. Symbolic Control Characters.

Chapter 31 (*ASCII Table*) in the Reference Manuals presents the full ASCII character set.

1.1.2 Atoms

An atom is a sequence of characters that are parsed together as a constant.

Alphanumeric atoms

An alphanumeric atom is a sequence of characters that begins with a lower case letter, and is followed by zero or more alphanumeric characters, possibly including ‘_’.[1] Here are some examples of alphanumeric atoms:

```
foobar123   zIPPY   bread_and_butter  money
```

Quoted atoms

A quoted atom is formed by placing any sequence of characters between single quotes (‘’’). A single quote can be included in the text of the atom by using two consecutive single quotes for each one desired, or by prefixing the embedded single

1. Earlier versions of ALS Prolog allowed presence of the ‘$’ symbol in unquoted atoms. This has been dropped as part of conformance to the Prolog Standard.

quote with the backslash (\) escape character. The following are all quoted atoms:

```
    'any char will do'   '$*#!#@%#*'   'Can''t miss'
    'Can\'t miss'    '99999'
```

If the characters that compose a quoted atom can be interpreted as an atom when they occur without the enclosing single quotes, then it is not necessary to use the quoted form. However, if the atom contains characters that aren't allowed in a simple atom, then the quotes are required. Note that the last example above is an atom whose print name is `99999`, not the integer `99999`.

Quoted atoms can span multiple lines, but in this case the end of each such line must be preceeded by the backslash escape character, as in the following example of an atom:

```
   'We are the stars which sing. \
   We sing with our light; \
   We are the birds of fire, \
   We fly over the sky. \
       -- Algonquin poem.'
```

Special atoms

A special atom is any sequence of characters from the following set:

```
   +-*/\^<>=`:.?@#&.
```

In addition, the atoms, `[]`, `!`, `;` and `,` are considered to be special atoms. Some other examples of special atoms are:

```
   +=   &&   @>=   ==   <---------
```

Most special atoms are automatically read as quoted atoms unless they have been declared as operators (See "Operators" on page 9).

1.2 Variables

A variable consists of either a `_` (underbar character) or an upper case letter, followed by a sequence of alphanumeric characters and dollar signs. Here are some variables:

```
   Variable X123a    _a$bc     _123      _
```

1.3 Compund Terms

A compound term is consists of a symbolic constant, called a functor, followed by a left parenthesis followed by one or more terms separated by commas, followed by a right parenthesis. The number of terms separated by commas enclosed in the parentheses is called the *arity* of the structure. For example, the compound term

```
    f(a,b(X),y)
```

has arity 3.

1.4 Curly Braces

Instead of prefixing a structured term with a functor, the curly brace notation allows a sequence of terms, separated by commas, to be grouped together in a comma list with '`{}`' as the principal functor. For example,

```
    {all,the,young,dudes}
```

parses internally into:

```
    '{}'((all,the,young,dudes))
```

1.5 Lists

The simplest list is the empty list, represented by the atom '`[]`'. Any other list is a structured term with `./2` as principal functor and whose second argument is a list. Lists can be written by using '`.`' explicitly as a functor, or using the special *list* notation.

A list using list notation is written as a `[` followed by the successive first arguments of all the sublists in order seperated by commas, followed by `]`. The following are all different ways of writing the same list:

```
    a.b.c.[]      [a,b,c]      '.'(a,'.'(b,'.'(c,[])))
```

Unless specified, the last tail of a list is assumed to be `[]`. A tail of a list can be specified explicitly by using `|`, as in these examples:

```
    [a|X]   [1,2,3|[]]     [Head|Tail]
```

The list notation for lists is preferrable to using '`.`' explicitly because the dot is also used in floating point numbers and to signal termination of input terms.

1.6 Strings

A string is any sequence of characters enclosed in double quotes ("). The parser automatically translates any string into the list of ASCII codes that corresponds to the characters between the quotes. For example, the string

```
"It’s a dog’s life"
```

is translated into

```
[73,116,39,115,32,97,32,100,111,103,39,115,32,108,10
  5,102,101]
```

Double quotes can be embedded in strings by either repeating the double quote or by using the backslash escape character before the embedded “, as for example in

```
"She said, ""hi.""".
"She said, \"hi.\"".
```

1.7 Operators

The prefix functor notation is convenient for writing terms with many arguments. However, Prolog allows a program to define a more readable syntax for structured terms with one or arguments. For example, the parser recognizes the text

```
a+b+c
```

as an expression representing

```
+(+(a,b),c)
```

because the special atom + is declared as an infix operator. Infix operators are written between their two arguments. For the other operator types, prefix and postfix, the operator (functor) is written before (prefix) or after (postfix) the single argument to the term.

What Makes an Operator?

Operators are either alphanumeric atoms or special atoms which have a corresponding *precedence* and *associativity*. The associativity is sometimes referred to as the *type* of an operator. Operators may be declared by using the `op/3` builtin.

Precedences range from 1 to 1200 with the lower precedences having the tightest binding. Another way of looking at this is that in an expression such as `1*X+Y`, the operator with the highest precedence will be the principal functor. So `1*X+Y` is equivalent to `'+'('*'(1,X),Y)` because the '`*`' binds tighter than the '`+`'.

The types of operators are named

> `fx`, `fy`, `xf`, `yf`, `xfx`, `yfx`, and `xfy` ,

where the'`f`' shows the position of the operator. Hence, `fx` and `fy` indicate prefix operators, `yf`, and `xf` indicate postfix operators, and `xfx`, `yfx`, and `xfy` indicate infix operators. An '`x`' indicates that the operator will not associate with operators of the same or greater precedence, while a '`y`' indicates that it will associate with operators of the same or lower precedence, but not operators of greater precedence.

The default or predefined operators are listed in the following tables:

Table 4: Predefined Binary Operators in ALS Prolog

Operator	Specifier	Precedence	Operator	Specifier	Precedence
:-	xfx	1200	=:=	xfx	700
-->	xfx	1200	=\=	xfx	700
==>	xfy	1200	<	xfx	700
when	xfx	1190	=<	xfx	700
where	xfx	1180	>	xfx	700
with	xfx	1170	>=	xfx	700
if	xfx	1160	:=	xfy	600
;	xfy	1100	+	yfx	500
|	xfy	1100	-	yfx	500

Table 4: Predefined Binary Operators in ALS Prolog

Operator	Specifier	Precedence	Operator	Specifier	Precedence
->	xfy	1050	/\	yfx	500
,	xfy	1000	\/	yfx	500
:	xfy	950	xor	yfx	500
.	xfy	800	or	yfx	500
=	xfx	700	and	yfx	500
\=	xfx	700	*	yfx	400
==	xfx	700	/	yfx	400
\==	xfx	700	//	yfx	400
@<	xfx	700	div	yfx	400
@=<	xfx	700	rem	yfx	400
@>	xfx	700	mod	yfx	400
@>=	xfx	700	<<	yfx	400
=..	xfx	700	>>	yfx	400
is	xfx	700	**	xfx	200
			^	xfy	200

Table 5: Predefined Prefix Operators in ALS Prolog

Operator	Specifier	Precedence	Operator	Specifier	Precedence
:-	fx	1200	nospy	fx	800
?-	fx	1200	-	fy	200
vi	fx	1125	+	fy	200
edit	fx	1125	\	fy	200
ls	fx	1125	export	fx	1200
cd	fx	1125	use	fx	1200
dir	fx	1125	module	fx	1200
not	fx	900	‘‘	fx	925
\+	fx	900	‘	fx	930
trace	fx	800	~	fy	300
spy	fx	800			

Special Cases

It is possible to declare an operator via `op/3` that can never be parsed. Even though quoted atoms can be assigned a precedence and associativity, the parser will only interpret alphanumeric atoms or special atoms as operators.

White space

White space, or *layout characters*, refers to the part of source code, data, and goals that is not made up of readable characters. The term white space comes from the fact that these unreadable characters appear white when source code is printed on a sheet of white paper. White space is any sequence of spaces, tabs, or new lines.

Generally speaking, white space has little meaning to the parser. It is occasionally important for recognizing full stops, and for delimiting constructs which, if they were run together, would not be recognizable as separate constructs. There are also places where additional white space is either inappropriate or changes the meaning of the text. For example, you can't embed a space in a number.

1.8 Comments

Comments can be put anywhere white space can occur. Comments can take one of two forms:

1. A line comment: anything following a percent sign (`%`) is ignored until the end of line.
2. A block comment: anything enclosed in a '`/* */`' pair is ignored. Block comments may span many lines if desired. Block comments may be nested, thus allowing commented code to be commented out.

```
/*
 *
 *  /*
 *   *    This is one way to use block comments
 *   */
 *
 */

connected(footbone, legbone).

/*    Here's another    */

connected(headbone, neckbone). % line comments can
connected(dogbone, fishbone).  % look good
                               % next to code that
                               % you write
```

1.9 Preprocessor Directives

ALS Prolog supports ***preprocessor directives*** which can affect the text at the time the program is compiler (or loaded into an image). These expressions include the following[1]:

```
   #include   #if   #else  #elif   #endif
```

Each of these must occur at the beginning of a line of program text. Each of `#include`, `#if`, and `#elif` must be followed by a Prolog term, but each of `#else` and `#endif` must stand on a line by themselves. The `#include` directive should be followed by a Prolog double quoted string, intended to name a file:

```
   #include “/mydir/foo.pro”
```

No fullstop (.) should follow this expression, nor the expressions following `#if` and `#elif`. The expression following `#if` or `#elif` can be an arbitrary Prolog term.

The expressions `#if`, `#else`, `#elif`, `#endif` must be organized as conditionals in a manner similar to their use in C programs. Thus, the first expression occurring must be an `#if`, and the last must be an `#endif`. Between them there can be zero or more occurrences of `#else` and `#elif`. There can be at most one occurrence of `#else` between a given `#if` ... `#endif` pair, and it must follow all of the zero or more occurrences of `#elif` between the same pair.

Preprocessor directive semantics appears in Section 2.3 (*Preprocessor Directives.*) .

1. This list might be extended in the future. The most notable candidate would be `#define.`

2 Prolog Source Code

Just like most other computer languages, Prolog allows you to store programs and data in text files. The builtin predicates `consult/1`, `reconsult/1`, `read/1`, and their variants will translate the textual representation for programs and data into the internal representations used by the Prolog system. This section describes what kinds of syntactic objects can appear in source files and how they are interpreted.

2.1 Source Terms

Every Prolog source file must be a sequence of zero or more Prolog terms, each term followed by a period (`.`) and a white space character. A period followed by a white space character is called a *full stop*. Full stops are needed in source files to show where one term ends and another begins. Each term in a file is treated as a closed logical formula. This means that even though two seperate terms have variable names in common, each term's variables are actually distinct from the variables in any other term. Most variables are quantified once for each term. However, there is a special variable, the anonymous variable (written '_ '), which is quantified for each occurrance. This means that within a single term, every occurrance of '_' is a different variable.

2.1.1 Rules

A *rule* is the most common programming construct in Prolog. A rule says that a particular property holds if a conjunction of properties holds. Rules are always written with `:-/2` as the ***principal functo***r. The first argument of the `:-` is called the *head*, and the second argument is called the *body*. Here are some examples of rules:

```
   a(X) :- b(X).
   blt :- bacon, lettuce, tomato.
   test(A,B,C) :- cond1(A,B), cond2(B,C).
```

`consult/1` and `reconsult/1` load rules (and facts - see below) from a source file into the internal run-time Prolog database in the order they occur in the source file.

2.1.2 Facts

A ***fact*** is any term which is not a rule and which cannot be interpreted as a directive or declaration. For example,

```
    module mymodule.
```

would not be interpreted as a fact since it is a module declaration - see Chapter 3 (*Modules*) . More specifically, a fact is any term that cannot be interpreted as a declaration and whose principal functor is not `:-/1`, `?-/1`, or `:-/2`. One way to understand a fact is to say that it is a rule without a body, or a rule with a trivial body (one that is always true). These are example facts:

```
   mortal(socrates).
   big(ben).
   identical(X,X).
```

As with rules, `consult`/1 and `reconsult`/1 load facts (and rules)from a source file into the internal database in the order they occur in the source file.

2.1.3 Commands and Queries

A *command* or *directive* is any term whose principal functor is `:-/1`. Queries are terms whose principal functor is `?-/1`. The single argument to a command or query is a conjunction of goals to be run when `consult` or `reconsult` encounters the construct in a source file.

Commands are often used to add operator declarations to the parser, or to implement command files. Queries are just like commands except they print out `yes` or `no` depending on whether the query succeeded for failed.

Commands are silent unless the command fails, or unless some goal inside the command writes to the current output output stream. If a command fails during the process of consulting a file, a warning message is written to standard output, which is usually the screen or console window.

Here are some examples of commands:

```
   :- op(300, xfx, #).
   :- [file1], [file2],
          write('Files 1&2 have been loaded').
```

```
:- initializeProgram, topLevelGoal.
```

2.1.4 Declarations

Declarations are terms that have a special interpretation when seen by `consult` or `reconsult`. Here are some example declarations:

```
use builtins.
export a/1, b/2, c/3.
module foobar.
```

2.2 Program Files

Program files are sequences of source terms that are meant to be read in by `consult/1` or `reconsult/1`, which interpret the terms as either clauses, declarations, commands, or queries.

2.2.1 Consulting Program Files

To consult a file means to read the file, load the file's clauses into the internal Prolog database, and execute the commands or directives occurring in the file. Reconsulting a file causes part or all of the current definitions in the internal database for procedures which occur in the file to be discarded and the new ones (from the file) to be loaded, as well as executing commands or directives in the file. See Chapter 11 (*Prolog Builtins: Non-I/O*) `consult/1`.

A file is consulted by the goal

```
?- consult(filename).
```

or reconsulted by the goal

```
?- reconsult(filename).
```

Several files can be consulted or reconsulted at once by enclosing the file names in list brackets, as in

```
?- [file1,file2,file3].
```

By default, files listed this way (inside list brackets) are *reconsulted*.[1] To insist that one or more files in such a list be consulted (which might cause some of the clauses from the files to be doubled in memory), prefix a '+' to the filename, as in:

```
    ?- [file1,+file2,file3].
```

In this case, `file2` will be consulted instead of reconsulted. For consistency and backwards compatibility, one can also prefix a '-' to indicate that the file should be reconsulted, even though this is redundant:

```
   ?- [file1,+file2,-file3].
```

When any of these consult goals are presented, first the terms from `file1` are processed, then the terms from `file2`, and finally the terms from `file3`. It is permitted that clauses for the same procedure to occur in more than one file being consulted. In this case, clauses from the earlier file are listed in the internal database before clauses from the later file. Thus, if both `file1` and `file2` contain clauses for procedure `p`, those from `file1` will be listed in the internal database before those from `file2`. Clauses in the internal database are 'tagged' with the file from which they originated. When a file is reconsulted, only those clauses in memory which are tagged as originating from that file will be discarded at the start of the reconsult operation. Thus, suppose that both `file1` and `file3` contain clauses for the procedure `p`, and that we initally perform

```
    ?- [file1,file2,file3].
```

Then suppose that we edit `file3`, and then perform

```
    ?- [file3].
```

The clauses for `p` originally loaded from `file1` will remain undisturbed. The clauses currently in memory for `p` originally from `file3` will be discarded, and the new clauses from `file3` will be loaded.

2.2.2 Using Filenames in Prolog

Note: Complete path names to files are of course quite variable across operating systems. The discussions below are only intended to describe those aspects of file names and path names which affect how ALS Prolog locates files. Examples are provided for all the operating systems supported by ALS Prolog. File names follow

1. This reverses the convention of earlier versions of ALS Prolog as well as Edinburg Prolog, but reflects the preferences of most contemporary Prolog developers.

the ordinary naming conventions of the host operating system. Thus all of the following are acceptable file names:

Unix:

```
   fighter     cave.man   hack/cave.man
   /usr/hack/cave.man
```

Macintosh:

```
   fighter     cave.man   :hack:cave.man
   usr:hack:cave.man
```

Win32:

```
   fighter     cave.man   hack\cave.man
   C:\usr\hack\cave.man
```

In general, file names should be enclosed in single quotes (making them quoted atoms). The exception is any file name which is acceptable as an atom by itself.

Simple file names consist of only the file name, or a file name together with an extension. All others are *complex file names*. Absolute path names provide a complete description of the location of a file in the file system, while relative path names provide a description of a file's location relative to the current directory. Simple file names are interpreted as relative path names.

The way that the program-loading predicates react to the different kinds of path names is described below. In general, however, the loading predicates attempt to determine whether a file exists, and if so, they load the clauses from the file. If the file does not exist, the loading predicates raise an error exception.

If an absolute path name is used as an argument to one of the program loading predicates (`consult/1`, `reconsult/1`, etc.), that file is loaded if it exists. If the file does not exist, an error exception is raised.

If a complex relative path name or a simple file name is passed to consult, the system first attempts to locate the file relative to the current directory. In particular, for a simple file name, the system simply looks in the current directory for the file. In either case, if the file exists, it is loaded.

If the file cannot be found relative to the current directory, ALS Prolog searches for another directory containing that file. Ultimately, the directories (folders) through which ALS Prolog searches are determined by a dynamic collection of facts `searchdir/1` maintained in the `system` (or `builtins`) module. Operationally, ALS Prolog forms the list `PlacesToTry` consisting of all `D` such that

```
    searchdir(D).
```

is true in the module `builtins`, putting the current directory at the head of this list, even when no `searchdir/1` assertion mentions it. Then it works its way through the elements `D` of `PlacesToTry`, attempting to locate the sought-for file relative to directory `D`. The first file located in this manner is loaded. This process is determinate: the system never restarts the search process once a file meeting the relative path desrcription has been found.

If none of the directories listed on PlacesToTry provide a path to the sought-for file, ALS Prolog locates the *alsdir* subdirectory from its own installation, and attempts to locate the file relative to two of the subdirectories, *builtins* and *shared*, which are found in *alsdir*.

If none of these directories provides a means of locating a file with the the original complex relative path name or simple file name, the system raises an error exception.

The facts `searchdir/1` in module `builtins` can be manipulated by a user program or by the user at the console. However, ALS Prolog provides several automatic facilities for installing these facts.

- On Unix and Windows, if the ALSPATH environment variable is set , the entries from this are used to create `searchdir/1` assertions.
- If ALS Prolog was started from the command line, any ‘-s’ switches on the command line will cause `searchdir/1`assertions to be added.

Thus, the directories which will be search appear as follows:

1. First, the current directory is searched.
2. Next, any directories appearing as ‘-s’ command line switches are searched, in the order they appear from left to right on the command line.

3. Next, any directories appearing in an ALSPATH environment variable are searched, in the order they appear in the variable statement.
4. The subdirectory *builtins* of *alsdir* is searched.
5. The subdirectory *shared* of *alsdir* is searched.

Of course, if additional `searchdir/1` have been asserted or retracted, this order will be modified. Note, in particular, that `searchdir/1` assertions for module `builtins` can be included in an ALS Prolog autoload file.

2.2.3 How are Filename Extensions treated?

For your convenience, if you have a file ending with a *.pro* or a *.pl* extension, you don't have to type the extension in calls to the program loading predicates. The following goal loads the Prolog file *wands.pro*:

```
   ?- consult(wands).
```

What really happens is this. On a call to load a file (simple or complex) with no extension, ALS Prolog first searches for a file with exactly that name. If found, that file (with no *.pro* extension) is loaded. If no such file is found, then ALS Prolog attempts to find a file of that name with a *.pro* extension, and following that, with a *.pl* extension. Thus the example above will load *wands.pro* only if there is no file *wands* to be found, not only in the current directory, but also in the directories on the search path described above.

Whenever ALS Prolog loads a Prolog source file, it compiles the file and immediately loads and links the resulting code in memory. If the source file had a *.pro* extension, but the call to load it omitted the *.pro* extension, ALS Prolog also creates a file on the disk containing a relocatable object version of the compiled code. On all operating systems, if the source file had a *.pro* extension, but the call to load the file omitted the *.pro* extension, a file with the same name, but the extension *.obp* is created to hold the relocatable object code. Once a relocatable object file has been created, any call to load the original file will cause the relocatable object file to be loaded instead, provided that the original source file has not been modified since the object file was created. (This is determined by the date-time stamps on the two files.) The advantage of this lies in the fact that object files load much more quickly than source files. Note that on all systems but the Macintosh, the following call will not create an object file for *wands* :

```
            ?- consult('wands.pro').
```

Thus, when consulting or reconsulting a file with no extension, ALS Prolog proceed as follows:

- The system will first look for the file without any extension; if found, it will load the file as is and will not create an object file.
- If the file is not found, the system will then attach the extensions *.pro* and *.obp* and look for both of these files.
- If a *.obp* version of the file exists and is newer than the *.pro* version, then the *.obp* version is loaded.
- On the other hand if the *.pro* version is newer, then the *.pro* version is loaded and a new *.obp* version is created (which is now newer than the *.pro* version).

For the system to correctly decide which file is newer, *.pro* or *.obp* (or the resource fork on the Macintosh), the system date and time should always be set correctly. The directories in which Prolog files reside should be writeable by ALS Prolog so that *.obp* versions of Prolog source files can be produced.

ALS Prolog has facilities for controlling where these **.obp* files are placed, and correspondingly, where they are searched for when (re-)loading files.

2.2.4 Splitting up Prolog Programs

It is common practice to place lines of the form

```
   :- [file1,file2].
```

in files which are being consulted. This will cause both *file1* and *file2* to also be consulted. For both the consult and reconsult operations, this directive behaves as if the text for *file1* and *file2* was placed in the file being consulted at the place where the command occurred. This facility is similar to the `#include` facility found in C. A full description of all predicates for loading programs can be found on the builtins reference page for `consult/1`.

2.3 Preprocessor Directives.

Assume that *PFile* is the name of a file being consulted into ALS Prolog. If *<Filename>* is the name of another valid Prolog source file, then the effect of the preprocessor directive

```
#include “<Filename>”
```

is to textually include the lines of *<Filename>* into *PFile* as if they had actually occurred in *PFile* at the point of the directive.

The conditional preprocessor directives `#if,` #else, `#elif,` and `#endif` behave more or less as they do for C programs. However, the expressions following the `#if` and `#elif` are taken to be Prolog goals, and are evaluated in the current environement, just as for embedded commands of the form `:- G.` Here are some examples. Let *f1.pro* be the following file:

```
:-dynamic(z/1).
%z(f).

p(a).

#if (user:z(f))
p(b).
#else
p(c).
#endif

p(ff).
```

After consulting *f1.pro*, we use listing/0 to see what happened:

```
?- listing.

% user:p/1
p(a).
p(c).
p(ff).
```

```
   yes.
```

In this case, p(c) was loaded, but not p(b). Now let *f2.pro* be the following file:

```
   :-dynamic(z/1).
   z(f).

   p(a).

   #if (user:z(f))
   p(b).
   #else
   p(c).
   #endif

   p(ff).
```

After consulting *f2.pro* to a clean image, we obtain the following:

```
   ?- listing.

   % user:p/1
   p(a).
   p(b).
   p(ff).

   % user:z/1
   z(f).
```

This time, p(b) was loaded instead of p(c).

3 Modules

ALS Prolog provides a module system to facilitate the creation and maintenance of large programs. The main purpose of the module system is to partition procedures into separate groups to avoid naming conflicts between those groups. The module system provides controlled access to procedures within those groups.

The ALS module system only partitions procedures, not constants. This means that the procedure `foo/2` may have different meanings in different modules, but that the constant `bar` is the same in every module.

3.1 Declaring a Module

New modules are created when the compiler sees a module declaration in a source file during a `consult` or `reconsult`. Every module has a name which must be a non-numeric constant. Here are a few valid module declarations:

```
 module dingbat.
module parser.
module compiler.
```

Following a module declaration, all clauses will be asserted into that module using `assertz` until the end of the module or until another module declaration is encountered. In addition, any commands that appear within the scope of the module will be executed from inside that module.

The end of a module is signified by an `endmod`. The following example defines the predicate `test/0` in two different modules. The definitions don't conflict with each other because they appear in different modules.

```
 module mod1.
     test :- write('Module #1'), nl.
endmod.

module mod2.
     test :- write('Module #2'), nl.
endmod.
```

Clauses which are not contained inside an explicit module declaration are added to the default module `user`.

If a module declaration is encountered for a module that already exists, the clauses appearing within that declaration are simply added to the existing contents of that module. In this way, the code for a single module can be spread across multiple files—as long as each file has the appropriate module declaration and ends with a corresponding `endmod`.

The end of a file does not signal the end of the module as shown in the following conversation with the Prolog shell:

```
 ?- [user].
Consulting user ...
module hello.
a.
b.
c.
user consulted

yes.
?- [user].
Consulting user ...
module hello.
d.
endmod.
user consulted

yes.
?- listing(hello:_).

% hello:a/0
a.
% hello:b/0
b.
% hello:c/0
c.
```

```
% hello:d/0
d.
```

If module `hello` had been closed by the EOF of the *user* file, then the `d/0` fact would have appeared in the `user` module instead of the `hello` module. Consequently, it is important to terminate a module with `endmod`. That is, `module` and `endmod` should always be used in matched pairs.

3.2 Sharing Procedures Between Modules

By default, all the procedures defined in a given module are visible only within that module. This is how *name conflicts* are avoided. However, the point of the module system is to allow controlled access to procedures defined in other modules. This task is accomplished by using *export declarations* and *use lists* . `Export` declarations render a given procedure visible outside the module in which it is defined, while `use` lists specify visibility relationships between modules. Each module has a `use` list.

3.3 Finding Procedures in Another Module

Whenever the Prolog system tries to call a procedure, it first looks for that procedure in the module where the call occured. This is done automatically, and independently of `use` list and inheritance declarations.

If the called procedure `p/n` is not defined in some module, say M, from which it is called, then the system will search the `use` list of M for a module M1 that exports the procedure (`p/n`) in question. If such a module M1 is found, then all occurrences of the procedure `p/n` in the calling module M will be 'forwarded' to the procedure `p/n` defined in the module M1. After the procedure `p/n` has been forwarded from module M to another module M1, all future calls to procedure `p/n` from within M will be automatically routed to the proper place in M1 without further intervention of the module system.

The forwarding process is determinate. That is, once a call on procedure `p/n` has been forwarded to `p/n` in module M1, even if backtracking occurs, ALS Prolog will *not* attempt to locate another module M2 containing a procedure to which p/n can be forwarded.

Finally, if no module on the `use` list for M exports the procedure in question (`p/n`), then the procedure `p/n` is undefined in M, and the call fails.

3.3.1 Export Declarations

An ***export declaration*** tells the module system that a particular predicate may be called from other modules. Here are some export declarations:

```
export translate/3.
export reduce/2, compose/3.
export a/0, b/0, c/0.
```

Export declarations can occur anywhere within a module. However, one good programming style dictates that procedures are exported just before they're defined. Another stylistic alternative is to group all the export declarations for a module together in the beginning of the module. The only restriction is that visible procedures must be exported before they can be called from another module. This can happen during the execution of a command or query inside a `consult`.

3.3.2 Use Lists

Associated with each module M is a ***use list*** of other modules where procedures not defined in the given module M may be found. `Use` lists are built by ***use declarations*** which take the forms

```
use mod
use mod1, mod2, ...
```

where `mod` is the name of the module to be used. Here are some examples:

```
use bitOps, splineOps.
use polygons.
```

Each `use` declaration adds the referenced module to the front of the existing `use` list for the module M in which the `use` declaration occurs. If there is more than one module in a given `use` declaration (as in the first example above), then the listed modules are added to the front of the existing use list in reverse order from their original order in the `use` declaration. During the forwarding process, `use` lists are always searched from left to right. This means that the most recently '`used`' modules (i.e., those whose `use` declaration was made most recently) will be searched first. Here's an example of a module with `use` declarations building a `use` list:

```
module graphics.
use bitOps, splineOps.
use polygons.

test :- drawPoly(5, 0, 0).
endmod.
```

In this example, the resulting `use` list for module `graphics` would be:

```
polygons, splineOps, bitOps
```

and this is the order in which the modules will be searched, as shown in Figure 1 (*Use List Searching*).

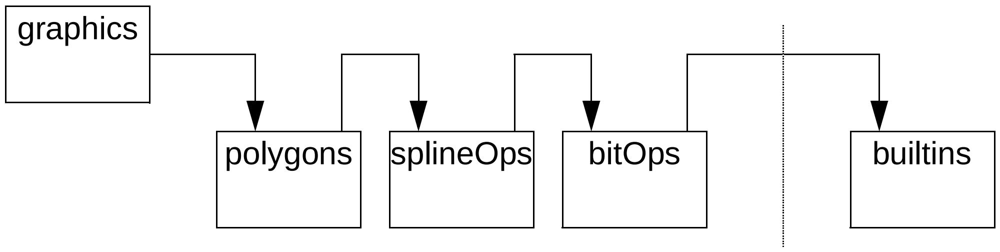


Figure 1. Use List Searching

3.4 Default Modules

Two modules, `builtins` and `user`, are automatically created when the ALS Prolog system starts up. The `builtins` module contains code that defines the standard builtin predicates of the system. All modules automatically `use` the `builtins` module, as suggested in Figure 1 (*Use List Searching*), so therefore the following declaration is implicit:

```
use builtins.
```

`user` is the default module. Any source code that is not contained within a module declaration is automatically placed in the `user` module. In addition, the `user` module automatically uses every other module (in the order the modules are actually created), so it inherits all exported procedures.

3.5 References to Specific Modules

In addition to the `export` and `use` list conventions, the module system allows access to specific modules via the operator `:/2`, whose left hand argument is interpreted as the name of a module, and whose right hand argument is the goal to be called. In the following example, the procedure `zip` in `module1` specifically references the procedure `bar` in `module2`, even though `bar` isn't exported:

```
module module1.
    zip :- module2:bar.
endmod.
module module2.
    bar :- true.
endmod.
```

As this example demonstrates, the `export` declarations of a module aren't sacred and can be violated by `:/2`. However, good software engineering practice suggests that explict references be used only when there are compelling reasons for avoiding the `use` list and export declaration mechanism.

3.6 Nested Modules

ALS Prolog does not currently support the nesting of modules in the way Pascal does for procedures. Instead, ALS Prolog allows modules to be nested, but processes each nested module independently. Consequently, the visibility of a nested module is not limited to the module in which it is declared. The following example illustrates the effect of placing code for a module inside of another module declaration. The Prolog code below shows a declaration for a module `rhyme`, containing a three clause Prolog procedure called `animal/1`. The module is closed off by the last `endmod` declaration. In between the last two clauses of the `animal/1` procedure is the module `reason`. The module `reason` has a two clause procedure named `mineral/1`.

```
module rhyme.
export animal/1.
```

```
     animal(frog).
     animal(monkey).

          % The following module declaration
          % (temporarily) closes off the rhyme module
          % in addition to starting the reason module:
     module reason.
     export mineral/1.

          mineral(glass).
          mineral(silver).

     endmod. % reason

     animal(tiger).

   endmod. % rhyme
```

Here is a conversation with the Prolog shell illustrating the effects of loading the above code:

```
?-listing.
% reason:mineral/1.
mineral(glass).
mineral(silver).
% rhyme:animal/1.
animal(frog).
animal(monkey).
animal(tiger).
```

As you can see, even though the module `reason` was nested in the module `rhyme`, the two modules are processed independently.

3.7 Facilities for Manipulating Modules

When Prolog starts up, the *current module* is `user`. This means that any queries you submit will make use of the procedures defined within `user` and the modules which are accessible from `user`'s `use` list. The current module can always be determined using `curmod/1`. It is called with an uninstantiated variable which is then bound to the current module. The predicate `modules/2` can be used to determine all of the modules currently in the system, together with their `use` lists. Assume that the following code has been consulted:

```
module m1.
use m2.
  p(a).
  p(b).
endmod.

module m2.
  q(c).
  q(d).
endmod.
```

Then the following illustrates the action of `modules/2`:

```
?- modules(X,Y).

X = user
Y = [m2,m1,builtins];

X = builtins
Y = [user];

X = m1
Y = [m2,builtins,user];

X = m2
Y = [builtins,user];
no.
```

4 Using Definite Clause Grammars

Prolog is a very powerful tool for implementing parsers and compilers. The Definite Clause Grammar (DCG) notation provides a convenient means of exploiting this power by automatically translating grammar rules into Prolog clauses. ALS Prolog translates DCG rules occurring in source files into their equivalent Prolog clauses, which are then asserted into the database. The translator itself is a Prolog program contained in the file ***dcgs.pro*** which resides in the *alsdir* directory together with the other builtins files. The sections below provide a simple sketch of the use and operation of DCGs. A more detailed presentation of the use of DCGs and the development of translators for them can be found in [bowen]. Advanced treatment of logic-based grammars is provided by [abramson], [dahl85], [dahl88], and [pereira]. DCGs have the general form

```
non-terminal --> dform1, ..., dformN.
```

where `dform1` through `dformN` are either *non-terminals*, *terminals*, or Prolog goals. Non-terminals are similar in spirit to nouns and verb phrases in natural language, while terminals resemble actual words.

```
sentence --> noun, verbPhrase.
```

The example above uses the non-terminals `noun` and `verbPhrase` to define another non-terminal called `sentence`. The intended reading of the rule is that a sentence can be formed by appending a verb phrase after a noun.

4.1 How Grammar Rules are Translated Into Clauses

The DCG expander works by adding two extra arguments (which are in fact variables) to each non-terminal. These two variables are used to pass the list of tokens to be parsed. The rule that defines a sentence would be translated into the following Prolog clause:

```
sentence(S,E) :- noun(S,I0), verbPhrase(I0,E).
```

This rule means that if `S` is a list of tokens, and if some initial sequence of `S` can be parsed as a sentence, then `E` is the list of tokens which remain after one sentence has been parsed. The first part of the sentence, the noun, is constructed from the tokens beginning with `S` up to `I0`. The verb phrase picks up where the noun left off, and consumes tokens up to `E`. For example, if '`cat`' is a noun, and '`ran`' is a verb phrase, then the following queries will succeed:

```
?- sentence([cat,ran],[]).
?- sentence([cat,ran,away],[away]).
```

In the same manner, if `noun/2` is given the list `[cat,ran]`, it will consume `cat` and return the list `[ran]`. Similarly, `verbPhrase/2` consumes `ran` and hands back the rest of the input token list.

4.2 Writing a Grammar

Because DCG rules are translated into Prolog clauses, it is possible to have many rules that define what it means to be a sentence or a noun or a verb. If one rule can't parse the list of tokens, Prolog will fail and try the next rule. The following set of rules says that `cat`, `dog`, and `pig` are all nouns. In addition, two compound verb phrases are defined.

```
noun --> [cat].
noun --> [dog].
noun --> [pig].

verbPhrase --> verb.
verbPhrase --> verb, adverb.

verb --> [ran].
verb --> [chased].

adverb --> [away].
adverb --> [fast].
```

Here are some examples that make use of these rules:

```
?- noun([dog,chased,cat],[chased,cat]).
?- noun([pig,ate,slop],[ate,slop]).
?- sentence([cat,ran,away],[]).
?- sentence(
       [pig,ran,fast,dog,chased,cat],
       [dog,chased,cat]).
```

The following picture illustrates the consumption of the sentence:

```
    [pig,ran,fast,dog].
```

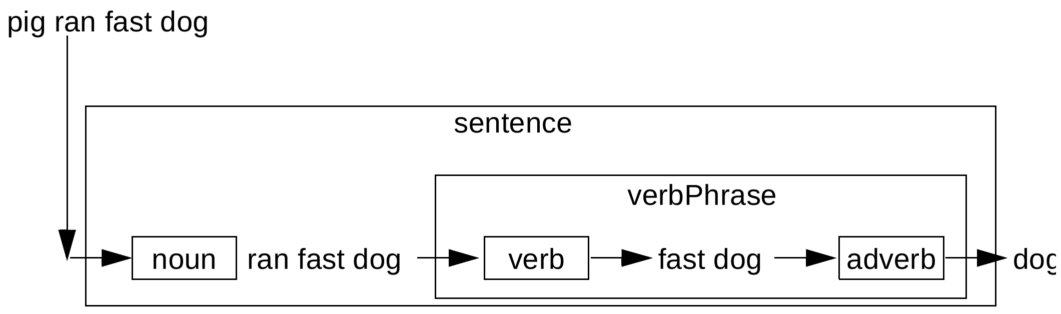


Figure 2. DCG Parsing as Filtering.

The way to read this diagram is to regard each box as a filter. The filter consumes some of the input, and allows the remaining part to pass through to the next filter. The following diagram is a tree which illustrates the structure of the parsed list:

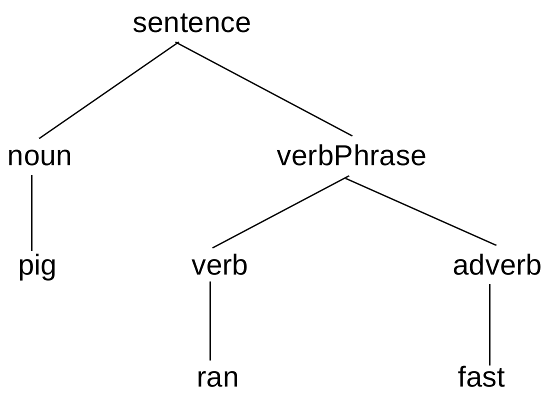


Figure 3. A Parse Tree.

DCG rules can have variables in the non-terminals which can be used to pass and return information. For instance, consider the following collection of DCG rules:

```
noun(animal(pig)) --> [pig].
noun(food(slop)) --> [slop].

nounPhrase(noun(Det,Noun)) -->
  determiner(Det),noun(Noun).

determiner(the) --> [the].
determiner(a) --> [a].
```

Here, `noun` has been defined to return a structure which would be used to differentiate between the different types of `noun`s parsed by the DCG rule. These DCGs would be translated into the following Prolog rules:

```
noun(animal(pig),[pig|E],E).
noun(food(slop),[slop|E],E).

nounPhrase(noun(Det,Noun),S,E) :-
  determiner(Det,S,I0),noun(Noun,I0,E).

determiner(the,[the|E],E).
determiner(a,[a|E],E).
```

Prolog goals can also appear within DCGs if placed between curly braces (`{` and `}`). Goals thus protected by braces are passed through untouched by the DCG expander and do not have the extra arguments added to them. For example, the following rule could be used to recognize numbers:

```
quantity(quantity(Value,Unit)) -->
  [Number],
  {convertnumber(Number,Value),number(Value),!},
  unit(Unit).
```

This rule is translated into:

```
quantity(quantity(Value,Unit),[Number|I0],E) :-
  convertnumber(Number,Value),
  number(Value),!,
  unit(Unit,I0,E).
```

Many of the builtin predicates are also left untouched whether enclosed by the curly braces or not. These are shown in Figure 4

`;/2`	`atom/1`
`</2`	`atomic/1`
`=/2`	`fail/0`
`=:=/2`	`integer/1`
`=</2`	`is/2`
`=\=/2`	`nonvar/1`
`>/2`	`true/0`
`>=/2`	`var/1`

Figure 4. Builtin Predicates Untouched by the DCG Expander.

The ALS Prolog Language: Extensions

5 Abstract Data Types: Structure Definition

One powerful modern programming idea is the use of abstract data types to hide the inner details of the implementation of data types. The arguments in favor of this technique are well-known (cf. [Ref: Liskov]). Of course, it is possible to use the abstract data type idea ’by hand’ as a matter of discipline when developing programs. However, like many other things, programming life becomes easier if useful tools supporting the practice are available. In particular, good tools make it easy to modify abstract data type definitions while still maintaining efficient code.

The *defStruct* tool provides such support for a common construct: the use of Prolog structures (i.e., compound terms) which must be accessed for values and may be (destructively) updated. For example, the implementation of a window system often passes around structures with many slots representing the various properties of particular windows. When programming in C, one would use a C struct for the entity. The analogue in Prolog is a flat compound term.

For speed of access to the slot values, one wants to use the arg/3 builtin. For destructively updating the slot values, one uses the companion mangle/3 builtin. The difficulty with using these builtins is that both require the slot *number* as an argument. As is well-known, hard-coding such numbers leads to opaque code which is difficult to change. The *defStruct* approach allows one to assign symbolic names to the slots, with the corresponding numbers being computed once and for all at compile time. Instead of making calls on arg/3 and mangle/3, the programmer makes calls on access predicates which are defined in terms of arg/3 and mangle/3. (These calls can themselves be macro-processed to replace the access predicate calls by direct calls on arg and mangle, thus making it possible to utilize good coding practice with no loss in performance. See Section [Ref: Macros] for more information.)

Consider the following example which is a simplified version of a defStruct used in an early ALS windowing package. The definition of the structure is declaratively specified by the following in a file with extension ***.typ,*** say ***wintypes.typ*** :

```
:- defStruct(windows,
       [
     propertiesList =
        [windowName,       % name of the window
```

```
            windowNum,        % assigned by window sys
            borderColor/blue, % for color displays
            borderType/sing,  % single or double lines
            uLR, uLC,         % coords(Row,Col) of
                              % upper Left corner
            lRR, lRC,         % coords(Row,Col) of
                              % lower Right corner
            fore/black,       % foreground/background
            back/white        % text attribs
           ],
        accessPred  = accessWI,
        setPred     = setWI,
        makePred    = makeWindowStruct,
        structLabel = wi
       ]
      ).
```

We will discuss the details of this specification below. It can be placed anywhere in a source file, and acts like a macro, generating the following code in its place:

```
   export accessWI/3.
   export setWI/3.
   accessWI(windowName,_A,_B) :- arg(1,_A,_B).
   setWI(windowName,_A,_B) :- mangle(1,_A,_B).

   accessWI(windowNum,_A,_B) :- arg(2,_A,_B).
   setWI(windowNum,_A,_B) :- mangle(2,_A,_B).
   ...

   accessWI(back,_A,_B) :- arg(10,_A,_B).
   setWI(back,_A,_B) :- mangle(10,_A,_B).

   export makeWindowStruct/1.
   makeWindowStruct(_A) :-
     _A=..[wi,_B,_C,blue,sing,_D,_E,_F,_G,black,white].
```

```
export makeWindowStruct/2.
makeWindowStruct(_A,_B) :-
       struct_lookup_subst(
            [windowName,windowNum,borderColor,
             borderType,uLR,uLC,lRR,lRC,fore,back],
            [_C,_D,blue,sing,_E,_F,_G,_H,
             black,white],_B,_I),
        _A=..[wi|_I].

export xmakeWindowStruct/2.
xmakeWindowStruct(wi(_A,_B,_C,_D,_E,_F,_G,_H,_I,_J),
                 [_A,_B,_C,_D,_E,_F,_G,_H,_I,_J]).
```

Now let us examine the details.

5.1 Specifying Structure Definitions

defStructs directives are simply expressions of the form:

```
:-defStruct(Name, EqnsList).
```

These are simply binary Prolog terms whose functor is `defStruct`. The first argument is an atom functioning as an identifying name for the type (it has no other use at present). The second argument is a list of *equality statements* providing the details of the definition. An *equality statement* is an expression of the form:

```
Left = Right
```

For defStructs, the left component of the equality statements must be one of the following atoms:

- propertiesList
- accessPred
- setPred
- makePred
- structLabel

The right sides of the defStruct equality statements are Prolog terms whose structure depends on the left side entry. The right side corresponding to 'propertiesList' is a list of atoms which are the symbolic names of the properties or slots of the structure being defined. For all of the rest of the equality statements, the right side is a single atom. The roles of these right side atoms are described below:

5.1.1 accessPred

The name of the ternary (3-argument) predicate to be used for accessing the values of the slots in the structure.

5.1.2 setPred

The name of the ternary (3-argument) predicate to be used for setting or changing the values of the slots in the structure.

5.1.3 makePred

The name of the unary predicate used for obtaining a fresh structure of the defined type.

5.1.4 structLabel

The name of the functor of the structure defined.

5.1.5 propertiesList

This is a list of slot specifications. A ***slot specification*** is on of the following:

- an atom, which is the name of the particular slot, or
- an expression of the form

  ```
      SlotName/Term,
  ```

  where `SlotName` is an atom serving as the name of this slot, and `Term` is an arbitrary Prolog term which is the default value of this particular slot, or
- an ***include*** expression which is a term of the form

  ```
    include(File, Type)
  ```

  where `File` is a path to a file, and `Type` is the name of a defStruct which appears in that file; if `File` can be located, and if the defStruct `Type` appears in `File`, the elements of `propertiesList` for `Type` are interpolated at the point where the ***include*** expression occurred; ***include*** expressions may be recursively nested. [Note: The typecomp compiler does not change its directory location when handling include expressions. Thus, if you utilize relative paths in recursive includes, these paths must always be valid from the directory in which the compiler was invoked.]

5.2 Using Structure Definitions

As can be seen from the generated code for the wintypes example at the beginning of this section, the atoms on the right sides of the accessPred and setPred equality statements become names for ternary predicates which are surrogates for arg/3 and mangle/3, respectively. And the atom on the right side of the makePred equality statement becomes the name of a unary predicate producing a new instance of the structure when called with a variable as its argument. Formally:

accessPred=*acpr*	`acpr(Slot_name,Struct,Value)` succeeds precisely when `Slot_name` is an atom occurring on the propertiesList in the defStruct, `Struct` is a structure generated by the makePred of the defStruct, and `Value` is the argument of Struct corresponding to the the slot `Slot_name`.
setPred=*stpr*	`stpr(Slot_name,Struct,Value)` succeeds precisely when `Slot_name` is an atom occurring on the propertiesList in the defStruct, `Struct` is a structure generated by the makePred of the defStruct, and `Value` is any legal Prolog term; as a side-effect, the argument of Struct corresponding to `Slot_name` is changed to become `Value`.
makePred=*mkpr*	`mkpr(Struct)` creates a new structured term whose functor is the right side of the `structLabel` equality statement of the defStruct and whose arity list the length of the propertiesList of the defStruct, and unifies `Struct` with that newly created term; as a matter of usage, `Struct` is normally an uninstantiated variable for this call.

Thus, the goal

```
   makeWindowStruct(ThisWinStruct)
```

will create a `wi(...)` structure with default values and bind it to `ThisWinStruct`. Besides the unary generated ‘make’ predicates, two other construction predicates are created:

makePred=*mkpr* `mkpr(Struct, ValsList)` creates a new structured term whose functor is the right side of the `structLabel` equality statement of the defStruct and whose arity list the length of the propertiesList of the defStruct, and unifies `Struct` with that newly created term; `ValsList` should be a list of equations of the form `SlotName = Value`, where `SlotName` is one of the slots specified on `PropertiesList`; the newly created structured term will have value `Val` at the postion corresponding to `SlotName`; these “local defaults” will override any “global defaults” specified in the `defStruct`.

makePred=x*mkpr* `mkpr(Struct,SlotVars)` creates a new structured term whose functor is the right side of the `structLabel` equality statement of the defStruct and whose arity list the length of the propertiesList of the defStruct, and unifies `Struct` with that newly created term; no defaults are installed, and SlotVars is a list of the variables occurring in Struct. This binary predicate x*mkpr*`mkpr(Struct,SlotVars)` is equivalent to

```
   Struct =.. [ StructLabel | SlotVars].
```

6 ObjectPro: Object-Oriented Programming

ALS ObjectPro is an object-oriented programming toolkit fully integrated with ALS Prolog. Unlike some other approaches to object-oriented programming in Prolog, it is not implemented as a system on top of Prolog. Instead, it is seamlessly integrated with Prolog: object-oriented facilities can be smoothly accessed from ordinary Prolog programs, and the full power of Prolog can be used in the definition of object methods.

6.1 Overview of ObjectPro

The *objects* of ObjectPro are frame-like entities possessing state which survives backtracking. Each object belongs to a class from which it obtains its methods. Classes are arranged in a hierarchy, with lower classes inheriting methods from parent classes. The behavior of an object is determined by two aspects:

- The object's state, and
- The object's methods.

An object's *state* is a frame-like object consisting of named slots which can hold values. Figure 5 (*Illustration of an Object's State.*) illustrates the states of some simple objects.

slot name	*slot value*
myName	
locomotionType	
powerSource	
numWheels	
engine	
autoClass	
manufacturer	

Figure 5. Illustration of an Object's State.

Changes to the object's state amount to changes in the values of one or more slots.

Such changes are permanent and survive backtracking. The values which appear in slots can be any Prolog entity, including (the state of) other objects. Messages are sent to objects by calls of the form

```
   send(Object, Message).
```

In general, objects are created, held in variables, passed around among routines, and sent messages in the stype above. When necessary, an object can be assigned a global name when it is created which can be used for sending messages to the object. An object's *methods* are determined by the class to which it belongs.

A *class* is determined by three things:

- A local *state-schema* which describes the structure of part of the state of any object belonging to the class;
- The methods directly associated with the class;
- The classes from which this class inherits.

Classes are also required to have names -- these are principally used in defining objects. The complete *state-schema* for a class C is a structure whose collection of slots is the union of all of the slots appearing in the local state-schemata of classes from which C inherits, together with the slots from the local state-schemata of C. Slots in child classes must be distinct from slots in all ancestor classes. The methods associated with a class are defined by Prolog clauses which can utilize various primitive predicates for manipulating objects, as well as any ordinary Prolog predicates.

Objects are activated by sending them *message* . The methods of the class to which the object belongs (or from which its class inherits) determine the object's reaction to the message. A message can be an arbitrary Prolog term which may include uninstantiated variables, thus implementing the partially-instatiated message paradigm of Concurrent Prolog [Ref]

The ALS ObjectPro system is integrated with the module system of ALS Prolog, in that class adefinitions in ALS ObjectPro may be exported from their defining modules so as to be visible in other modules, or may be left unexported, rendering them local to the defining module. However, each object 'knows' the module of its defining class, so that if one has hold of the object in a variable `Object`, then the call

```
send(Object, Message)
```

can be made from the context of any module.

6.2 Defining Objects and Sending Messages

An object is defined by an expression of the form

```
create_object(Eqns, Obj)
```

where `Obj` is an uninstantiated variable which will be bound to the new object, and `Eqns` is a list of *equations* of the form

```
Keyword = Value
```

The acceptable keywords, together with their associated `Value` types, are the following:

```
instanceOf  - atom (name of a class)
values      - list of equations
```

The `instanceOf` keyword equation is the only required equation; the value on the right side of this equation must be an atom which is the name of class which is visible from the module in which the `create_object` call is made. Here is an example of a simple object definition, where `iC_Engine` must be the name of class:

```
create_object([instanceOf=iC_Engine ], Obj)
```

The equations appearing on a list which is the right side of a

```
values =ValuesList
```

equation are expressions of the form

```
SlotName = SlotValue
```

where `SlotName` is one of the named slots in the structure defining the object's state. These slots are determined by the class to which the object belongs, and may be slots from the state-schema of the immediate class parent, or may also be slots from any of the state-schemata of ancestor classes. The intent of the `values` equation is to enable the programmer to prescribe initial values for some of the object's slots when it is created.

When a global atomic name for the object is required, one includes an equation of the form

```
name  =  <atom> .
```

A message is sent to an object with a call of the form

```
send(Object, Message)
```

where `Object` is the target object (or an atom naming the object), and `Message` is an arbitrary Prolog term. The `Message` may include uninstantiated variables which might be instantiated by the object's method for dealing with `Message`. Such calls to `send/2` can occur both in ordinary Prolog code, and in the code defining methods of classes (and hence objects). For convience, or conceptual emphasis, a call

```
send_self(Object, Message)
```

is provided. This is merely syntactic sugar for

```
send(Object, Message)
```

That is, the implementation makes no attempt to verify that a `send_self` message is being truly sent from an object to itself.

6.3 Defining Classes

A class is defined by a directive of the form

```
:- defineClass(Eqns).
```

Here `Eqns` is a list of *equations* of the form

```
Keyword = Value
```

The acceptable keywords, together with their associated `Value` types, are the following:

```
name       - atom
subclassOf - atom (name of a (parent) classe)
addl_slots - list of atoms (names of local slots)
defaults   - list of default values for slots
constrs    - list of constraint expressions for slots
export     - yes or no
```

```
   action      - atom
```

The `name` equation and the `subclassOf` equation are both required.

The ObjectPro system pre-defines one top-level class named `genericObjects`; all classes are ultimately subclasses of the `genericObjects` class. `genericObjects` provides one visible slot, `myName`, which is always instantiated to the object's name. Several other slots, normally non-visible, are also provided.

A class is said to be an *immediate subclass* of the (parent) class named in the `subclassOf` equation. The relation *subclass* is the transitive closure of the *immediate subclass* relation.

The atoms on the `addl_slots` list specify slots in the structure defining the state of objects which are instances of this class. These new slot names must not be slot names in any of the ancestor classes from which the new class inherits; hence the nomenclature "addl_slots". The *state-schema* of a class is the union of the `addl_slots` of the class with the `addl_slots` of all classes of which the class is a subclass. Reiterating, it is required that the slot names occurring on all these `addl_slot` lists be distinct.

Here are several examples of simple class definitions:

```
   :- defineClass([name=vehicle,
            subclassOf=genericObjects,
           addl_slots=[locomotionType, powerSource] ]).
   :- defineClass([name=wheeledVehicle,
            subclassOf=vehicle,
            addl_slots=[numWheels] ]).
   :- defineClass([name=automobile,
            subclassOf=wheeledVehicle,
         addl_slots=[engine,autoClass,manufacturer] ])
   :- defineClass([name=wingedVehicle,
            subclassOf=vehicle,
            addl_slots=[numWings] ]).
```

The inheritance relations among these clesses is shown in Figure 6 .

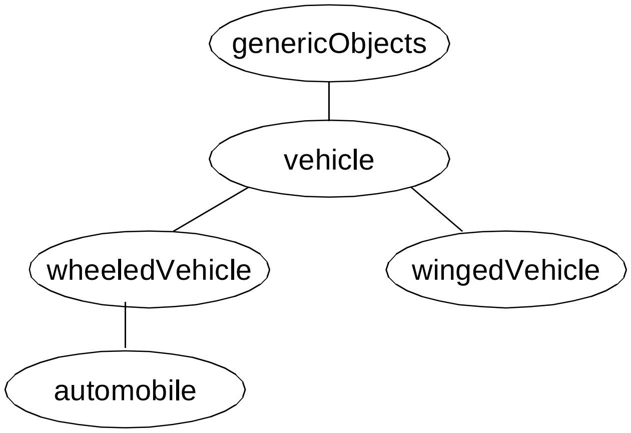


Figure 6. Example Class Inheritance Relations.

The state-schemata (not including the slots provided by `genericObjects`) for each of these classes are shown below:

```
vehicle        - [locomotionType, powerSource]
wheeledVehicle - ]locomotionType, powerSource,
                  numWheels]
automobile     - [locomotionType, powerSource,
                  numWheels,
                  engine,autoClass,manufacturer]
wingedVehicle  - [locomotionType, powerSource,
                  numWings]
```

An object which is instance of a class has a slot in its state structure corresponding to each entry in the state-schema for the class.

A class definition can supply default values for slots using the equation:

defaults = list of default values for slots

More specifically, the expression on the right should be a (possibly empty) list of equation pairs

<SlotName> = <Value>,

where <SlotName> is any one of the slotnames from the complete state schema of the class, and <Value> is any appropriate value for that slot. Omitting this keyword in a class definition is equivalent to including

```
    defaults = []
```

If an `export = yes` equation appears on the `Eqns` list of a class definition, the class methods and other information concerning the class are exported from the module in which the definition takes place.

Of course, the call could also fail if `C's` method code for `Message` fails. The `action=Name` equation is used to override the default name for the methods predicate of the class. If such an equation is present, the methods predicate will be `Name/2` instead of the default indicated above.

The `constraints` equation allows the programmer to impose constraints on the values of particular slots in the states of objects which instances of the class. The general form of a constraint specification is

```
   constrs = list of constraint expressions
```

Three types of constraint expressions are supported:

- `slotName = value`
- `slotName < valueList`
- `slotName - Var^Condition`

The first two cases are special cases of the third, and are provided for convenience. In all three cases, the left side of the expression is the name of a slot occurring in the complete state-schema of the class being defined (i.e., it is either the name of a slot on the `addl_slots` list of the class, or is a slot in the schema of a superclass from which the class being defined inherits). In the case of `slotName = value`, `value` is any Prolog term. This constraint expression indicates that any instance of the class being defined must have the value of slot `slotName` set equal to `value`. The generated code ensures that when instances of the class are initialized (via the call `send(Object, initialize)`), the value of `slotName` is set to `value`. The constraint expression `slotName < valueList` requires that the values of `slotName` be among the Prolog terms appearing on the list `valueList`. Here '<' is a short hand for 'is an element of'. The generated code for the class methods applies a test to any attempted update of the value of `slotName` to ensure that the new value is on the list `valueList`.

As indicated, the third constraint expression subsumes the first two. `Var` is a Prolog variable, and `Condition` is an arbitrary Prolog call in which `Var` occurs. `Conditon` expresses a condition which any potential value for `slotName` in an instance of the class must meet in order to be installed. The generated code imposes this test on all attempts to update the value of `slotName`. The test is imposed by binding the incoming candidate value to the variable `Var` , and then calling the test `Conditon`.

Here is a class specification inclulding a constraint:

```
defineClass([name=engine,
             subclassOf=[genericObjects],
             addl_slots=
                [powerType,fuel,engineClass,
                 cur_rpm,running,temp],
             constrs=
                [engineClass<
               [internalCombustion,steam,electric]]
            ])
```

6.4 Specifying Class Methods

To specify the methods of a class, the programmer must define a two argument predicate which will specify the reactions of instances of the class to various messages. The default name of this action predicate is

<class name>Action

However, the name of the predicate can be specified by using a line

```
action = <atom>
```

in the class definition. Thus, using the default, the head of the clauses for the action predicate will be of the form:

```
<ClassName>Action(Message,State)
```

The clauses for this predicate specify the methods which the class objects will use for responding to the various messages they are prepared to accept. The `Message` argument can be any Prolog term, and may include uninstantiated variables. The `State` argument will be instantiated at execution time to the state of the object which is using this method to respond to `Message`. The programmer has no knowledge of the detailed structure of `State`. However, access to the slots of State is provided by two predicates:

```
   setObjStruct(SlotDescrip, State, Value)
   accessObjStruct(SlotDescrip, State, VarOrValue)
```

The first call

```
   setObjStruct(SlotName, State, Value)
```

destructively updates the slot `SlotName` of `State` to contain `Value`, which cannot be an uninstantiated variable. However, Value can contain uninstantiated variables. Any constraints imposed on this slot by the class must be satisfied by the incoming `Value`. The second call

```
   accessObjStruct(SlotName, State, Value)
```

accesses the slot `SlotName` of `State` and unifies the value obtained with `VarOrValue`.

The value of `SlotDescrip` above is a *slot description* , which is either a slot name, or an expression of the form

```
   SlotName^SlotDescrip
```

The latter is used in cases of compound objects in which the value installed in a slot may be the state of another object. Thus if the contents of SlotName in State is another object O2, then

```
   accessObjStruct(SlotName^SlotDescrip, State, V)
```

effectively performs

```
   accessObjStruct(SlotDescrip, O2, V) .
```

Two convenient alternatives for these predicates are supplied as “syntactic sugar”:

```
   State^SlotDescrip := Value
```

for

```
   setObjStruct(SlotDescrip, State, Value)
```

and

```
   VarOrValue := State^SlotDescrip
```

for

```
   accessObjStruct(SlotDescrip, State, VarOrValue)
```

Besides these two constructs, calls on `send/2` can be used in the clauses defining methods. The code for the action predicate should be defined in the same module as the definition of the class. (But it can reside in separate files.)

Consider the class `engine` specified in the preceeding section. Simple `start` and `stop` methods can be implemented for this class by the following clauses:

```
   engineAction(start,State) :-
               State^running := yes.
   engineAction(stop, State) :-
               State^running := no.
```

A method to query the status of an engine is given by:

```
   engineAction(status(What),State) :-
           What := State^running.
```

The `genericObjects` class provides three pre-defined methods, effectively defined as follows:

```
    genericObjectsAction(get_value(SlotDesc,Value),State)
           :-
           accessObjStruct(SlotDesc,State,Value).
    genericObjectsAction(set_value(SlotDesc,Value),State)
           :-
           setObjStruct(SlotDesc,State,Value).
```

6.5 Examples

The first simple example implements an elementary stack object:

```
   :- defineClass([name=stacker,
                subclassOf=[genericObjects],
                addl_slots=[theStack, depth]
               ]).

   :- defineObject([name=stack,
                 instanceOf=stacker,
                 values=[theStack=[], depth=0]
                ]).


   stackerAction(push(Item),State)
     :-
     accessObjStruct(theStack, State, CurStack),
     setObjStruct(theStack, State, [Item | CurStack]),
     accessObjStruct(depth, State, CurDepth),
     NewDepth is CurDepth + 1,
     setObjStruct(depth, State, NewDepth).

   stackerAction(pop(Item),State)
     :-
     accessObjStruct(theStack, State, [Item |
     RestStack]),
     setObjStruct(theStack, State, RestStack),
     accessObjStruct(depth, State, CurDepth),
     NewDepth is CurDepth - 1,
     setObjStruct(depth, State, NewDepth).

   stackerAction(cur_stack(Stack),State)
     :-
     accessObjStruct(theStack, State, Stack).

   stackerAction(cur_depth(Depth),State)
     :-
     accessObjStruct(depth, State, Depth).
```

We can create a small loop to exercise an object of this class as follows:

```
run_stack :-
  create_object([instanceOf=stacker], Obj),
  rs(Obj).

rs(Obj)
  :-
  write('4stack:>'),flush_output,read(Msg),
  rs(Msg, Obj).

rs(quit, _).
rs(M, Obj)
  :-
  send(Obj, M),
  printf('Msg=%t\n', [M]),
  flush_output,
  rs(Obj).
```

Here is a sample session using this code:

```
?- [stacker].
Attempting to consult stacker...
... consulted /apache/als_dev/tools/objects/new2/
  stacker.pro

yes.
?- run_stack.
4stack:>push(2).
Msg=push(2)
4stack:>push(rr(tut)).
Msg=push(rr(tut))
4stack:>cur_stack(X).
Msg=cur_stack([rr(tut),2])
4stack:>pop(X).
Msg=pop(rr(tut))
4stack:>quit.
```

```
yes.
```

Our second example, the vehicles sketched earlier, illustrates the construction of compound objects. First, here are the class defintions:

```
:- defineClass([name=vehicle,
       subClassOf=genericObjects,
       addl_slots=[locomotionType, powerSource] ]).
:- defineClass([name=wheeledVehicle,
       subClassOf=vehicle,
       addl_slots=[numWheels] ]).
:- defineClass([name=automobile,
       subClassOf=wheeledVehicle,
       addl_slots=[engine,autoClass,manufacturer]
        ]).
:- defineClass([name=engine,
       subClassOf=genericObjects,
       addl_slots=[powerType,fuel,engineClass,
                 cur_rpm,running,temp],
       constrs=[
       engineClass<
            [internalCombustion,steam,electric]]
       ]).
:- defineClass([name=iC_Engine,
       subClassOf=engine,
       addl_slots=[manuf],
       constrs = [engineClass = internalCombustion]
       ]).
```

Now here are the methods:

```
engineAction(start,State)
  :-
  State^running := yes.

engineAction(stop, State)
  :-
  State^running := no.
```

```
automobileAction(start,State)
  :-
  send((State^engine),start).

automobileAction(stop,State)
  :-
  send(State^engine,stop).

automobileAction(status(Status),State)
  :-
  send(State^engine,
       get_value(running,EngineStatus)),
  (EngineStatus = yes ->
       Status = running;
       Status = off
  ).
```

As in the stack example, we can create a simple loop to exercise this code:

```
run_vehicles
  :-
  set_prolog_flag(unknown, fail),
  create_object([instanceOf=iC_Engine ], Engine1),
  create_object([instanceOf=automobile,
        values=[engine=Engine1] ], Auto1),
  create_object([instanceOf=iC_Engine ], Engine2),
  create_object([instanceOf=automobile,
       values=[engine=Engine2] ], Auto2),

  run_vehicles(a(Auto1, Auto2)).

run_vehicles(Autos)
  :-
  printf('::>', []), flush_output,
  read(Cmd),
  disp_run_vehicles(Cmd, Autos).

disp_run_vehicles(quit, Autos) :-!.
disp_run_vehicles(Cmd, Autos)
  :-
  exec_vehicles_cmd(Cmd, Autos),
  run_vehicles(Autos).

exec_vehicles_cmd(Msg > N, Autos)
  :-
  arg(N, Autos, AN),
  send(AN, Msg),
  !,
  printf('%t-|| %t\n', [N,Msg]).

exec_vehicles_cmd(Cmd, Autos)
  :-
  printf('Can\'t understand: %t\n', [Cmd]).
```

And here is a trace of an execution of this code:

```
  ?- run_vehicles.
  ::>start > 1.
  1-|| start
  ::>status(A1) > 1.
  1-|| status(running)
  ::>start > 2.
  2-|| start
  ::>status(A2) > 2.
  2-|| status(running)
  ::>stop > 2.
  2-|| stop
  ::>status(X) > 2.
  2-|| status(off)
  ::>quit.
  yes.
```

7 Working with Uninterned Atoms

Like most symbolic programming langauges, ALS Prolog implements atoms in two different ways:

- Atoms can be *interned* which means that they have been installed in the Prolog symbol table. Atoms which have been interned are called ***symbols***.
- Atoms can also be *uninterned* which means that they have not been installed in the symbol table. These atoms are called ***UIAs*** (UnInterned Atoms).

Because UIAs are stored on the heap, they are efficiently garbage collectable. Ordinary Prolog programs cannot distinguish between interned and uninterned atoms, except for possible differences in efficiency. However, programs which must interface to other external programs can sometimes find UIAs very useful.

7.1 The Efficiency of UIAs

Symbols are entered in the symbol table only once, so comparison between atoms which are symbols is very fast. This is because only the symbol table indices need to be compared. In contrast, UIAs are stored on the heap as the sequence of characters in the atom's print name (together with header/footer information). Comparison of a symbol with a UIA, or a UIA with a UIA, is somewhat slower because the two atoms must be compared by comparing the characters in their print names.

Thus, it is desirable to store atoms as symbols if they are likely to often be compared with other atoms. This includes the functors of structures and the distinguished program constants such as ':-' or '+', etc. On the other hand, many programs contain atoms which are seldom or never compared with other atoms. Prompt messages and other output strings are good examples, as are atoms read when searching a file. These objects should usually be stored as UIAs to avoid clogging up the symbol table.

7.1.1 When is a UIA created?

ALS Prolog uses the following rules to decide whether a given occurrence of an atom should be a symbol or a UIA.

1. All functors, operators, and predicate names are put into the symbol table.
2. Atoms appearing in the text without single quotes are put in the symbol table.
3. Atoms appearing in the text enclosed in single quotes are stored as UIAs unless the string which forms the atom is already in the symbol table, or unless the first rule applies.
4. Atoms created by `name/2` are UIAs unless the string which forms the atom is already in the symbol table.

Consider the following clauses:

```
    p('x',y) :- q('f','x').
    p(f(y),'wombat').
    p(x,'wombat').
```

Let us assume that none of `p`, `q`, `x`, `y`, `f`, or `wombat` are initially in the symbol table when these clauses are first read. Both `p` and `q` will be put into the symbol table because they are predicate names. `y` will also be put into the symbol table because it does not appear between single quotes. On the other hand, `wombat` will be stored as a UIA becasue it is surrounded by single quotes. Similarly, `x` and `f` will initially start out as UIAs because they appear in single quotes. But both of them will eventually be entered into the symbol table because `f` appears as a functor in the second clause and `x` appears unquoted in the third clause.

The rationale behind making atoms which are enclosed in single quotes into UIAs is that these sort of atoms most often appear as filenames or messages to write out. As such, they are rarely compared with other atoms.

7.2 Interning UIAs

It is sometimes desirable, under direct program control, to intern an atom which was originally stored as a UIA. This will cause all future occurrences of the atom, whether read by the parser or processed by `name/2`, to be turned into symbols. This is accomplished by using `functor/3`. Suppose that the constant `'ProgramConstant'` should be interned. This atom cannot be written in a program text without enclosing it in single quotes, because otherwise it would be read as a variable. The way to turn this into a constant is to issue the goal:

```
   functor(_,'ProgramConstant',0).
```

If a large number of constants need to be interned, it may be desirable to write an intern predicate which might take the following form.

```
   intern(X) :- atom(X), !, functor(_,X,0).
   intern([H|T]) :- intern(H), intern(T).
```

This could then be called in the following manner:

```
   intern([ 'ProgramConstant',
            'AnotherConstant',
            'YetAnotherConstant' ]).
```

All three quoted strings will be interned so that later occurrences will be stored as symbols. The `PI_forceuia()`function can also be used to intern UIAs. See `PI_forceui` in the Foreign Interface Reference.

7.3 Manipulating UIAs

Creating UIAs

There are several additional predicates which can be used to manipulate UIAs. A UIA of specific length can be created with a call to $uia_alloc/2 with the following arguments:

```
   '$uia_alloc'(BufLen,UIABuf)
```

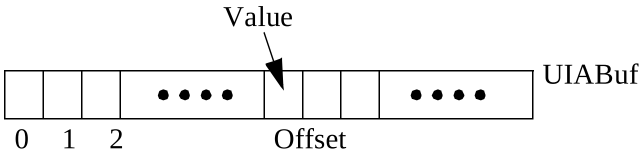
`BufLen` should be instantiated to a positive integer which represents the size (in bytes) of the UIA to allocate. The actual size of the buffer allocated will be a multiple of four greater than or equal to `BufLen`. `UIABuf` should be a variable. UIAs created with `$uia_alloc` are initially filled with zeros, and will unify with the null atom (`''`).

Modifying UIAs

Values can be inserted into a UIA buffer using a number of different routines. We will discuss two of them here: $uia_pokeb/3 and $uia_pokes/3. The modifications are destructive, and persist across backtracking.[1] `$uia_pokeb/3` is called as follows:

```
‘$uia_pokeb’(UIABuf,Offset,Value)
```

`UIABuf` should be a buffer obtained from `$uia_alloc/2`. The buffer is viewed as a vector of bytes with the first byte having offset zero. `Offset` is the offset within the buffer to the place where `Value` is to be inserted. Both `Offset` and `Value` are integer,. and the byte at position `Offset` from the beginning of the buffer is changed to `Value`. Figure 7 (*Action of $uia_alloc/2.*) illustrates this ac-



tion.

Figure 7. Action of `$uia_alloc/2`.

`$uia_pokes/3` is called in the folloiwng form:

```
‘$uia_pokes’(UIABuf,Offset,Insert)
```

`UIA Buf and Offset` are as above. `Insert` is an atom or another UIA. Like `$uia_pokeb/3`, `$uia_pokes/3` views the buffer as a vector of bytes with offset zero specifying the first byte. But instead of replacing just a single byte, `$uia_pokes/3` replaces the portion of the buffer beginning at `Offset` and having length equal to the length of `Insert`, using the characters of `Insert` for the replacement. If `Insert` would extend beyond the end of the buffer, `Insert` is truncated at the end of the buffer. This is illustrated in Figure 8 (*Action of*

1. These procedures can be used to modify system atoms (file names and strings that are represented as UIAs). However, this use is strongly discouraged.

$uia_pokes/3.) .

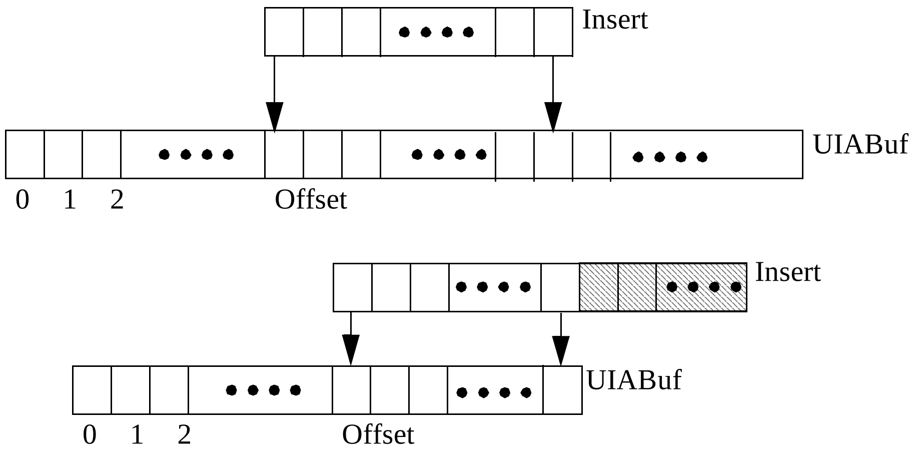


Figure 8. Action of `$uia_pokes/3`.

Accessing UIA Components

$uia_peekb/3, `$uia_peeks/3`, and `$uia_peeks/4` are used to obtain specific bytes and symbols (UIAs) from a buffer created by `$uia_alloc/2`. The parameters for these procedures are specified as follows:

```
'$uia_peekb'(UIABuf,Offset,Value)
'$uia_peeks'(UIABuf,Offset,Extract)
'$uia_peeks'(UIABuf,Offset,Size,Extract)
```

These parameters are interpreted in the same manner as the parameters for `$uia_pokeb/3` and `$uia_pokes/3`, where `Size` must also be an integer. `$uia_peekb/3` binds `Value` to the byte at position `Offset`. `$uia_peeks/3` binds `Extract` to a UIA consisting of the characters beginning at position `Offset` and extending to the end of the buffer. `$uia_peeks/3` binds `Extract` to a UIA consisting of the characters beginning at position `Offset` and extending to position `End` where `End = Offset + Size`. If End would occur beyond the end of the buffer, `Extract` simply extends to the end of the buffer.

An Example.

The following example procedure illustrates how to create a buffer and fill it with the name of a given atom with using `$uia_pokes/3`.

```
copy_atom_to_uia(Atom, UIABuf) :-
  name(Atom,ExplodedAtom),
  copy_list_to_uia(ExplodedAtom,UIABuf).

copy_list_to_uia(Ints,UIABuf) :-
  length([_|Ints], BufLen),
  ‘$uia_alloc’(BufLen, UIABuf),
  copy_list_to_uia(Ints, 0, UIABuf).

copy_list_to_uia([],_,_) :- !.

copy_list_to_uia([H | T], N, Buf) :-
  ‘$uia_pokeb’(Buf,N,H),
  NN is N+1,
  copy_list_to_uia(T, NN, Buf).
```

Below is a full list of the routines which may be used to modify and access component values of a UIA. Details can be found in the ALS Prolog Reference Manual.

`$uia_clip/2`	- clip the given UIA
`$uia_pokeb/3`	- modifies the specified byte of a UIA
`$uia_peekb/3`	- returns the specified byte of a UIA
`$uia_pokew/3`	- modifies the specified word of a UIA
`$uia_peekw/3`	- returns the specified word of a UIA
`$uia_pokel/3`	- modifies the specified long word of a UIA
`$uia_peekl/3`	- returns the specified long word of a UIA
`$uia_poked/3`	- modifies the specified double of a UIA
`$uia_peekd/3`	- returns the specified double of a UIA
`$uia_pokes/3`	- modifies the specified substring of a UIA
`$uia_peeks/3`	- returns the specified substring of a UIA
`$uia_peeks/4`	- returns the specified substring of a UIA
`$uia_peek/4`	- returns the specified region of a UIA
`$uia_poke/4`	- modifies the specified region of a UIA

There are two useful routines for dealing with the sizes of UIAs. The call

```
‘$uia_size’(UIABuf,Size)
```

returns the actual size (in bytes) of the given UIA. If `Size` is less than or equal to the actual size of the given `UIABuf`, the call

```
‘$uia_clip’(UIABuf,Size)
```

reduces the size of `UIABuf` by removing all but one of the trailing zeros (null bytes). When `Atom` is a Prolog atom (symbol or UIA),

```
‘$strlen(Atom,Size)’
```

returns the length of the print name of that atom (thus not counting the terminating null byte).

7.4 Observations on Using UIAs.

As indicated by the rules presented in Section 7.2 (*Interning UIAs*) , ALS Prolog automatically handles much of the use of UIAs. The preceeding Section presented predicates for explicitly creating and manipulating UIAs. The routines for explicit manipuulation of UIAs allow one to treat the bytes making up the UIA as raw memory to be manipulated at a low level. Two areas where explicit manipulation of UIAs can be useful are:

- Creating and manipulating data structures not supported by ALS Prolog.
- Communicating with external programs.

One example which in essence combines both uses is communication with external C programs, such as X Windows and Motif, which require both C strings and C structs are function arguments. An analysis of any such situation usually leads to the following observations:

- Strings and structs which are created on the C side of the interface should usually stay there, and pointers to them be passed to the Prolog side.
- Strings and structs which are created on the Prolog side and which are ephemeral in the sense that the C side will consume them when they are initially passed, and no further reference will be made to them from the C side, can be created as UIAs. Note that if after control returns to Prolog, a gar-

bage collection will sooner or later take place. In all likelihood, the UIA object will either pass out of existence, or at least move its location on the heap, so that it C 'holds on' to the pointer it was passed, this pointer will no longer be valid. Thus, one only wants to pass UIAs to C when they are ephemeral in the sense above: C will not hold on to a pointer to the UIA after control returns to Prolog.

- When non-ephemeral objects are to be created under Prolog control, it is best to create these in 'C space' by calling `malloc`. This can be done either by creating a specific C-defined Prolog predicate which carries out the work, or by using the C interface utilities which allow Prolog to call `malloc` and manipulate the allocated C memory.

8 Global Variables, Destructive Update & Hash Tables

ALS Prolog provides a method of globally associating values with arbitrary term (which occur on the heap).. The associations are immune to backtracking. That is, one an association is installed, backtracking to a point prior to creation of the association does not undo the association. (However, see the discussion below for fine points concerning this.) Because both the associated term and value may occur on the heap, both a term and its associated value can contain uninstatiated variables.

8.1 'Named' Global Variables

The underlying primitive predicates set_global/2 and get_global/2 defined in the next section maintain a uniform global association list. This has the disadvantage that as the number of distint associations to be mainted grows, the performance of both set_global/2 and get_global/2 will degrade. The facility described in this section avoids this problem by providing individual global variables which are accessed by programmer-specified unary predicates; hence this mechanism is said to provide 'named global variables.'

make_gv/1
make_gv(Name)
make_gv(+)

This predicate creates a single (primitive) global variable (see the next section), together with predicates for setting and retrieving its value. `If Name` is either an atom or a Prolog string (list of ASCII codes), the call

```
make_gv(Name)
```

allocates a primitive global variable and dynamically defines (asserts clauses for) two predicates, `setNAME/1` and `getNAME/1`, where `NAME` is the atom `Name` or the atom corresponding to the string `Name`. The definitions are installed in the module in which `make_gv/1` is called. These two predicates are used, respectively, to set or get the values of the global variable which was allocated. Here are some examples:

```
?-make_gv('_flag').
yes.

?-set_flag(hithere).
yes.

?-get_flag(X).
X = hithere.

?-make_gv('CommonCenter').
yes.

?-setCommonCenter(travel_now).
yes.

?-getCommonCenter(X).
X = travel_now.
```

8.2 The Primitive Global Variable Mechanism.

The underlying or primitive global variable mechanism is best described in terms of a simple implementation point of view. Global variables are value cells with the following properties:

- They can contain pointers into the heap (but not into the stack)
- These value cells do not lie on either the heap or the stack.
- The pointers contained in these value cells are not affected by either the backtracking process or the garbage collection process.

Figure 9 suggests the global variable mechnism.

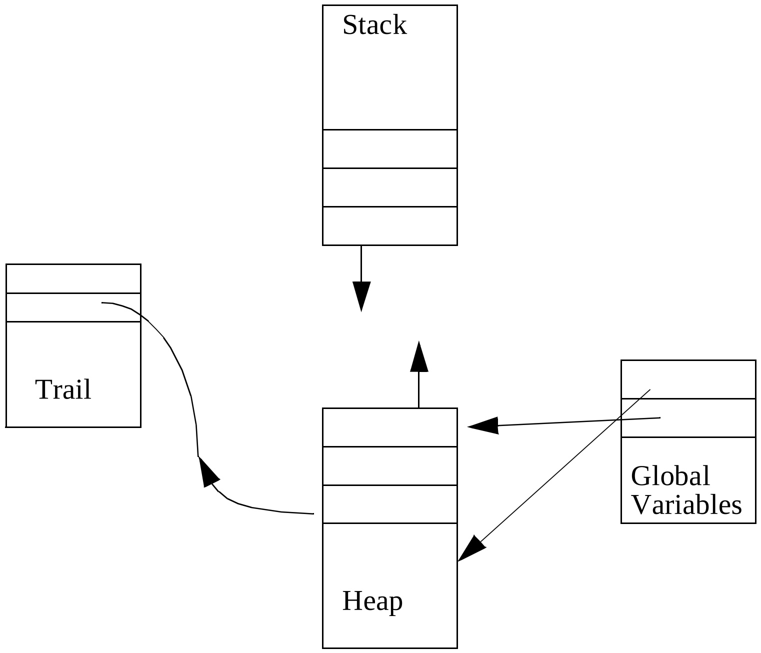


Figure 9. The Global Variables Area and the Heap.

The underlying mechanism is implemented by the following routines:

gv_alloc/1
gv_alloc(Num) **-** *allocates a global variable*
gv_alloc(+)

gv_free/1
gv_free(Num) **-** *frees a global variable*
gv_free(+)

gv_get/2
gv_get(Num, Value) - *gets the value of a global variable*
gv_get(+, -)

gv_set/2
gv_set(Num, Value) - *sets the value of a global variable*
gv_set(+, +)

These four predicates implement the primitive global variable mechanism. They achieve an effect often implemented using assertions in the database. The value of the present mechanism is its greater speed, its separation from the database, and its ability to deal with terms from the heap which may incorporate uninstatioated variables. Global variables are referred to by unique identifying integers sequentially starting from 1. The number of available global variables is implementation dependent. Note that the system itself allocates a number of global variables.

`gv_alloc(Num)` allocates a free global variable and unifies the number of this variable with `Num`. `gv_free(Num)` deallocates global variable number `Num`, which can then be reused by subsequent calls to `gv_alloc`/1. Since several global variables are used by the system itself, the first call to `gv_alloc(Num)` normally returns an integer greater than 1.

`gv_set(Num,Value)` sets the value of global variable number `Num` to be Value, which can be any Prolog term, including partially instantiated terms[1]. Correspondingly, `gv_get(Num, Value)` unifies `Value` with the current value of global variable number `Num`. A call to `gv_get(Num, Value)` before a call to `gv_set(Num, Value)` returns the default value for global variables, which is `0`.

Attempts to use `gv_set(Num,Value)` or `gv_get(Num,Value)` without a preceeding call to `gv_alloc(Num)` returning a value for the variable `Num` is an error which will generally cause unpredictable behavior, including system crashes.

The ***immediate*** values of global variables survive backtracking and persist across top level queries. However, if a global variable is set to a structure containing an unbound variable, say X, which is later bound during a computation, the binding of X is an ordinary Prolog binding which will not survive either backtracking or return to the top level of the Prolog shell. Thus variables in a structure which is bound to

1. The following earlier restriction has been removed: “However, it must not be a single free-standing uninstantiated variable. Unpredictable behavior will result if Value is an uninstantiated variable.”

a global variable do not inherit the globalness of the outermost binding.

Here are some examples:

```
?- gv_alloc(N), gv_set(N,hi), write(hi).
hi
N = 2
yes.

?- gv_get(2,V),write(V).
hi
V = hi
yes.

?- gv_set(2,bye).
yes.

?- gv_get(2,V1),write(V1),nl,fail;
        gv_get(2,V2),write(V2).
bye
bye
V1 = _4
V2 = bye
yes.

?- gv_get(2,V).
V = bye
```

Note that `gv_set/2` is a constant time operation so long as the second argument is an atom or integer. Otherwise, it requires time linearly proportional to the current depth of the choicepoint stack.

8.3 Destructive Modification/Update of Compound Terms

ALS Prolog provides a predicate which allows programs to destructively modify arguments of compound terms (or structures). This predicate is `mangle/3`. The effects of mangle/3 are destructive in the sense that they survive backtracking. The calling pattern for this predicate is similar to `arg/3`:

```
mangle(Nth, Structure, NewArg)
```

This call destructively modifies an argument of the compound term `Structure` in a spirit similar to Lisp's `rplaca` and `rplacd`. `Structure` must be instantiated to a compound term with at least `N` arguments. The `Nth` argument of `Structure` will become `NewArg`. Lists are considered to be structures of arity two. `NewArg` must satisfy the restriction that `NewArg` is not itself an uninstatiated variable (though it can be a compound term containing uninstatiated variables). Modifications made to a structure by `mangle/3` will survive failure and backtracking.

Even though `mangle/3` implements destructive assignment in Prolog, it is not necessarily more efficient than copying a term. This is due to the extensive cleanup operation which ensures that the effects of a `mangle/3` persist across failure.

Here are some examples:

```
?- Victim = doNot(fold,staple,mutilate),
       mangle(2,Victim,spindle).
Victim = doNot(fold,spindle,mutilate)
yes.
```

8.4 'Named' Hash Tables

The allocation and use of hash tables is supported by exploiting the fact that the implementation of terms is such that a term is an array of (pointers to) its arguments. So hash tables are created by combining a term (created on the heap) together with access routines implemented using basic hashing techniques. The destructive update feature mangle/3 is used in an essential manner. As was the case with global variables, at bottom lies a primitive collection of mechanisms, over which is a more easily usable layer providing 'named' hash tables.

The predicate for creating named hash tables is

make_hash_table/1
make_hash_table(Name) - ***creates a hash table with access predicates***
make_hash_table(+)

If Name is any atom, including a quoted atom, the goal make_hash_table(Name) will create a hash table together a set of access methods for that table. The atom `Name` will be used as the suffix to the names of all the hash table access methods. Suppose for the sake of the following discussion that `Name` is bound to the atom '`_xamp_tbl`'. Then the goal

```
make_hash_table('_xamp_tbl')
```

will create the following access predicates:

`reset_xamp_tbl` - throw away old hash table associated with the '_xamp_tbl' hash table and create a brand new one.

`set_xamp_tbl(Key,Value`

– associate `Key` with `Value` in the hash table `Key` should be bound to a ground term. Any former associations that `Key` had in the hash table are replaced.

`get_xamp_tbl(Key,Value)`

– get the value associated with the ground term bound to `Key` and unify it with `Value.`

del_xamp_tbl(Key,Value)

– delete the `Key/Value` association from the hash table. `Key` must be bound to a ground term. `Value` will be unified against the associated value in the table. If the unification is not successful, the table will not be modified.

`pget_xamp_tbl(KeyPattern,ValPattern)`

– The "`p`" in `pget` and `pdel`, below, stands for pattern. `pget_xamp_tbl` permits `KeyPattern` and `ValPattern` to have any desired instantiation. It will backtrack through the table and locate associations matching the "pattern" as specified by `KeyPattern` and `ValPattern`.

`pdel_xamp_tbl(KeyPattern,ValPattern)`

– This functions the same as `pget_xamp_tbl` except that the association is deleted from the table once it is retrieved.

Consider the following example (where we have omitted all of the ‘yes’ replies, but retained the ‘no’ replies):

```
?- make_hash_table(‘_assoc’).
?- set_assoc(a, f(1)).
?- set_assoc(b, f(2)).
?- set_assoc(c, f(3)).

?- get_assoc(X, Y).
no.

?- get_assoc(c, Y).
Y = f(3)

?- pget_assoc(X, Y).
X = c
Y = f(3);

X = b
Y = f(2);

X = a
Y = f(1);

no.

?- del_assoc(b, Y).
Y = f(2)
?- pdel_assoc(X, f(3)).
X = c

?- pget_assoc(X, Y).
X = a
Y = f(1);

no.
```

```
?- reset_assoc.
yes.

?- pget_assoc(X,Y).

no.
```

8.5 Primitive Hash Table Predicates

The core hash tables are physically simply terms of the form

```
hashArray(.........)
```

We are exploiting the fact that the implementation of terms is such that a term is an array of (pointers to) its arguments. So what makes a hash table a hash table below is the access routines implemented using basic hashing techniques. We also exploit the destructive update feature `mangle/3.` Each argument (entry) in a hash table here is a (pointer) to a list `[E1, E2, ....]` where each `Ei` is a cons term of the form

```
      [Key Value]
```

So a bucket looks like:

```
    [ [Key1 Val1], [Key2 Val2], ....]
```

where each `Keyi` hashes into the index (argument number) of this bucket in the term

```
    hashArray(.........)
```

The complete hash tables are terms of the form

```
    hastTable(Depth,Size,RehashCount,hashArray(....))
```

where:

Depth	= the hashing depth of keys going in;
Size	= arity of the `hashArray(...)` term;
RehashCount	= counts (down) the number of hash entries which have been

made; when then counter reaches 0, the table is expanded and rehashed.

The basic (non-multi) versions of these predicates overwrite existing key values; i.e., if `Key-Value0` is already present in the table, then hash inserting `Key-Value1` will cause the physical entry for `Value0` to be physcially altered to become `Value1` (using `mangle/3`).

The "-multi" versions of these predicates do NOT overwrite existing values, but instead treat the `Key-___` cons items as tagged pushdown lists, so that if

```
[Key Value0]
```

was present, then after hash_multi_inserting `Key-Value1`, the `Key` part of the bucket looks like: `[Key [Value1 Value0] ];` i.e., it is

```
[Key, Value1 Value0]
```

Key hashing is performed by the predicate

```
hashN(Key,Size,Depth,Index).
```

9 Freeze, Exceptions, Events, Interrupts, Signals.

9.1 Freeze

ALS Prolog supports a ‘freeze’ control construct similar to those that appear in some other prolog systems. Using ‘freeze’, one can implement a variety of approaches to co-routining and delayed evaluation.

freeze/2
freeze(Var, Goal)
freeze(?, +)

In normal usage, `Var` is an uninstantiated variable which occurs in Goal. When invoked in module `M`, the call

```
freeze(Var, Goal)
```

behaves as follows:

1. If `Var` is instantiated, then `M:Goal` is executed;
2. If `Var` is not instantiated, then the goal `freeze(Var, Goal)` immediately succeeds, but creates a ‘delay term’ (on the heap[1]) which encodes information about this goal. If `Var` becomes instantiated (at some point) in the future, at that time, the goal `M:Goal` is run (with, of course, `Var` instantiated).

For example, here is an example of an extremely simple producer-consumer coroutine:

```
pc2 :-
    freeze(S, produce2(0,S)), consume2(S).

produce2(N, [N | T])
    :-
    M is N+1,
    write(‘-p-’),
    freeze(T, produce2(M,T)).
```

1. See [carlsson] for general information on delay terms and implmentation strategies.

```
consume2([N | T])
    :-
    write(n=N),nl,
    ((N > 3, 0 is N mod 3) -> gc; true),
    (N < 300 ->
        consume2(T) ; true).
```

Without the presence of the ‘freeze’ constructs, this program will simply loop in produce2/2, doing nothing but incrementing the counter and printing ‘-p-’ on the terminal. However, using the freeze construct, the program ‘alternates’ between produce2/2 and consume2/1, producing the following behavior on the terminal:

```
?- pc2.
-p-n = 0
-p-n = 1
-p-n = 2
-p-n = 3
-p-n = 4
-p-n = 5
<...snip...>
-p-n = 294
-p-n = 295
-p-n = 296
-p-n = 297
-p-n = 298
-p-n = 299
-p-n = 300

yes.
?-
```

Here is one very simple illustrative example:

```
u :-
    freeze(W1, silly(W1,yellow)),
    freeze(W2, grump(W2,blue)),
    W2=W1,
    W2 = igloo.

grump(A,B)
    :-
    write(grump_running(A,B)),nl,flush_output.

silly(A,B)
    :-
    write(silly_running(A,B)),nl,flush_output.
```

Running u/0 yields:

```
    ?- u.
    silly_running(igloo,yellow)
    grump_running(igloo,blue)

    yes.
```

Uisng silly and grump from above, here is another example:

```
    u1 :-
        freeze(W1, silly(W1,yellow)),
        u11(W1).

    u11(W1)
        :-
        freeze(W2, grump(W2,blue)),
        W2=W1,
        u111(W2).

    u111(W2)
        :-
        freeze(W3, grump(W3,purple)),
        W3 = W2,
        u1_4(W3).
```

```
u1_4(W3)
    :-
    W3 = igloo.

u11(W1).
u111(W1).
u1_4(W3).
```

Runing this produces:

```
?- u1.
silly_running(igloo,yellow)
grump_running(igloo,blue)
grump_running(igloo,purple)

yes.
```

The following example[1] illustrates the interaction of freeze with backtracking:

```
fred(2) :- write(fred(2)),nl.
fred(3) :- write(fred(3)),nl.
fred(4) :- write(fred(4)),nl.

freeze_backtrack
    :-
    freeze(X, write(thaw(X))), fred(X), fail.
```

The output here is:

```
?- freeze_backtrack.
thaw(2)fred(2)
thaw(3)fred(3)
thaw(4)fred(4)

no.
```

Finally, here is an example[2] of cascading freezes:

1. Due to Bill Older.

```
fd([], 1).
fd([A | As], B)
    :-!,
    freeze(A, fd(As, B)).

fdtest([A,B,C,D]) :-
    fd([A], B),
    fd([A,B], C),
    fd([B,C], D).
```

Here are two different uses of fdtest:

```
?- fdtest([A,B,C,D]).

A-> fd([],B),user:fd([B],C)
B-> fd([C],D)
C = C
D = D

yes.
?- fdtest([A,B,C,D]), A = 5.

A = 5
B = 1
C = 1
D = 1

yes.
?-
```

9.2 Exceptions.

The exception mechanism of ALS Prolog allows programs to react to extraordinary circumstances in an efficient and appropriate manner. The most common extraordinary circumstance to be dealt with is errors. Often an error (perhaps inappropriate

2. Due to Bill Older.

user input, etc.) is detected deep in the calling sequence of predicates in a program. The most appropriate reaction on the part of the program may be to return to a much earlier state. However, if the code is written to support such a return using the ordinary predicate calling mechanisms, the result is often difficult to understand and has poor effeiciency. The exception mechanism allows the program to mark a point in its calling state, and to later be able to return directly to this marked point independently of the pending calls between the marked state and the later state. This notion is illustrated in Figure 10

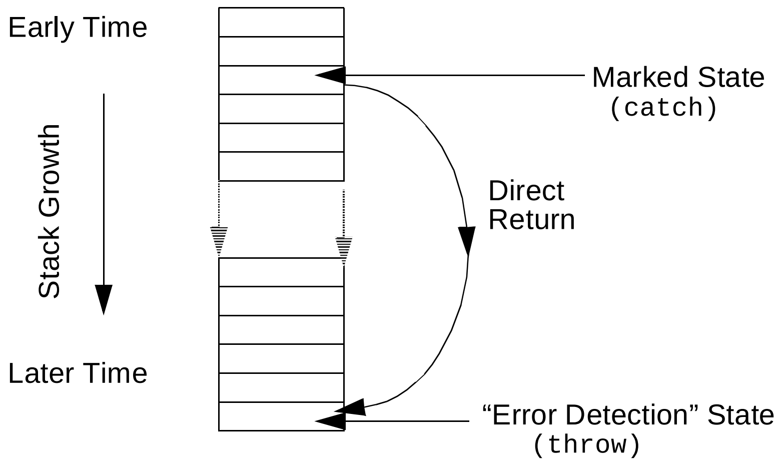


Figure 10. Direct Return to an Earlier State.

This exception mechanism is implemented using two predicates, catch/3 and throw/1.

catch/3
catch(WatchedGoal, Pattern, ExceptionGoal)
catch(+, +, +)

throw/1
throw(Term)
throw(+)

The two predicates `catch/3` and `throw/1` provide a more sophisticated controlled abort mechanism than the primitive builtins `catch/2` and `throw/0` (although the former are implemented in terms of the latter, which are described below). `catch/3` is used to mark a state in the sense of the discussion above. We will say that the call

```
    catch(WatchedGoal, Pattern, ExceptionGoal)
```

catches a term `T` if `T` unifies with `Pattern`. A call `throw(T)` is ***caught by*** a call on `catch/3` if the argument `T` is caught by the call on `catch/3`, an there is no call on `catch/3` between the given calls on `catch/3` and `throw/1` which also catces `T`.

If `M` is the current module for the call on `catch/3`, then the first argument of `catch/3`, `WatchedGoal`, is run in module `M` just as if by `call/1`; i.e., as if `catch/3` were `call/1`. If there is no subsequent call to `throw/1` which is uncaught by an intervening call to `catch/3`, then the call on `catch/3` is exactly like a call on `call/1`. However, if i) there is a subsequent call to `throw/`1 whose argument `Ball` unifies with the second arguement of the call the `catch/3`, and if ii) there is no interposed call to `catch/3` whose second argument also unifies with `Ball`, then all computation of the call on the first argumentt, `WatchedGoal`, is aborted, and the third argument of the call to `catch/3`, `ExceptionGoal`, is run as a result of the call to `throw/1`.

When the system executes throw/1, it will behave as if the head of throw/1 failed. However, instead of backtracking to the most recent choicepoint, the system will instead backtrack to the state it was in just before the most recent enclosing catch/3 whose second argument unifies with the argument of the throw/1 call; then the system will run the corresponding ExceptionGoal. catch and throw are dynamically scoped in that throw/1 must be called somewhere in an execution of WatchedGoal which is initially invoked by catch/3. If throw/1 is called outside the scope of some invocation of catch/3 (meaning, with nothing to catch its abort of execution), the system aborts to the Prolog shell. Figure 11 below illustrates the behavior of these predicates.

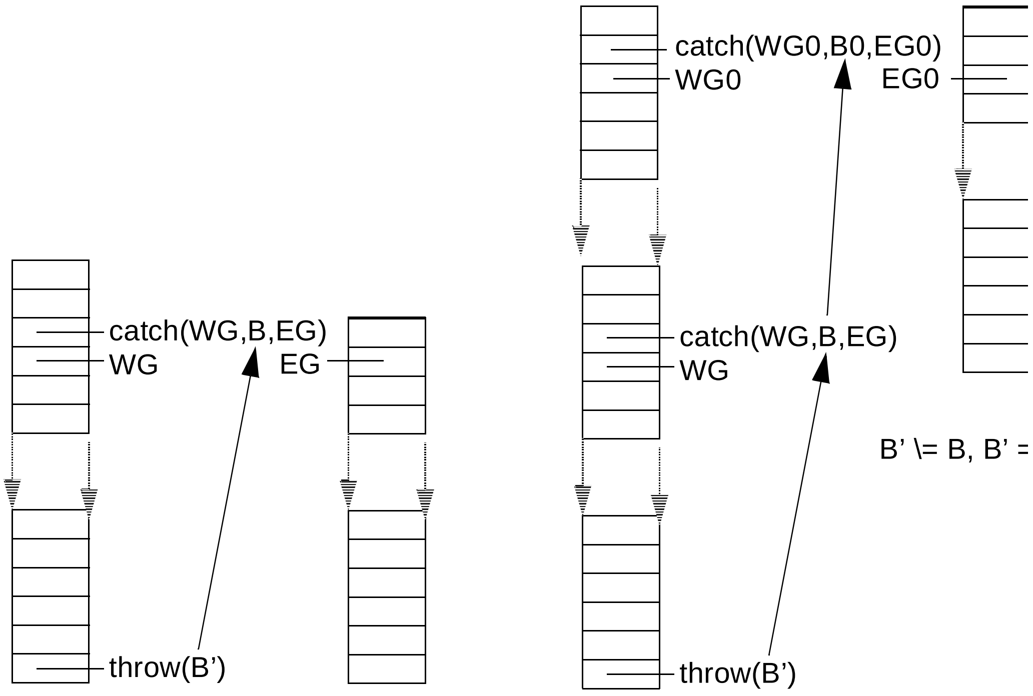


Figure 11. Action of `catch/3` and `throw/1`.

Consider the sample code:

```
ct :-         catch(c1, p1(X), e(c1,X)).
c1 :-        write(c1),nl, catch(c2, p2(X), e(c2,X)).
c2 :-        write(c2),nl, catch(c3, p1(X), e(c3,X)).
c3 :-         write('c3-->'), read(Item),
              write(throwing(Item)),nl, throw(Item).
e(H,I) :-     printf("Handler %t caught item
  %t\n",[H,I]).
```

This leads to the following execution behavior on a TTY interface, with the user input indicated in Helvetica.

```
?- ct.
```

```
c1
c2
c3-->p1(a).
throwing(p1(a))
Handler c3 caught item a
yes.
?- ct.
c1
c2
c3-->p2(a).
throwing(p2(a))
Handler c2 caught item a
```

The file *catch.pro* records the item being thrown by `throw/1` in the Prolog database, while the file *catchg.pro* records the item in a global variable. For small items, there is no significant difference between the two versions, but for large items, the *catchg* version will be more efficient.

catch/2
catch(WatchedGoal,ExceptionGoal)
catch(WatchedGoal,ExceptionGoal)

throw/0
throw

The two predicates `catch/2` and `throw/0` provide the primitive form of controlled abort underlying `catch/3` and `throw/1`. The builtin `abort/0` normally aborts to the Prolog shell.

- `WatchedGoal` is simply run from the current module as if by `call/1`.
- `ExceptionGoal` is a goal that will be run as a result of a call to `throw/0` during the execution of the `WatchedGoal`.

When the system executes `throw/0` it will behave as if the head of `throw/0` failed. However, instead of backtracking to the most recent choicepoint, the system will instead backtrack to the state it was in just before the most recent enclosing `catch/2` and then run the corresponding `ExceptionGoal`. `catch` and `throw` are dynamically scoped in that `throw/0` must be called somewhere in the execution of `WatchedGoal` which is initially invoked by `catch/2`. If `throw/0` is called outside the scope of some invocation of `catch/2` (meaning, with nothing to catch its execution), the system aborts to the Prolog shell.

```
?- throw.
Execution aborted.
If we define the following clauses:
goal(Person) :-
       printf("%t: Chris, take out that
  garbage!\n",[Person]),
       responseTo(Person), okay(Person).

responseTo('Mom') :- throw.
responseTo('Dad').

okay(Person) :-
       printf("Chris: Okay %t, I'll do
  it.\n",[Person]).

interrupt :- printf("Chris: I want to go hiking with
  Kev.\n").
Then
?- catch(goal('Mom'),interrupt).
Mom: Chris, take out that garbage!
Chris: I want to go hiking with Kev.
yes.

?- catch(goal('Dad'),interrupt).
Dad: Chris, take out that garbage!
Chris: Okay Dad, I'll do it.
yes.
```

Notice that with Mom, it's okay to interrupt, but you don't try it with Dad. In the above example, Chris responds to Dad with the `okay/1` predicate, but Chris did not respond to Mom because the `okay/1` predicate was never reached. After a `throw/0` predicate is executed, control is given to the `ExceptionGoal`. After the `ExceptionGoal` is run, control starts after the call to `catch/2` which handled the exception. Invocations of catch/2 may be nested and a throw/0 will always go to the most recent enclosing catch/2.

9.3 Interrupts.

Each time a procedure is called, ALS Prolog compares the distance between the top of the heap and its boundary to see if a garbage collection is necessary. If this distance ever becomes less than a pre-defined value, called the *heap safety value*, the program is interrupted, and the garbage collector is invoked. The test is done at the entrance to every procedure. This check is the basis for the internal ALS Prolog interrupt mechanism.

When a procedure is called by a WAM call or execute instruction (cf. [warren83]), control is transfered to a location in the name table entry for the procedure which is being called. The first action carried out in this patch of code is the heap overflow check. If no overflow has been detected, control continues on. This overflow check is useful as a general interrupt mechanism in Prolog. Since it is always carried out upon procedure entry, and since all calls must go through the procedure table, any call can be interrupted. If the overflow check believes that the heap safety value is larger than the current distance between the heap and backtrack stack, the next call will be stopped. The key word is ‘ believes’: the heap safety value could have been set to an absurdly large value leading to the interruption.

The key to using this as the basis for a general Prolog interrupt mechanism is to provide a method of specifying the reason for the interrupt, together with an interrupt handler which can determine the reason for the interrupt and dispatch accordingly. The entire mechanism is implemmented in Prolog code. Either ALS Prolog system code or user code can trigger an interrupt by setting the heap safety to a value which guarantees that the next call will be interrupted. When the interrupt occurs, the interrupted call is packaged up in a term and passed as an argument to the interrupt handler. The continuation pointer for the handler will point into the interrupted clause, and the computation will continue where it would have continued if the call had never been interrupted after the handler returns.

An example will help make this clearer. Suppose the goal

```
      :- b, c, f(s,d), d, f.
```

is running , that the call for `c/0` has returned, and that `f/2` is about to be called. Something happens to trigger an interrupt (i.e., to set the heap safety value to a very large value) and `f/2` is called. The heap overflow check code will run and the goal will now operationally look as though it were

```
      :- b, c, '$int'(f(s,d)), d, f.
```

Rather than `f/2` running, `$int/1` will run. When `$int/`1 returns, `d/0` will run, which is what would have happened if `f/2` had run and returned. If `$int/1` decides to run `f/2`, all it has to do is call `f/2`. `$int/1` can leave choice points on the stack, and also be cut, since it is exactly like any other procedure call. Any cuts inside `$int/1` will have no effects outside of the call. In other words, it is a fairly safe operation. Once the interrupt handler is called, the interrupt trigger should be reset, or the interrupt handler will interrupt itself, and go into an infinite loop.

If some thought is given to the possibilities of this interrupt machanism, it becomes apparent that it can be used for a variety of purposes, as sketched below.

<u>A clause decompiler in Prolog itself</u>: The `$int/1` code might be of the form

```
      '$int'(Goal) :-
         save Goal somewhere,
         set a 'decompiler' interrupt.
```

The goal would be saved somewhere, and the interrupt code would merely return after making sure that the next call would be interrupted. It is not necessary to call Goal, because nothing below the clause being decompiled is of interest.

<u>A debugging trace mechanism</u>: The `$int/1` code would be of the form

```
      '$int'(Goal) :-
         show user Goal,
         set a 'trace' interrupt and call Goal.
```

Here, the code will show the user the goal and then call it, after making sure that all subgoals in Goal will be interrupted.

<u>A `^C` trapper</u>: The `$int/1` code would keep the current goal pending. Then the user could be given a choice of turning on the trace mechanism, calling a break package which would continue the original computation when it returned, or even

stop the computation altogether.

In order for the above operations to take place, the interrupt handler needs to know which interrupt has been issued. This is done through the ***magic value***. `Magic` is a global variable, which is provided as the first argument to the `$int/2` call

```
      ‘$int’(Magic,Goal)
```

Calling `$int/2` with the value of `Magic` passed (as first argument) means that the proper interrupt handler will be called. If the value of `Magic` is allowed to be a regular term, information can be passed back from an interrupt, such as the accumlated goals from a clause which is being decompiled. The mechanisms of setting interrupts clearly must include the setting of `Magic` to appropriate values.

In order to write code such as the decompiler in Prolog, several routines are needed. The system programmer must be able to set and examine the value of `Magic`. This is done with the

```
   setPrologInterrupt/1
   getPrologInterrupt/1
```

calls. The programmer must also be able to interrupt the next call. This is done with the

   forcePrologInterrupt/0

call. For example, the goal

```
      :- forcePrologInterrupt, a.
```

will call

```
      ‘$int’(Magic,a)
```

If the clause

```
      b :- forcePrologInterrupt.
```

is called by the goal

```
      :- b,a.
```

then

```
      ‘$int’(Magic,a)
```

will be called once again, since after `b` returns, `a/0` is the next goal called. Finally, there must be a way of calling a goal without interrupting it, but setting the interrupt so that the the goal after the goal called will be interrupted. If `a/0` is to be called and the next call following it is to be interrupted, the call

```
      :- callWithDelayedInterrupt(a)
```

is used. For example, if `a/0` is defined by

```
      a :- b.
```

then

```
      :- callWithDelayedInterrupt(a).
```

will call

```
      :- ‘$int’(Magic,b).
```

not

```
      :- ‘$int’(Magic,a).
```

However, if `a/0` is merely the fact

```
      a.
```

then the call

```
      :- callWithDelayedInterrupt(a),b.
```

will end up calling

```
      :- ‘$int(Magic,b).
```

As an extended example of the use of these routines, we will construct a simple clause decompiler. The code sketched earlier outlines the general idea:

```
      ‘$int’(Goal) :-
         save Goal somewhere,
         set a ’decompiler’ interrupt.
```

The goal can be saved for the next call inside a term in the variable `Magic`. The clause so far would be

```
      ‘$int’(s(Goals,Final),NewGoal) :-
         setPrologInterrupt(s([Goal|Goals],Final)),
         forcePrologInterrupt.
```

The term being built inside `Magic` has the new goal added to it, and the trigger is set for the next call. To start the decompiler, the clause should be called as though it were to be run. However, each subgoal will be interrupted and discarded before it can be run. The starting clause would be something of the form:

```
      $source(Head,Body) :-
         setPrologInterrupt(s([],Body)),
         callWithDelayedInterrupt(Head).
```

First, the value of `Magic` is set to the decompiler interrupt term with an initially empty body and a variable in which to return the completed body of the decompiled clause. The goal is then called with `callWithDelayedInterrupt/1`, which will make sure that the next goal called after `Head` will be interrupted. The above clause for `$int/2` will then catch all subgoals. The head code for `Head` will bind any variables in `Head` from values in the head of the clause, and all variables that are in both the head and body of the clause will be correct in the decompiled clause, since an environment has been created for the clause. Since the clause is actually running, each subgoal will pick up its variables from the clause environment. If the decompiler should ever backtrack, the procedure for `Head` will backtrack, going on to the next clause, which will be treated in the same way. The only tricky thing is the stopping of the decompiler. The two clauses given above will decompile the entire computation, including the code which called the decompiler. The best method is to have a goal which the decompiler recognizes as being an ‘end of clause flag’. However, having a special goal which would always stop the decompiler would mean that the decompiler would not be able to decompile itself. So some way must be found to make only the particular call to this ‘distinguished’ goal be the one at which the decompiler will stop. The clauses above can be changed to the following to achieve this goal:

```
   ‘$int’(s(ForReal,Goals,Final),$endSource(Variable):-
      ForReal == Variable,!.

   ‘$int’(s(ForReal,Goals,Final),Goal) :-
      setPrologInterrupt(s(ForReal,
                              [Goal|Goals],Final)),
      forcePrologInterrupt.

   '$source'(Head,Body) :-
      setPrologInterrupt(s(ForReal,[],Body)),
      callWithDelayedInterrupt(Head),
      '$endSource'(ForReal).
```

Here, `$source/2` has a variable `ForReal` in its environment. This is carried through the interrupts inside the term in `Magic`. If the interrupted goal is ever `$endSource(ForReal)`, the decompiler stops. Note that `$endSource(ForReal)` will be caught when `$source/2` is called, since all subgoals are then being caught, and it's argument will come from the environment of `$source/2`. Otherwise, the interrupted goal is added to the growing list of subgoals, and the computation continues. If `$source/2` is called by `$source/2`, there will be a new environment and the first `$endSource/1` encountered will be caught and stored, but not the second one. The complete code for the decompiler appears in the file *builtins.pro.* This decompiler is used as the basis for `listing` as well as for `retract`. In addition, it is used to implement the debugger, found in the file *debugger.pro.*

9.4 Events

The event handling mechanism[1] provides implements both the system-level error and exception mechanisms, together with the general user-level event mechanisms such as coupling to signals and application-based interrupts. The event mechanism in ALS Prolog is based on the design presented in "Event handlin in prolog", by Micha Meier, in E.Lusk & R.Overbeek (eds), ***Logic Programming, Proceedings of the North American Converence, 1989,*** MIT Press, pp. 871ff. Most of the machinery of the event mechanism is readily discernible in the builtins file *blt_evt.pro.*

At the present time, there are five predefined types of events:

`sigint`	- raised when control-C or its equivalent is hit
`reisscntrl_c`	- raised for "reissued control-C"

1. The particular implementation in ALS Prolog was developed by Kevin Buettner.

`libload`	- raised when the stub of a library predicate is encountered
`prolog_error`	- raised by prolog errors (mostly from builtins)
`undefined_predicate`	- raised when an undefined predicate is encountered

Events are handled (and thereby defined) by a local or global event handler. Global handlers are specified in a simple database builtins:global_handler/3:

```
    global_handler(EventId, Module, Procedure):

    sigint,builtins,default_cntrl_c_handler
    reisscntrl_c,builtins,silent_abort
    libload,builtins,libload
    prolog_error,builtins,prolog_error
    undefined_predicate,builtins,undefined_predicate
```

The `global_handler/3` database is best manipulated using the following predicates (which are ***not*** exported from the module `builtins`):

set_event_handler/3
set_event_handler(Module, EventId, Proc)
set_event_handler(+, +, +)

remove_event/1
remove_event(EventId)
remove_event(+)

Additional global event handlers, for example to handle the signal sigalarm , are installed using `set_event_handler/3`, and removed used `remove_event/1`.

An event can be triggered by a program (including system programs) by the following predicate (which ***is*** exported from module builtins):

trigger_event/2
trigger_event(EventId, ModuleAndGoal)
trigger_event(+, +)

The argument ModuleAndGoal is normall of the form `Module:Goal.`

Local event handlers are installed and manipulated using the trap/2 system predicate:

trap/2
trap(Goal,Handler)
trap(Goal,Handler)

Here, `Handler` is a local handler such that

1. `Hander` is in force while `Goal` is running;
2. `Hander` ceases to be in force when `Goal` succeeds or fails;
3. `Hander` returns to force if `Goal` is backtracked into after succeeding
4. `Hander` is capable of dealing with any events which occur while `Goal` is running;

trap/2 is a module closure (meta-predicate), so that the module in which it is called is available to its implementing code. Regarding item 4 above, Handler is usually devoted to one particular type of event, such as handling specific kinds of signals; it will deal with all other events by propagating them to the appropriate “higher level” handlers, either surrounding local handlers, or the global handlers. This propagation is carried out using the following predicate:

propagate_event/3
propagate_event(EventId,Goal,Context)
propagate_event(EventId,Goal,Context)

For example, here is an alarm handler which will be discussed in more detail in the section on signals:

```
alarm_handler(EventId, Goal, Context)
    :-
    EventId \== sigalrm,
    !,
    propagate_event(EventId,Goal,Context).
```

```
alarm_handler(_,Goal,_)
    :-
    write('a_h_Goal'=Goal), nl,
    setSavedGoal(Goal),
    remQueue(NewGoal),
    NewGoal.
```

Note that the first clause uses `propagate_event/3` to pass on all events except `sigalrm`, which is handled by the second clause.

9.5 Signals.

ALS Prolog provides a strong mechanism for interfacing to external operating system signaling mechanisms. The machinery allows the programmer to connect external signals to internal Prolog events as described generally as described in the previous section. The details for the coupling are found in the builtins file *blt_evt.pro.* The connection between signal numbers and signal names is provied by the predicate `signal_name/2`:

```
signal_name(1,sighup).
signal_name(2,sigint).   %% interrupt (as in Cntrl-C)
signal_name(3,sigquit).
.....
signal_name(13,sigpipe).
signal_name(14,sigalrm).    %% alarm clock
signal_name(15,sigterm).
.....
signal_name(29,siglost).
signal_name(30,sigusr1).
signal_name(31,sigusr2).
```

This database is used by the predicate `signal_handler/3` to convert from numeric signal idenfiers to symbolic identifiers:

```
signal_handler(SigNum,Module,Goal)
    :-
    signal_name(SigNum,SigName),
    !,
    get_context(Context),
    propagate_event(SigName,Module:Goal,Context).
```

signal_handler/3 is called by the underlying C-defined signal handling mechanism to pass in signals from the operating system. At the present time, there are only two signals for which this mechanism is in place: sigint (control-C) and sigalrm.

The alarm mechanism is currently only available for Unix-based versions of ALS Prolog. Alarm signals are set using the predicate:

alarm/2
alarm(First, Interval)
alarm(+, +)

Both First and Interval should be non-negative real numbers. First specifies the number of seconds until the first alarm signal is sent to the ALS Prolog process. If Interval > 0, an alarm signal is sent to the process every Interval seconds after the first signal is sent. Thus alarm(First, 0) will result in only one alarm signal (if any) being sent. A subsequent call to alarm/2 causes the alarm mechanism to be reset according to the parameters of the second call. Thus, even if the first alarm has not yet been sent, a call alarm(0, 0) will turn off all alarm signals (until another call to alarm/2 is used to set the alarms again).

The sample program *par1.pro* illustrates the use of these mechanisms in implementing a simple producer-consumer program.; the entry point is main/0.

```
    main :-
        trap(main0,alarm_handler).

    main0 :-
        initQueue,
        produce(0,L),
        consume(L).

    consume(NV) :-
        nonvar(NV),
        consume0(NV).

    consume(NV) :-
        consume(NV).

    consume0([H|T]) :-!,
        write(H),nl,
        consume(T).
    consume0([]).

    produce(100,[]) :- !.
    produce(N,[N|T]) :-
        NN is N+1,
        sleep(produce(NN,T)).
    /*----------------------------*
     | Process Management
     *----------------------------*/
    alarm_handler(EventId, Goal, Context) :-
        EventId \== sigalrm,
        !,
        propagate_event(EventId,Goal,Context).

    alarm_handler(_,Goal,_) :-
        write('a_h_Goal'=Goal), nl,
        setSavedGoal(Goal),
        remQueue(NewGoal),
        NewGoal.

    /*-----------------------------------------------*
     | sleep/1
     |  - put a goal to sleep to wait for the next alarm.
     *-----------------------------------------------*/

    :- compiletime, module_closure(sleep,1).
```

```
sleep(M,G) :-
    addQueue(M:G),
    getSavedGoal(SG),
    set_alarm,
    SG.

set_alarm :-
    alarm(1.05,0).
/*--------------------------------------------------*
 | Queue Management:
 |
 |  initQueue/0    -- initializes goal queue to empty
 |  remQueue/1     -- removes an element to the queue
 |  addQueue/1     -- adds an element to the queue
 *--------------------------------------------------*/
initQueue :-
    setGoalQueue(gq([],[])).

remQueue(Item) :-
    getGoalQueue(GQ),
    arg(1,GQ,[Item|QT]),    %% unify Item, QT, and
                            %% test for nonempty
   remQueue(QT,GQ).     %% fix queue so front is gone

    %% Queue is empty:
remQueue([],GQ) :-!,
   mangle(1,GQ,[]),       %% adjust front to be empty
   mangle(2,GQ,[]).   %% adjust rear to be empty also

    %% Queue is not empty:
remQueue(QT,GQ) :-
   mangle(1,GQ,QT).  %% adjust front to point at tail

addQueue(Item) :-
    getGoalQueue(Q),
    arg(2,Q,Rear),          %% get Rear of Queue
    addQueue(Rear,Q,[Item]).

addQueue([],Q,NewRear) :-!,
    mangle(1,Q,NewRear),
    mangle(2,Q,NewRear).

addQueue(Rear,Q,NewRear) :-
    mangle(2,Rear,NewRear),   %% add the new rear
   mangle(2,Q,NewRear).  %% new rear now rear of queue
```

Prolog Builtins and Library

10 Prolog I/O

Most programs need to communicate with the outside world. There are a wide variety of outside entities with which a program can communicate, ranging from the screen, keyboard, and files to other programs over networks. This section describes the facilities which ALS Prolog provides for input/output (I/O) communication. The initial sections describe the fundamental ***stream***-based communication facilities of ALS Prolog. Following this, the earlier so-called ***DEC-10-style*** facilities are described; these are implemented in terms of the stream-based facilities[1].

10.1 Streams, Sources, and Sinks.

No matter how sophisticated the point of view one chooses to take, at bottom, computer communication is based on the notion of ***sequences of characters.*** Such sequences are generated by typing on keyboards, can appear on screens, can be recorded in files, can be transmitted across networks, etc. These sequences of characters are called ***streams***, or, when more precision is necessary, ***character streams***. The word ’stream’ is used in this context both because it conveys a sense of motion and because it also conveys a sense of direction, as with the natural notion of stream illustrated in Figure 12 (*Natural Streams*.)

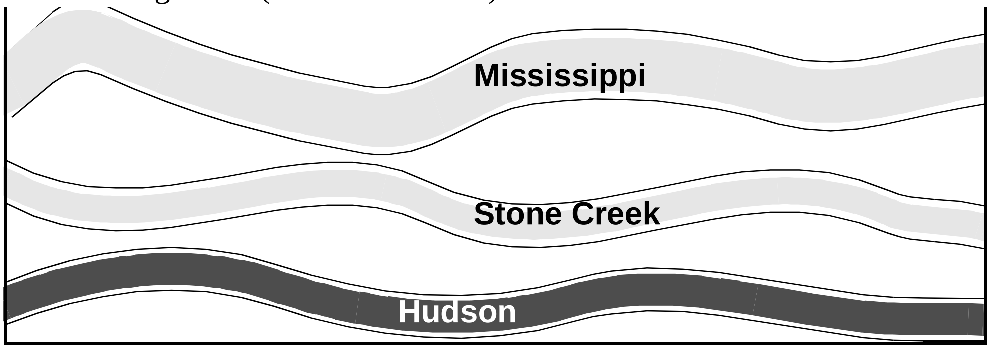


Figure 12. Natural Streams.

1. Except for the most primitive aspects, the I/O system for ALS Prolog is entirely implemented in ALS Prolog itself. Almost all of this code is contained in the following builtins files: *sio.pro, sio_wt.pro, sio_rt.pro, and blt_io.pro.*

In addition, natural streams have a notion of ***source*** (the ’headwaters’) and ***sink*** or ultimate destination (the ’estuary’). Finally, a natural stream also conveys the notion of a point on the bank where one can stand and watch the stream flow by. All of these natural notions have corresponding concepts in the computer notion of character streams.

From the logical point of view, the notions of stream, source, and sink are fundamental notions. However, as indicated above, a stream is a finite or potentially infinite sequence of characters. Every stream is associated with a source and a sink. When a stream is manipulated by a program, the program itself is either the source or the sink of the stream. If the program is ***consuming*** the stream, the program is then the ***sink*** for the stream. If the program is ***producing*** or ***generating*** the stream, the program is then the ***source*** of the stream. (It is also possible for the same program to be both source and sink for a stream.)

When the program is the sink for the stream, in general some other entity in the computing environment is the source for the stream. Possible external sources include files, keyboards, devices such as tapes cd-roms, and other programs communicating with the program in question via interprocess communication facilities, either locally or remotely. When the program is the source for the stream, some other entity is normally the sink for the stream. In this case, the normal possible external sinks include files, screens (or windows on screens), devices, and again, other programs. The notions of source and sink correspond to the notion of direction of flow for natural streams. The characters in a computer stream flow ***from*** the source ***to*** the sink.

Streams always have a beginning, but have an end only if they are finite. In prinicple, there is a sense of location, called the ***stream position***, for all streams. This sense of location, or stream position, corresponds to the natural notion of the point on the bank of the stream where one stands and watches the stream flow by. In the natural world, one can sometimes change the stream position by running along the bank, thereby either viewing an earlier portion of the stream (the water) or advancing to a later portion. Some kinds of character streams allow this sort of repositioning, while others do not.

A fundamental principle underlying the notion of stream is this:

> A program manipulating a stream need have no knowledge of what lies at the other end of the stream.

Thus, a program which is the source of a stream (is producing a stream) need have no knowledge of what is consuming the stream, and a program which is the sink for a stream (is consuming a stream) need have no knowledge of what is producing the stream.

Internally, a stream consists of an open source or sink of characters (e.g., a file, a socket, a window, etc.), a pointer to the next place to read or write, and a buffer for holding information until it's reasonable to transmit. The internal components illustrated in Figure 13 are the following:

- the (open) file;
- the pointer to the next place to read or write is called the *file pointer*. It is set to the beginning of the file when the file is opened. Whenever a read or write operation is performed on the file, the file pointer is moved.
- The buffer is used for efficiency. Reading or writing one character at a time from or to the disk (or most other sources or destinations of characters) would be very slow. Instead, for output, characters are written to the memory-resident buffer. The buffer is flushed when it reaches its capacity. Flushing causes the contents of the buffer to be written to disk. For input, blocks of characters are moved from the disk to the memory resident buffer. Prolog can then read the characters one at a time from the buffer much more efficiently

.

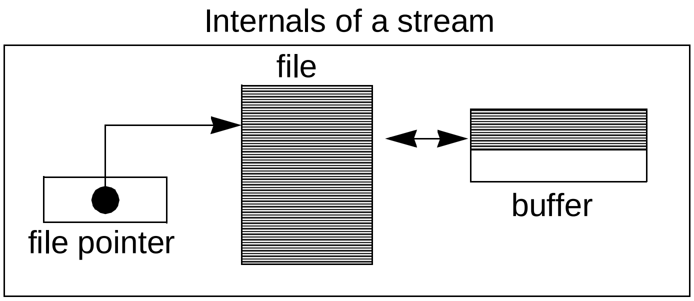


Figure 13. A Look Inside a Stream to a File.

The operations for dealing with streams fall into three groups:

- Operations for ***opening*** (or creating) streams.
- Operations for manipulating streams which are open (i.e., which exist).
- Operations for ***closing*** (or destroying) streams.

The only time a program must concern itself with what is at the other end of the stream is when it must open or create the stream. At this time, the program must specify what is to be at the other end of the stream. That is, it must specify what is to be the source or the sink for the stream. Thereafter, whether manipulating or closing the stream, the program need not worry about the nature or identity of the source or sink at the other end of the stream. It is the job of the underlying implementation of the stream facilities (provided by ALS Prolog) to take care of all of the details of moving the character stream between the program and the source or sink.

Under normal conditions, every ALS Prolog program automatically has two I/O character streams automatically opened for it by the underlying ALS Prolog system. These are called the ***default I/O*** streams. One of them is the default input stream and is normally connected to the keyboard, while the other is the default output stream, and is normally connected to the computer screen, or to a particular window on the screen when running under a graphical operating system. These will be discussed in more detail in a later section.   All other streams which the program seeks to manipulate must be explicitly opened by the program, and should also be closed by the program when they are no longer required. Under normal circumstances, all streams which remain open when an ALS Prolog program exits to the operating system are automatically closed.

All streams have both a ***mode*** and a ***type***. The ***mode*** of a stream basically reflects the direction of flow of information in the stream. The two fundamental stream modes are `read` and `write`. In `read` mode, the program is the consuming the stream's information, so that the program is the sink for the stream. In `write` mode, the program is producing the information on the stream, so that the program is the stream's source. Other modes are possible and will be discussed later.

The ***type*** of a stream reflects deeper information about the computing environment. The great majority of computing systems and programming languages (including earlier versions of Prolog and ALS Prolog) identify characters with bytes. However, this does not provide good support for alphabets with larger numbers of characters, and so a distinction is made between characters and bytes in the Prolog standard. Characters are internally represented as Prolog atoms, while bytes, as normally done, are represented by small integers. At bottom, a computer really moves bytes around, not characters. So at bottom, what a program thinks of as a stream of characters is really a stream of bytes. Since there is now a distinction between the notions of characters and bytes, a program can choose to view a data stream as either a stream of characters or as a stream of bytes. The type of a stream indicates this distinction. A ***text*** stream is a stream that is being viewed as a stream of characters. A ***binary*** stream is a stream that is being viewed as a stream of bytes. Facilities are provided for opening streams either as text or binary, and for manipulating them in both modes.

10.2 Opening and Closing Streams.

To open (or create) a stream, a program must indicate a ***source/sink*** for the stream (the other end from the program), must indicate a ***mode*** for the stream, and possible should indicate some ***options*** for the creation of the stream. Moreover, the process of opening or creating the stream should provide the program with some ***descriptor*** or handle with which to refer to the created stream for future manipulation.

10.2.1 Stream opening predicates.

There are two predicates used for opening streams:

open/3
open(SourceSink, Mode, Descriptor)
open(+, +, -)

open/4
open(SourceSink,Mode,Descriptor,Options)
open(+, +, -, +)

The three-argument version is simply definable in terms the four-argument version by:

```
open(SourceSink, Mode, Descriptor)
  :-
  open(SourceSink, Mode, Descriptor, []).
```

The arguments for `open/4` are described below.

10.2.2 SourceSink Terms.

A ***sourcesink*** term describes a target 'other end' of a stream. (The Prolog program of course holds on to 'this end' of the stream.) The particular sourcesink terms correspond to the various kinds of entities which can act as sources or sinks.

Files.

If the target source or sink is to be a file, the sourcesink term is a Prolog atom which is a name for the file, possibly including path information. (And conversely, an atom in the sourcesink position can only indicate a file as target source or sink.) As with `consult/1`, the file name may be either an abolute path name or a relative path name. (On most operating systems, the 'raw' keyboard and screen are handled more or less as special files. They will be discussed later.)

Strings.

Prolog strings (lists of characters) are acceptable sources and sinks for streams. When used as a source, a Prolog string `S` must be ground (fully instantiated), while when used as a sink, the string `S` must be an uninstantiated variable (which could be the tail of a larger list). In these cases, the sourcesink term is of the form

```
string(S)
```

When used as a sink, a string S (initially an uninstantiated variable) is viewed as a potentially infinite stream, which grows as characters are written to it.

Atoms and UIAs.

Atoms and UIAs are also acceptable sources and sinks for streams. In this case, the sourcesink term is of the form

```
atom(A)
```

where `A` is the atom or UIA in question. When used as a sink, the atom or UIA `A` is a stream of finite length, and any characters initially contained in `A` are gradually overwritten by the output process.

Sockets.

Sockets may also be used as source or sinks. The sourcesink term is of one of the following two forms:

```
socket(Target)   socket(DescriptionList)
```

In the first case, `Target` is any atom.. This first case is a shorthand for a particular instance of the second case, namely,

```
socket([target=Target]).
```

In the second case, which is the general case, `DescriptionList` is a list of ***equations***, each of which is of the form

```
Tag = Value.
```

The possible values `Tag` may take on are:

```
domain   type   protocol   port   target.
```

The expressions which `Value` may take on are determined by the value of `Tag`. The only required tag which must appear is the `target` tag. Default values are supplied for all other tags if no equation is present. The socket tags, the range of corresponding values, and their defaults, are described below.

domain:	values = [af_unix, af_inet];
	default = af_unix

type:	values = [sock_stream, sock_dgram];
	default = sock_stream
protocol:	values = [0, ip, icmp, tcp, udp];
	default = ip
port:	values = ***any acceptable port number;***
	default: sock_stream = 1599; sock_dgram = 1598.
target:	values = ***an atom which is an acceptable machine name;***

When the socket is a read (incoming) socket, the null atom '' can be used.

Here are several simple examples:

```
socket(jarrett)
socket('')
socket([target='', domain=af_inet,
  type=sock_stream])
socket([target=jarrett, domain=af_inet,
  type=sock_dgram])
```

Windows.

When running the Tcl/Tk windowed version of ALS Prolog, text windows are acceptable sources and sinks for streams. In this case, the sourcesink term is of the form

```
tk_win(Interp, Name)
```

where `Interp` is the Tcl/Tk intepreter under which the text window has *already* been created, and `Name` is an atom which is a name for the target window (see the Sections on use of the Tcl/Tk interface in the Development Tools part of the manuals).

Null Streams.

For various design reasons, it is sometimes convenient to utilize *null streams:* i.e., virtual emtpy or infinite streams which are not attached to any system resource. Such streams are analogous to the erzatz device /dev/null on Unix. These null streams are availabe on all computing platforms in ALS Prolog, and are available both for output and for input. To utilize a null stream for output, execute the goal

```
open(null_stream(Name),write, S, Options),
```

where `Name` is an atom (which is *not* taken as an alias for the stream). Then arbitrarily much output can be written to the stream `S` with no effect on computing resources. Similarly, to utilize a null stream for input, execute

```
open(null_stream(Name), read, S, Options),
```

where `Name` is an atom. Then any input operations from stream `S` will always encounter the end_of_file condition without errors.

10.2.3 Immediate versu Delayed Streams.

A file sourcesink is said to be ***immediate*** in the sense that (normally) all of the characters (data) which will make up the stream are immediately available once the stream is opened to the file. In contrast, a socket sourcesink is called ***delayed*** in the sense that access to some (possibly) all of the characters making up the stream may be delayed to the consuming process. We say that a stream is either immediate or dealyed if its corresponding sourcesink is immediate or delayed, respectively. This distinction is of particular significance for term-level I/O reading from this stream, but also has effects for character-level consumption of a delayed stream. Consider the situation sketched in Figure 14 .

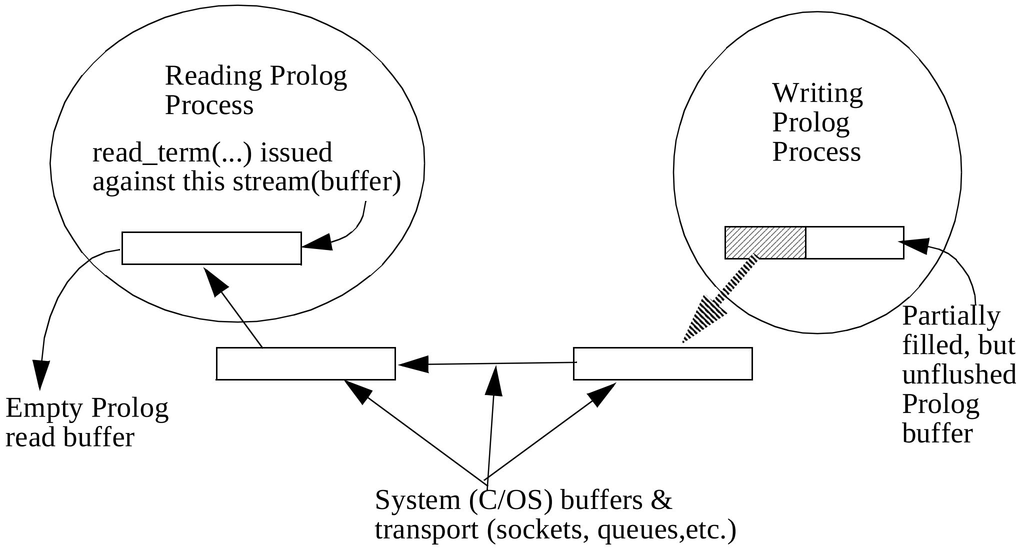

Reading Prolog Process
read_term(...) issued against this stream(buffer)
Writing Prolog Process
Empty Prolog read buffer
Partially filled, but unflushed Prolog buffer
System (C/OS) buffers & transport (sockets, queues,etc.)

Figure 14. A Delayed Stream in a Delayed State.

When the Prolog system attempts to fill the read buffer (on the left) in response to the read_term call, it is unable to obtain any characters from the underlying OS machinery. If the sourcesink for the reading processes were a file, this situation would be interpreted as end of file. However, that is not what we want to do for a socket (for example), since the writing process will presumably fill and/or flush the buffer sooner or later, and more characters will become available to the reading process. The refinements we introduce for this situation are detailed below.

Character Input from Delayed Streams.

`get_char/2` either returns (the code of) a character, which is a non-negative integer, or returns -1 to signify end of file. We extend `get_char/2` to return -2 when the stream is a delayed stream which is still open, the stream has not reached end of stream, but no characters are available for processing.

Term Input from Delayed Streams.

The behavior of `read_term/3` for a delayed stream is governed by the read option `blocking(Bool)`, where `Bool` is either `true` or `false`. Note that the default behavior is `blocking(true)` -- a blocking read. Under the default `blocking(true)` option, `read_term/3` behaves just as it does for immediate streams. The difference in behavior occurs for delayed streams. Suppose that the situation in Figure 14 came about as follows. The `read_term(...)` goal was initiated, and at that time, some charazcters were available. But before `read_term` can finish parsing a complete Prolog term, the characters are consumed. If the stream were an immediate stream, we only run out of characters at end of stream, and in that case, the system would raise an exception, indicating that `end_of_file` (if it were a file) was encountered improperly.

However, when the stream S is a delayed stream which is in the delayed state of Figure 14 , the goal

```
read_term(S, T, [blocking(false)]),
```

succeeds, and binds `T` to the distinguished term

```
unfinished read.
```

The tokens which were read out of the stream's buffer in attempting this read_term are saved in the stream data structure. Subsequent calls

```
read_term(S, T, [blocking(false)]),
```

will attempt to again read from the stream, beginning with the tokens which were saved, and then continuing with any (possibly) new characters which have arrived since the last unfinished read.

10.2.4 Modes.

There are four possible modes for a stream:

```
read
write
read_write
append
```

However, only file streams support the read_write and append modes at the present time; all other streams only support the read or write modes.

The mode names rather clearly indicate the manner in which the streams to which they apply will be used:

- A stream opened in `read` mode is being consumed by the program: the program is reading from the stream.
- A stream opened in `write` mode is being filled by the program: the program is writing to the stream. However, if the sink for this stream is a file which existed prior to the stream being opened, any previously existing contents of the file are discarded (i.e., the file is truncated).
- A stream opened in `read_write` mode is generally both read from and written to by the program; in general, this implies that the program's position in such a stream can be aribtrarily set and changed.
- Finally, `append` mode is like `write` mode, except that the previously existing contents of a file which is the sink for this stream are not lost: the stream position is automatically set to the end of the file and all output through the stream to the file is written at the end of the file.

10.2.5 Options.

The options argument of `open/4` is a list whose elements are acceptable stream open options. These provide additional information to the `open/4` procedure for refined control of the stream being created. These latter are differnt sorts of Prolog terms. Some of the options are applicable to all streams, while others apply only to streams connected to particular kinds or sources or sinks, or of particular modes or types.

text vs binary

At most one of `text` or `binary` can be present on the options list. When `text` is present, the stream is treated as a character stream. When `binary` is present, the stream is treated as a byte stream. If neither is present, the stream is treated as a character stream, so that the default is `text`.

aliases

An alias is an atom which acts as a global name for the stream to be opened. Once a stream has been opened, the stream descriptor (returned in the third argument of open/3 and the fourth argument of open/4) can be passed around between procedures and used during stream manipulations (typically reads and writes). However, if an alias is assigned to the stream, the stream descriptor which is returned by open/[3,4] can be ignored, and all stream manipulations (e.g. reads and writes) can refer to the stream by using the alias instead of the stream descriptor. To indicate that Atom is to be an alias for a stream to be opened, the expression

```
alias(Atom)
```

should be included on the options list of the call to open/4 which creates the stream. (There are also procedures for dynamically assigning an alias to a stream after stream creation; these will be discussed later.)

seek_type

Some streams can be repositioned during program execution. These options indicate the type of repositionion which is requested for the stream. Not all streams support such repositioning. It the stream to be opened does not support the requested repositioning, the repositioning request generates an exception from open/4.. There are two types of repositioning requests:

```
reposition(true)
reposition(false)
```

The first indicates that the stream should support repositioning to any meaningful position (The ISO standard only requires that the stream should support repositioning to any previously occupied position). The second indicates simply that repositioning is not requested.

buffering

These options allow the programmer to control the coordination between the stream's buffer and the ultimate external source or destination of the data. These options are most meaningful for file streams, but also have some significance for some other kinds of streams. A buffering option is indicated by a term of the form

```
buffering(BOption)
```

where BOption is one of the following three atoms:

```
byte
```

```
line
block
```

These options determine how often data is moved between the stream buffer and the source or destination. The first, `byte`, indicates that data should be moved on every character or byte (according as the stream is `text` or `binary`) handled by the program; in essence, this specifies no buffering should be used. The second, `line`, indicates that data should be moved on a line-by-line basis. The third option, `block`, essentially indicates that data should be moved in the largest units possible, as determined by the buffer size of the stream, and the block or buffer size of the external source or sink. The default is `block` buffering since it is generally the most efficient.

bufsize

This option allows the programmer to control the size of the buffer assigned to the stream. The option expressed by a term of the form

bufsize(N)

where N is an integer (which should be a power of 2). The default is 1024. The maximum value is determined by the largest contiguous area available on the Prolog heap.

prompt_goal

This option is useful when a pair of streams, one in `read` and one in write mode, are being used for interactive communication, say to a window, or to the keyboard and screen. However, this option strictly applies only to a single stream, and is meaningful only if the stream is in `read` mode. The option is of the form

```
prompt_goal(Goal)
```

where Goal is a Prolog term which indicates a goal which can be run. Whenever the buffer of the stream to which this option applies (which must be in read mode) is empty, before attempting to refill the stream's buffer from the external source, the system will first execute the goal `Goal`. Here is how this option is normally used. Suppose we wish to use a read mode and write mode stream to window myWin, and that whenever the read stream buffer is empty, we want a prompt to be printed on the window. Consider the following code fragment:

```
open(window(myWin),write, [buffering(line),text],
  OutStream),
open(window(myWin), read,
       [prompt_goal(user_prompt_goal(OutStream))],
  InStream),
```

Both streams are opened with `line` buffering; the `write` stream is explicitly indicated to be a `text` stream, while the `read` stream is a `text` stream by default (this is just by way of example). In addition, the read stream has a prompt_goal option applied. Whenever the buffer of the read stream is empty, the system will first run the goal

get_user_prompt(Prompt),

put_atom(Stream,Prompt),

flush_output(Stream).

s are opened with `line` buffering; the `write` stream is explicitly indicated to be a `text` stream, while the `read` stream is a `text` stream by default (this is just by way of example). In addition, the read stream has a prompt_goal option applied. Whenever the buffer of the read stream is empty, the system will first run the goal

```
user_prompt_goal(OutStream).
```

The code defining this goal could be:

```
user_prompt_goal(Stream)
  :-
  put_atom(Stream, '>>'),
  flush_output(Stream).
```

Here the desired prompt is `'>>'` . The I/O routines `put_atom/2` and `flush_output/1` will be described in later sections.

eof_action

[Not yet implemented.] For a stream which is opened in `read` or `read_write` mode, this option indicates what action the system should take if the program attempts to read beyond the end of the stream. The option is expressed by a term of the form

```
eof_action(Action)
```

where `Action` is one of the following atoms:

```
error
eof_code
reset
```

The interpretations of these action options are as follows:

`error:` An I/O end-of-file error exception is raised, signifying that no more input exists in this stream.

`eof_code:` The normal end-of-stream marker is returned (i.e., `end_of_file` for character and term input and -1 for character input).

`reset:` The stream is reset and another attempt is made to read from it.

write_eoln_type

This option allow the programmer to control which end-of-line (eoln) characters are output by nl/1. A write end-of-line option is indicated by a term of the form

```
write_eoln_type(Type)
```

where `Type` is one of the following three atoms:

```
cr
lf
crlf
```

These options determine what characters are output by `nl/1.` The first, `cr`, indicates that a carriage return `("\r")` should be output. The second, `lf,` indicates that a line feed `("\n")` should be output. The third, `crlf,` indicates that a carriage return followed by a line feed `("\r\n")` should be output.

The default for this option varies depending on the operating system being used. MacOS uses `cr`, unix systems use `lf`, and MS DOS and Win32 use `crlf`.

read_eoln_type

This option allows the programmer to control which characters should be used to detect an end-of-line (`eoln`) by `read/2` and `get_line/3`. A read end-of-line option is indicated by a term of the form

```
read_eoln_type(Type)
```

where Type is one of the following four atoms:

```
cr
lf
crlf
universal
```

These options determine what `read/2` and `get_line/3` recognize as an end-of-line. The first, `cr`, indicates that a carriage return `("\r")` should be interpreted as an end-of-line. The second, `lf`, indicates that a line feed `("\n")` should be interpreted as an end-of-line. The third, `crlf`, indicates that a carriage return followed by a line feed `("\r\n")` should be interpreted as an end-of-line. The fourth, `universal`, indicates that any of the end-of-line types (`cr, lf, crlf`) should be interpreted as an end-of-line. The default is universal since this allows the correct end-of-line interpretation for text files on all operating systems.

Socket options

`connects(N)` - N is the number of connection requests which can be queued by the system while it waits for the server to execute the accept system call; the default value for N is 1; on most systems, the maximum is 5.

10.2.6 Stream descriptors.

A ***stream descriptor*** is the term which is returned when a stream is opened (in the third argument of `open/3` and the fourth argument of `open/4`). It is a complex Prolog term. However, programmers should not attempt to 'look inside' of it nor attempt to rely on any of its structure. Appropriate predicates are supplied (see the following sections) for accessing and updating it as necessary. A stream descriptor is what the Prolog standard describes as ***implementation dependent***. As such, implementations are free to change the structure and nature of such terms. Conceivably, this could happen to stream descriptors in future releases of ALS Prolog. The stream descriptor is used simply as a means of referring to the stream in the predicates described in the following sections.

10.2.7 Closing Streams.

close/1.
close(Stream_or_Alias).
close(+).

Streams are very easily closed. One simply uses the unary predicate close/1 applied either to the stream descriptor or to an alias for the stream:

```
   close(Stream_or_Alias).
```

10.3 Stream Environment.

The stream environment of an ALS Prolog program is made up of the collection of streams which are open, together with the special roles which have been assigned to some of them. This section describes this environment together with predicates for querying and altering its state (besides the basic predicates for opening and closing streams described in the last section), together with predicates for querying the state(s) of individual streams.

10.3.1 Standard Streams.

Two streams are automatically opened for every ALS Prolog program. Both are `text` streams, and one is in `read` mode while the other is in `write` mode. The `read` mode stream is automatically assigned the alias `user_input` while the write mode stream is automatically assigned the alias `user_output`. In addition, for compatibility with older versions of Prolog, both streams are (ambiguously) assigned the alias `user`.

When ALS Prolog is run as a TTY-style program under operating systems such as Unix or DOS, the `read` mode stream `user_input` is connected to the process's standard input (`stdin`), while the `write` mode stream `user_output` is connected to the process's standard output (`stdout`). When ALS Prolog is run in one of its windowing versions (e.g., Motif), both `user_input` and `user_output` are connected to the ALS Prolog Worksheet window.

10.3.2 Current Streams.

No matter what streams have been opened (whether automatically or by the program), ALS Prolog always maintains a notion of the current input and output streams. The current input and output streams serve as defaults for all of the input/ouput operations to be described in the following sections. Thus, if a a version of an I/O operation is used without a stream argument (e.g. a read or a write without a stream argument), the operation is applied to the appropriate current input or output stream.

When ALS Prolog starts up, the current input and output streams are automatically set to the standard input and output streams. However, the program can change the settings of the current input and output streams. The following predicates are used for manipulating the current streams.

current_input/1
current_input(Stream)
current_input(?)

The goal

```
current_input(Stream)
```

is true iff the stream `Stream` is the current input stream. Operationally, this means that `current_input` unifies `Stream` with the stream descriptor of the current input stream. Note that this means that `current_input` applies to stream descriptors. In particular, even if `Alias` is an alias for the current input stream, calling `current_input(Alias)` will fail.

current_output/1
current_output(Stream)
current_output(?)

The goal

```
current_output(Stream)
```

is true iff the stream `Stream` is the current output stream. Operationally, this means that `current_output` unifies `Stream` with the stream descriptor of the current output stream. Note that this means that `current_output` applies to stream descriptors. In particular, even if `Alias` is an alias for the current output stream, calling `current_output(Alias)` will fail.

set_input/1
set_input(Stream_or_alias)
set_input(+)

`set_input/1` is used to set the current input stream. If `Stream_or_alias` is instantiated to either a stream descriptor of a stream in either read or read_write mode, or is instantiated to an alias for such a stream, then a call to `set_input(Stream_or_alias)` changes the current input stream to be the stream associated with `Stream_or_alias`. If `Stream_or_alias` is inappropriate for any reason, `set_input/1` raises an exception. Thus `set_input(S_or_a)` cannot fail. Either it succeeds or it raises an exception, in which case the current input stream remains unchanged.

set_output/1
set_output(Stream_or_alias)
set_output(+)

`set_output/1` is used to set the current output stream. If `Stream_or_alias` is instantiated to either a stream descriptor of a stream in either write, read_write, or append mode, or is instantiated to an alias for such a stream, then a call to

```
    set_output(Stream_or_alias)
```

changes the current output stream to be the stream associated with `Stream_or_alias`. If `Stream_or_alias` is inappropriate for any reason, `set_output/1` raises an exception. Thus `set_output(S_or_a)` cannot fail. Either it succeeds or it raises an exception, in which case the current output stream remains unchanged. .

10.3.3 Stream Charcteristics

stream_property/2
stream_property(Stream, Property)
stream_property(?, ?)

`stream_property/2` is used to determine whether or not a given property applies to a given stream; It can also be used to enumerate or generate the (open) streams possessing a certain property. Declaratively,

```
   stream_property(Stream, Property)
```

is true if and only if `Property` holds of `Stream`. The possible values for `Property` include all of the expressions which may appear on the `Options` list passesd to `open/4`, together with the following:

```
   input, output, and  mode(M),
```

where `M` is one of `text, binary`.

From a more procedural point of view, the action of `stream_property` is as follows. If both `Stream` is instantiated to the stream descriptor of a currently open stream, and `Property` is instantiated to a property descriptor which is true of `Stream`, then

```
   stream_property(Stream, Property)
```

succeeds. Either or both of `Stream` or `Property` may be uninstantiated. In this case,

```
   stream_property(Stream, Property)
```

is resatisfiable under backtracking. Thus, the action of in this case is effectively to compute the pairs S,P such that S is a currently open stream which has property P, in some undetermined order, and to unify `Stream` with S and `Property` with P.

For example, consider the goal

```
      stream_property(S, output).
```

If `S` is instantiated to a stream descriptor, this goal will check whether output is permitted on this stream. If `S` is uninstantiated, under backtracking, `S` will successively be instantiated to all streams currently open for output.

As another example, consider the goal

```
   stream_property(S, file_name(F)).
```

If `S` is instantiated to a stream descriptor, then if the source or sink for `S` is a file, `F` will be unified with the name of the file to which `S` is connected; otherwise, the goal will fail. If `S` is uninstantiated, but `F` is instantiated to an atom (which is the name of a file), then if some currently open stream has file `F` as its source or sink, `S` will be unified with that stream's descriptor. Finally, if both `S` and `F` are uninstantiated, this goal, under backtracking, will compute all the pairs `S,F` where `F` is a file name and `S` is a currently open stream connected to `F`.

When used in non-determinate ways, stream_property exhibits a "logical" semantics for state changes of the stream environment. For example, consider the goal

```
   stream_property(S,P), write(S:P), nl, close(S), fail.
```

This goal will enumerate all the properties for all streams which were open before this goal was run. Note that this example may call `close(S)` several times for each stream `S`, but this does not cause any problem since `close` simply succeeds if called on a stream which is already closed.

is_stream/2
is_stream(Stream_or_alias, Stream)
is_stream(+, ?)

Succeeds when `Stream_or_alias` is a stream or alias and will bind `Stream` to the corresponding stream.

assign_alias/2.
assign_alias(Alias, Stream_or_alias)
assign_alias(+, +)

If `Stream_or_alias` is associated with the stream S, and if `Alias` is a term, associates `Alias` to S as an alias. Note that a given stream can carry more than one alias, and that `Alias` can be a compound term.

cancel_alias/1.
cancel_alias(Alias)
cancel_alias(+)

If `Alias` is currently associated with stream S as an alias, removes the alias association between `Alias` and S.

reset_alias/2.

reset_alias(Alias, Stream_or_alias)
reset_alias(+, +)

If `Alias` is currently associated with stream S as an alias, and if `Stream_or_alias` is associated with stream S', first removes the association between `Alias` and stream S, and then associates `Alias` to stream S' as an alias.

current_alias/2.
current_alias(Alias,Stream)
current_alias(?,?)

Succeeds iff `Alias` is an alias which is associated with the stream `Stream`.

10.3.4 Stream Positions

at_end_of_stream/0
at_end_of_stream/1
at_end_of_stream(Stream_or_alias)
at_end_of_stream(+)

Consider a stream `S` which has been opened for input. If the stream `S` is of finite length, it is possible to reach a state in which all the characters or bytes in the stream `S` have been read by input routines

(such as `get_byte, get_code, get_char, or read),`

or when `set_stream_position/2` has been used to move directly to the end of the stream. At such a point, it is still valid to call an input routine. Each of the input routines returns a specific value to indicate that end of stream has been reached: `get_code` and `get_byte` return -1; `get_char` and `read` each return the atom `end_of_file`. When one of these terminating values has been read, the stream is said to be ***past*** the end of the stream, while the stream is said to be ***at*** the end of stream when no more characters or bytes are available for input, but no such input call has been made.

```
at_end_of_stream(Stream_or_alias)
```

succeeds if and only the stream associated with `Stream_or_alias` is either at end of stream or is past end of stream.

The predicate `at_end_of_stream/0` determines whether the current_input stream is at end of stream The predicate `at_end_of_stream(Stream)` still succeeds when called in the past end of stream state. A stream need not have an end, in which case this predicate would never succeed for that stream. If the source for `S_or_a` is a device such as a terminal, and if there is no input currently available on that device, then `at_end_of_stream` will wait for input just as get_code would do.

at_end_of_line/0.
at_end_of_line/1.
at_end_of_line(Alias_or_stream)
at_end_of_line(+)

These predicates determine whether a stream is at positioned at the end of a line, in an elementary way. They simply attempt to perform a `peek_char` on the stream, and determine if the character returned is identical with newline (i.e., the character with code 0'\n). The are defined by:

```
   at_end_of_line :-
       get_current_input_stream(Stream),
       at_end_of_line(Stream).

   at_end_of_line(Alias_or_stream) :-
       peek_char(Alias_or_stream,0'\n).
```

flush_output/0
flush_output/1
flush_output(Stream_or_alias)
flush_output(+)

If the stream associated with `Stream_or_alias` is a currently open output stream, then any output which is currently buffered by the system for that stream is (physically) sent to that stream, and `flush_output(Stream_or_alias)` succeeds.

`flush_output/0` flushes the current output stream; it is defined by

```
   flush_output :-
     current_output(Stream),
     flush_output(Stream.
```

flush_input/0
flush_input/1
lush_input(Stream_or_alias)
flush_input(+)

If the stream associated with `Stream_or_alias` is a currently open input stream, then any input which is currently buffered by the system for this stream is discarded, and `flush_input(Stream_or_alias)` succeeds.

`flush_input/0` flushes the current input stream; it is defined by

```
flush_input :-
  current_input(Stream),
  flush_input(Stream..
```

stream_position/3
stream_position(Stream_or_alias, Current_position, New_position)
stream_position(+, ?, ?)

If the stream associated with `Stream_or_alias` supports repositioning, then the call to `stream_position/3` causes `Current_position` to be unified with the current stream position of the stream, and, as a side effect, the stream position of this stream is set to the position represented by `New_position`. `New_position` may be one of the following values:

- An absolute integer which represents the address of a character in the stream. The beginning of the stream or the first character in the stream has position 0. The second character in the stream has position 1 and so on.
- The atom `beginning_of_stream`.
- The term `beginning_of_stream(N)` where `N` is an integer greater than zero. The position represented by this term is the beginning of the stream plus `N` bytes.
- The atom `end_of_stream`.
- The term `end_of_stream(N)` where `N` is an integer less than or equal to zero. This allows positions (earlier than the end of stream) to be specified relative to the end of the stream. The position represented by this term is

the end-of-stream position plus `N` bytes.

- The atom `current_position`.
- The term `current_position(N)` where `N` is an integer. This allows positions to be specified relative to the current position in the file.

set_stream_position/2
set_stream_position(Stream_or_alias, Position)
set_stream_position(+, +)

`set_stream_position(Stream_or_alias, Position)` changes the position of the stream associated with `Stream_or_alias` to `Position`. This predicate is effectively defined by:

```
set_stream_position(Stream_or_alias, Position) :-
  stream_position(Stream_or_alias, _, Position).
```

The possible error exceptions are the same as those for `stream_position/3.`

10.4 Byte Input/Output.

get_byte/1
get_byte(Byte)
get_byte(?)

Unifies Byte with the next byte obtained from the current input stream.

get_byte/2
get_byte(Alias_or_stream, Byte)
get_byte(+, ?)

Unifies `Byte` with the next byte obtained from the stream associated with `Alias_or_stream`.

put_byte/1
put_byte(Byte)
put_byte(Byte)

Outputs the byte `Byte` to the current output stream.

put_byte/2
put_byte(Alias_or_stream,Byte)
put_byte(Alias_or_stream,Byte)

Outputs the byte `Byte` to the stream associated with `Alias_or_stream`.

10.5 Character Input/Output.

The predicates in this section perform character-level input and output on streams. While these predicates are primarily inteded for use on streams opened in text mode, they have meaning for streams opened in binary mode, unless otherwise indicated. There are related byte-oriented predicates for streams opened in binary mode. (Note that ALS Prolog is more relaxed than the ISO standard; the latter states that character operations cannot be performed on binary streams, and that byte operations cannot be performed on character streams)

get_char/1
get_char(Char)
get_char(?)

get_char/2
get_char(S_or_a, Char)
get_char(+, ?)

`get_char(Char)` is equivalent to `get_char(S, Char)` where `S` is the current input stream; that is, `get_char/1` is effectively defined by:

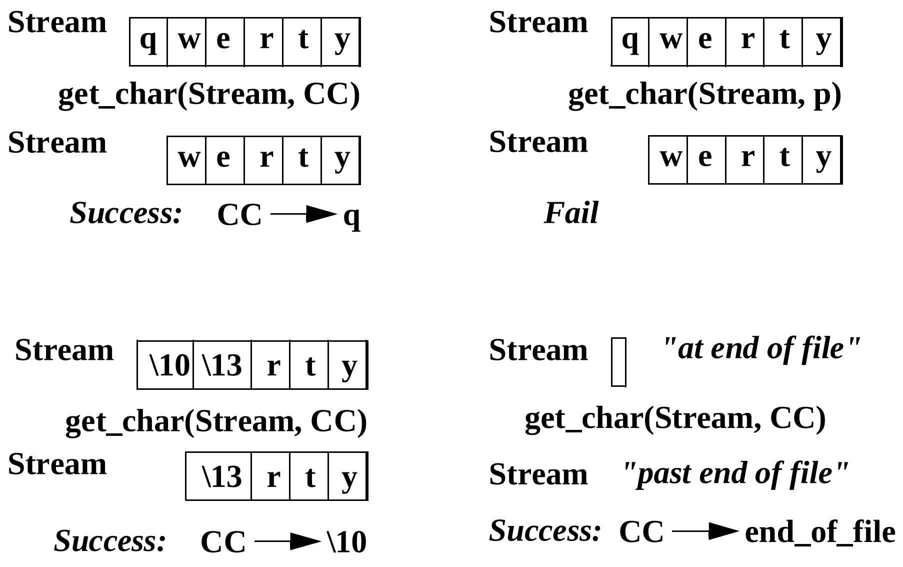
```
get_char(Char) :-
  current_input(Stream)
  get_char(Stream, Char).
```

Let `Stream_or_alias` be properly instantiated, and let S be the stream associated with `Stream_or_alias`. Then if S is a text stream,

```
get_char(Stream_or_alias, Char)
```

is true iff `Char` unifies with the next character to be read from S, while if S is a binary stream, it is true iff `Char` unifies with the next byte to be read from S. If S is at or past end of stream, the 'eof action' associated with S is performed. If S is a delayed stream, and is in the delayed state when the goal is issued, `Char` is bound to -2.

Examples



get_nonblank_char/1
get_nonblank_char(Char)
get_nonblank_char(-)

get_nonblank_char/2
get_nonblank_char(Stream, Char)
get_nonblank_char(+, -)

`get_nonblank_char/1` is defined by

```
   get_nonblank_char(Char) :-
       get_current_input_stream(Stream),
       get_nonblank_char(Stream,Char).
```

`get_nonblank_char(Stream, Char)` unifies `Char` with the next non-whitespace character obtained from the input stream associated with `Alias_or_stream`, if such a character occurs before the next end of line, and unifies `Char` with the atom

```
   end_of_line
```

otherwise.

get_atomic_nonblank_char/1
get_atomic_nonblank_char(Char)
get_atomic_nonblank_char(-)

get_atomic_nonblank_char/2
get_atomic_nonblank_char(Stream, Char)
get_atomic_nonblank_char(+, -)

`get_atomic_nonblank_char/1` is defined by

```
   get_atomic_nonblank_char(Char) :-
       get_current_input_stream(Stream),
       get_atomic_nonblank_char(Stream,Char).
```

`get_atomic_nonblank_char(Stream, Char)` unifies `Char` with the atomic form of the next non-whitespace character obtained from the input stream associated with `Alias_or_stream`, if such a character occurs before the next end of line, and unifies `Char` with the atom

```
   end_of_line
```

otherwise. It is defined by

```
   get_atomic_nonblank_char(Stream,Char)
       :-
       get_nonblank_char(Stream,Char0),
       (Char0 = end_of_line ->
           Char0 = Char
           ;
           name(Char, [Char0])
       ).
```

peek_char/1.
peek_char(Char)
peek_char(-)

peek_char/2
peek_char(Alias_or_Stream, Char)
peek_char(+, -)

`peek_char(Char)` unifies `Char` with the next character obtained from the default input stream. However, the character is not consumed.

`peek_char(Alias_or_Stream, Char)` unifies `Char` with the next character obtained from the stream associated with `Alias_or_Stream`. However, the character is not consumed.

put_char/1
put_char(Char)
put_char(+)

put_char/2
put_char(Stream_or_alias, Char)
put_char(+,+)

`put_char(Char)` is equivalent to `put_char(S, Char)` where S is the current output stream; that is, `put_char/1` is effectively defined by

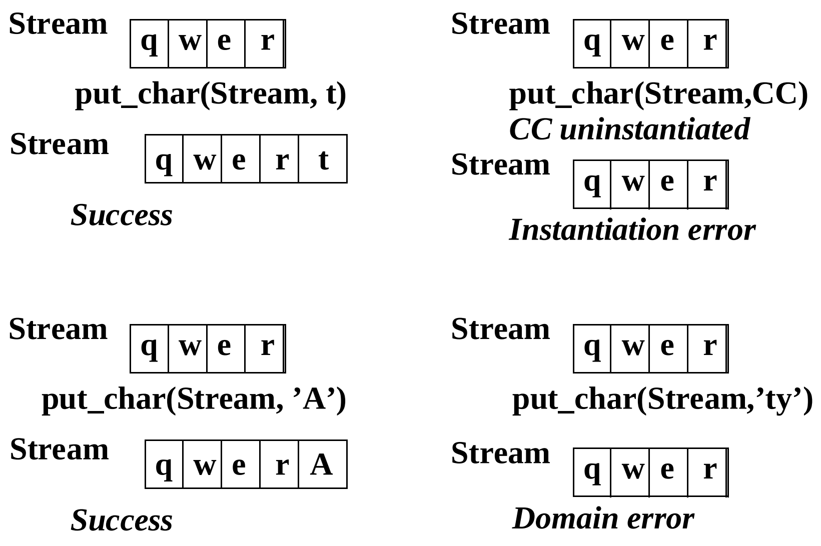
```
put_char(Char) :-
  current_output(Stream),
  put_char(Stream, Char).
```

If `Stream_or_alias` is properly instantiated, S is the stream associated with `Stream_or_alias`, and `Char` is a character, then

```
put_char(Stream_or_alias, Char)
```

outputs the character `Char` to S, and changes the stream position on S to take account of the character which has been output.

Examples



put_string/1
put_string(String)
put_string(+)

put_string/2
put_string(Alias_or_stream, String)
put_string(+, +)

`put_string(String)` is defined by

```
   put_string(String) :-
       get_current_output_stream(Stream),
       put_string(Stream, String).
```

If `String` is a Prolog string (i.e., a list of character codes), `put_string(Alias_or_stream, String)` recursively applies put_char to `String` to output the characters associated with `String` to `Alias_or_stream`.

put_atom/2

put_atom(Alias_or_stream,Atom)
put_atom(+,+)

Outputs the atom `Atom` to the stream associated with `Alias_or_stream`. Very efficient.

get_number/3
get_number(Alias_or_stream,InputType,Number)
get_number(+,+,?)

Attempts to read a number of the given type `InputType` from the stream associated with `Alias_or_stream`, and if successful, unifies the result with `Number`. The possible values for `InputType` are:

InputType	Type of Number
byte	signed byte (8 bit)
ubyte	unsigned byte (8 bit)
char	signed byte (8 bit) (synonymous with byte)
uchar	unsigned byte (8 bit) (synonymous with byte)
short	signed short integer (16 bit)
ushort	unsignged short integer (16 bit)
int	signed integer (32 bit)
uint	unsignged integer (32 bit)
long	signed integer (32 bit)
ulong	unsignged integer (32 bit)
float	floating point (32 bit)
double	floating point (64 bit)

put_number/3
put_number(Stream_or_alias,OutputType,Number)
put_number(+,+,+)

`put_number(Alias_or_stream,OutputType,Number)` outputs the number `Number` as `OutputType` to the stream associated with `Stream_or_alias`. `OutputType` may take on the following values:

```
   byte   short   long   float   double.
```

get_line/1
get_line(Line)
get_line(?)

`get_line(Line)` is defined by

```
   get_line(Line) :-
       get_current_input_stream(Stream),
       get_line(Stream,Line).
```

get_line/2
get_line(Stream_or_Alias, Line)
get_line(+, ?)

Reads the current line or remaining portion thereof from the stream associated with `Stream_or_Alias` into a UIA, and unifies this UIA with `Line`. If end-of-file is encountered before any characters, this predicate will fail. If end-of-file is encountered before the newline, then this predicate will unify `Line` with the UIA containing the characters encountered up until the end-of-file.

put_line/1
put_line(Line)
put_line(+)

put_line/2
put_line(Stream,Line)
put_line(+,+)

`put_line(Line)` is defined by

```
   put_line(Line) :-
       get_current_output_stream(Stream),
       put_line(Stream,Line).
```

`put_line(Stream, Line)` is defined by

```
put_line(Stream,Line) :-
    put_atom(Stream,Line),
    nl(Stream).
```

skip_line/0
skip_line/1
skip_line(Alias_or_stream)
skip_line(+)

skip_line/0 is defined by

```
skip_line :-
    get_current_input_stream(Stream),
    skip_line(Stream).
```

If `Alias_or_stream` is open for (text) input, `skip_line(Alias_or_stream)` skips to the next line of input for the stream associated with `Alias_or_stream`.

nl/0
nl/1
nl(Stream_or_alias)
nl(+)

`nl` is equivalent to `nl(S)` where S is the current output stream; that is,

```
nl :-
  current_output(Stream),
  nl(Stream).
```

`nl(Stream_or_alias)` causes the current line or record on the stream associated with `Stream_or_alias` to be terminated.

10.6 Character Code Input/Output

These predicates provide a means of directly manipulating streams at the character code level.

get_code/1
get_code(Code)

get_code(?)

get_code/2
get_code(Stream_or_alias, Int)
get_code(+,?)

`get_code(Code)` is equivalent to `get_code(S, Code)` where `S` is the current input stream; i.e., `get_code/1` is defined by:

```
get_code(Code) :-
  current_input(Stream),
  get_code(Stream,Code).
```

Assume that `Stream_or_alias` is instantiated to a stream descriptor or to the alias of a stream descriptor, and let `S` be the stream associated with `Stream_or_alias`. If `S` is a text stream then

```
get_code(Stream_or_alias, Code)
```

is true iff `Code` unifies with the character code corresponding to the next character to be read from `Stream`, else if `S` is a binary stream it is true iff `Code` unifies with the next byte to be read from `S`.

put_code/1
put_code(Code)
put_code(+)

`put_code(Code)` is equivalent to `put_code(S, Code)` where `S` is the current output stream; i.e., `put_code/1` is defined by:

```
put_code(Code) :-
  current_output(Stream),
  put_code(Stream, Code).
```

put_code/2
put_code(Stream_or_alias, Code)
put_code(+,+)

`put_code(Stream_or_alias, Code)` outputs the character with code `Code` to the stream associated with `Stream_or_alias`, and changes the stream position on the stream associated with `Stream_or_alias` to take account of the character which has been output.

10.7 Term Input/Output.

ALS Prolog provides a rich array of predicates for I/O at the term level. The predicates in this section provide means for reading Prolog terms from input streams and for writing Prolog terms to output streams. For both input of terms and output of terms, there are a variety of options which can be requested. These options are controlled through the use of options lists which are passed to the various term-level I/O predicates.

10.7.1 Read options

A ***read options list*** is a list of read options, where the possible read options are defined as follows. Let T be the term which is (to be) read from the input stream.

variables(Vars)	Vars is unified with a list of the variables encountered in a left to right traversal of the term T.
variable_names(VNs)	VNs is unified with a list of elements of the form V=A, where V is variable which occurs in the term T and A is the associated name of that variable; the elements V=A occur in the order in which the variables V are encountered in the term T when T is scanned left to right.
vars_and_names(Vars,Names)	Vars is unified with a list of the variables encountered in a left to right traversal of the term T; Names is a list of the associated names of the variables. '_' is the only variable name which may occur more than once on the list Names.
singletons(Vars,Names)	Vars is unified with the singleton variables (those occuring only once) in the term T; Names is unified with a corresponding list consisting of the names of those singleton variables. Variables with name '_' are excluded from these lists.

syntax_errors(Val)

Val indicates how the system is to handle any syntax errors which occur durin g the reading of T. The possible values of Val and their interpretation are:

error Occurrence of a sysntax error will cause the system to raise an exception, which includes outputing a warning message. This is the default.

fail Occurrence of a syntax error will cause the attempt to read T to fail, and and error message will be output.

quiet Occurrence of a syntax error will cause the attempt to read T to fail quietly, with no message output.

dec10. Occurrence of a syntax error will cause the attempt to read T to output an error message, to skip over the offending input charaters, and attempt to re-read T from the source stream.

blocking(Bool)

For streams, such as socket streams or IPC queue streams, it is possible for the stream to remain open, yet there be no characters available at the time a read is issued. The value of Type controls the behavior of the read in this setting. The values of Type are as follows:

true In this type of read, the read suspends or waits until enough characters are available to parse as a valid Prolog term.

false In this type of read, if no characters are available, the read will immediately return with success, unifying the 'read term argument' (which is argument 1 for read_term/2 and is argumen 2 for read_term/3) with the term unfinished_read; any tokens consumed in the read attempt are saved in the stream data structure, and subsequent attempts to read from this stream begin with these tokens, followed by tokens created from further characters which arrive at later times.

debugging This option is not handled in satisfy_options/4. Read terms are considered to be clauses and debugging information is attached. This is likely to of little direct use to the application programmer.

attach_fullstop(Bool) This option determines if a fullstop is | added to the tokens comprising a the term to be read. It is most | useful when used in conjunction with atom or list streams.

read_term/2
read_term(Term, Options)
read_term(?, +)

`read_term(Term, Options)` is equivalent to `read_term(S, Term, Options)` where S is the current input stream; i.e., `read_term/2` is defined by:

```
read_term(Term, Options) :-
  current_input(Stream),
  read_term(Stream, Term, Options).
```

read_term/3
read_term(Stream_or_alias, Term, Options)
read_term(+, ?,+)

`read_term(Stream_or_alias, Term, Options)` inputs a sequence TT of tokens from the stream associated with `Stream_or_alias` until an end token has been read. It is a syntax error if end of stream is reached before an end token is found. TT is then parsed as a Prolog term which is then unified with `Term`.

A 'sequence of tokens' implies that single quotes and double quotes (if included in the standard) are balanced. That is, an apparent end token appearing inside any kind of quotes is not an end token. However, parentheses and square brackets need not be balanced. The effect of this predicate may be modified by clauses of the special user-defined procedure `char_conversion/2.`

read/1
read(Term)
read(?)
read/2
read(Stream_or_alias, Term)
read(+,?)

`read(Term)` is equivalent to `read_term(S, Term, [])` where S is the current input stream; that is, `read/1` is defined by:

```
read(Term) :-
  current_input(Stream),
  read_term(Stream, Term, []).
```

`read(Stream_or_alias, Term)` is equivalent to

```
 read_term(Stream_or_alias, Term, []),
```

so that `read/2` is defined by:

```
read(Stream_or_alias, Term) :-
  read_term(Stream_or_alias, Term, []).
```

The following convenience predicates are quite useful:

atomread/2
atomread(Atom,Term)
atomread(+,-)

atomread/3
atomread(Atom,Term,Options)
atomread(+,-,+)

bufread/2
bufread(String,Term)
bufread(+,-)

bufread/3
bufread(String,Term,Options)
bufread(+,-,+)

These are defined as follows:

```
   atomread(Atom,Term)
       :-
       atomread(Atom,Term,[]).

   atomread(Atom,Term,Options)
       :-
       open(atom(Atom),read,Stream),
       read_term(Stream,Term,
                    [attach_fullstop(true)|Options]),
       close(Stream).
   bufread(String,Term)
       :-
       bufread(String,Term,[]).

   bufread(String,Term,Options)
```

```
        :-
        open(string(String),read,Stream),
        read_term(Stream,Term,
                    [attach_fullstop(true)|Options]),
        close(Stream).
```

10.7.2 Write options.

Just as the reading of terms from input streams can be affected by read options, the writing of terms to ouptut streams can be controlled by write options. The terms written are output in a pretty-printed format which breaks lines before wrapping, and uses indenting for legibility. Also, by default, the variables occurring in a term are represented using identifiers of the forms A, ..., Z, A1,....,A2,....... A ***write options list*** is a list of write options, which are one of the terms defined below. The default setting for each of these options is indicated in square brackets following each write option term. Let T be the term being written out, and let the expression Bool take on one of the values `true` or `false`.

quoted(Bool) [default: Bool = false]

If Bool = true, forces all symbols in T to be written out in such a manner that read_term/[2,3] may be used to read them back in. Bool = false indicates that symbols should be written out without any special quoting. In the latter case, embedded control characters will be written out to the output device as is.

ignore_ops(Bool) [default: Bool = false]

If Bool = true, operators in T will be output in function notation (i.e., operators are ignored.) If Bool = false, operators will be printed out appropriately.

portrayed(Bool)	not implemented yet

numbervars(Bool) [default: Bool = true]	If Bool = true, terms of the form $VAR(N) where N is an integer will print out as a letter.
lettervars(Bool) [default: Bool = true]	If Bool = true, variables occurring in T will be printed out as letters A, B, ..., or letters followed by numbers: A1,...,A2,... If Bool = false, variables will be printed as _N where N is computed via the internal address of the variable. This latter mode will be more suited to debugging purposes where correspondences between variables in various calls is required.
maxdepth(N,Atom1,Atom2) [default: maxdepth(20000,*,...)]	N is the maximum depth to which to print; Atom1 is the atom to output when this maximum depth has been reached in printing any term. Atom2 is the atom to output when this depth has been reached at the tail of a list.
maxdepth(N) [default: N = 20000]	Equivalent to maxdepth(N,*,...).
line_length(N) [default: N = 78]	N is the length in characters of the output line. The pretty printer will attempt to put attempt to break lines before they exceed the given line length.
indent(N) [default: N = 0]	N is the initial indentation to use.

quoted_strings(Bool)

If Bool = true, lists of suitably small integers will print out as a double quoted string. If Bool = false, these lists will print out as lists of small numbers.

depth_computation(Val) [default: Val = nonflat]

Val may be either flat or nonflat. This setting determines the nature of the pretty printer's "depth in term" computation. If Val = flat, all arguments of a term or list will be treated as being at the same depth. If Val = nonflat, then each subsequent argument in a term (or each sebsequent element of a list) will be considered to be at a depth one greater than the depth of the preceding structure argument (or list element).

line_end(Bool) [default: Bool = true]

When Bool = true, nl(_) is normal; when Bool = false, line-breaks (new lines) are preceeded by a \ .

write_term/2
write_term(Term, Options)
write_term(+, +)
write_term/3
write_term(Stream_or_alias, Term, Options)
write_term(+,+,+)

`write_term(Term, Options)` is equivalent to `write_term(Out, Term, Options)` where `Out` is the current output stream; that is, `write_term/2` is defined by:

```
   write_term(Term, Options) :-
     current_output(Stream),
     write_term(Stream, Term, Options).
```

`write_term(Stream_or_alias, Term, Options)` outputs `Term` to the stream associated with `Stream_or_alias` in a form which is defined by the write-options list `Options`.

Examples

write_term(S, [1,2,3]) $\longrightarrow$ **[1,2,3]**

write_term(S, [1,2,3], [ignoreops(true)]) $\longrightarrow$ **. (1, . (2, . (3, [])))**

write_term(S, ’1 < 2’) $\longrightarrow$ **1 < 2**

write_term(S, ’1 < 2’, [quoted(true)]) $\longrightarrow$ **’1 < 2’**

write_term(S, ’VAR’(0),[numbervars(true)]) $\longrightarrow$ **A**

write_term(S, ’VAR’(1),[numbervars(true)]) $\longrightarrow$ **B**

write_term(S, ’VAR’(28),[numbervars(true)]) $\longrightarrow$ **C1**

write/1
write(Term)
write(+)
write/2
write(Stream_or_alias, Term)
write(+,+)

`write(Term)` is equivalent to `write(Out, Term)` where `Out` is the current output stream; that is, `write/1` can be defined by:

```
write(Term) :-
  current_output(Stream),
  write(Stream, Term).
```

`write(Stream_or_alias, Term)` is equivalent to

```
write_term(Stream_or_alias, Term,
  [numbervars(true)]);
```

Thus, `write/2` can be defined by:

```
write(Stream_or_alias, Term) :-
  write_term(Stream_or_alias, Term,
  [numbervars(true)]).
```

Examples

write(S, [1,2,3]) $\longrightarrow$ **[1,2,3]**

write(S, 1 < 2) $\longrightarrow$ **1 < 2**

write(S, 'VAR'(0) < 'VAR(1)) $\longrightarrow$ **A < B**

writeq/1
writeq(Term)
writeq(+)
writeq/2
writeq(Stream_or_alias, Term)
writeq(+,+)

`writeq(Term)` is equivalent to `writeq(Out, Term)` where `Out` is the current output stream; i.e, `writeq/1` can be defined by:

```
writeq(Term) :-
  current_output(Stream),
  writeq(Stream, Term).
```

`writeq(Stream_or_alias, Term)` is equivalent to

```
write_term(Stream_or_alias, Term, [quoted(true),
  numbervars(true)]);
```

that is, `writeq/2` can be defined by:

```
writeq(Stream_or_alias, Term) :-
  write_term(Stream_or_alias, Term,
                 [quoted(true), numbervars(true)]).
```

Examples

writeq(S, [1, 2, 'A']) $\longrightarrow$ **[1, 2, 'A']**

writeq(S, '1 < 2') $\longrightarrow$ **'1 < 2'**

writeq(S, 'VAR'(0) < 'VAR(1)) $\longrightarrow$ **A < B**

write_canonical/1

write_canonical(T)
write_canonical(+)
write_canonical/2
write_canonical(Stream_or_alias, Term)
write_canonical(+,+)

`write_canonical(T)` is equivalent to `write_canonical(S, T)` where S is the current output stream; that is, `write_canonical/1` can be defined by:

```
write_canonical(T) :-
  current_output(Stream),
  write_canonical(Stream, T).
```

`write_canonical(Stream_or_alias, Term)` is equivalent to

```
write_term(Stream_or_alias, Term, [quoted(true),
  ignore_ops(true)]);
```

that is, `write_canonical/2` can be defined by:

```
write_canonical(Stream_or_alias, Term) :-
  write_term(Stream_or_alias, Term,
                [quoted(true), ignore_ops(true)]).
```

Examples

vrite_canonical(S, [1, 2, 3]) $\longrightarrow$ **'.'(1, '.'(2, '.'(3, [])))**

vrite _canonical(S, 1 < 2) $\longrightarrow$ **< (1, 2)**

vrite _canonical(S, '1 < 2') $\longrightarrow$ **' 1 < 2 '**

vrite_canonical(S, 'VAR'(0) < 'VAR'(1)) $\longrightarrow$ **< ('VAR' (0), 'VAR' (1))**

write_clause/1.
write_clause(Clause)
write_clause(+)

write_clause/2.
write_clause(Alias_or_stream, Clause)

write_clause(+, +)

write_clause/3.
write_clause(Alias_or_stream, Clause, Options)
write_clause(+, +, +)

These convenience predicates are defined by:

```
write_clause(Clause) :-
    get_current_output_stream(Stream),
    write_clause(Stream, Clause).
```

And:

```
write_clause(Stream, Clause) :-
    write_clause(Stream, Clause, []).
```

And:

```
write_clause(Stream, Clause, Options) :-
    write_term(Stream,Clause, Options),
    put_char(Stream, 0’.),
    nl(Stream).
```

Since one often must ouput sequences of clauses, the following predicates are useful:

write_clauses/1.
write_clauses(Clauses)
write_clauses(+)

write_clauses/2.
write_clauses(Alias_or_stream, Clauses)
write_clauses(+, +)

These predicates are defined by:

```
write_clauses(Clauses) :-
    get_current_output_stream(Stream),
    write_clauses(Stream, Clauses, []).

write_clauses(Stream, Clauses) :-
```

```
        write_clauses(Stream, Clauses, []).
```

write_clauses/3
write_clauses(Alias_or_stream, Clauses, Options)
write_clauses(+, +, +)

If `Clauses` is a list of terms (to be viewed as clauses), `write_clauses/3` recursively applies `write_clause/3` to the elements of `Clauses`.

EXT

printf/1
printf(Format)
printf(+)

printf/2
printf(Format,ArgList)
printf(+,+)

printf/3
printf(Alias_or_stream,Format,ArgList)
printf(+,+,+)

printf_opt/3
printf_opt(Format,ArgList,Options)
printf_opt(+,+,+)

printf/4
printf(Alias_or_stream,Format,ArgList,Options)
printf(+,+,+,+)

The printf/[...] goup of predicates provides a powerful formatted printing facility closely related to the corresponding facilities in the C programming language. `printf/[...]` accepts a format string together with a list of arguments to print, possibly a stream to print to, and possibly options. The format string contains characters to be printed, characters to control the formats of the items being printed, and argument placeholders. Figure 15 illustrates the general structure of the `printf` predicate.

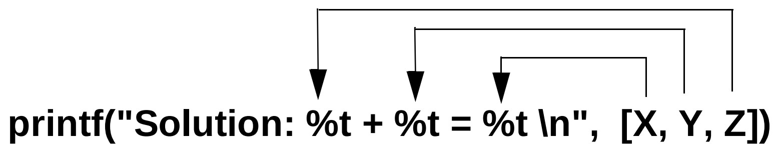


Figure 15. `printf` formatting

As a simple example, the following clause defines a predicate for adding two numbers and printing the result:

```
add(X,Y) :-
  Z is X + Y,
  printf("Solution: %t + %t = %t\n",[X,Y,Z]).
```

The `%t` placeholder tells `printf/2` that it should take the next argument from the argument list, and print it as a Prolog term. The `\n` at the end of the format string causes a newline character to be printed. The following shows the result of calling `add/2`:

add(7, 8) $\longrightarrow$ **Solution: 7 + 8 = 15**

The same effect could have been obtained without `printf/2`. It is instructive to see how it is done:

```
add(X,Y) :-
  Z is X + Y,
  write(X),
  write(’ + ’),
  write(Y),
  write(’ = ’),
  write(Z),
  nl.
```

The second version of the predicate is longer and somewhat harder to read. If no arguments must be supplied to `printf` (i.e., the string contains no placeholder characters), the unary version, `printf/1`, can be used.

The fundamental formatted output predicate is `printf/4`. The first four predicates above are convenience predicates and can be defined as follows:

```
printf(Format) :-
  current_output(Stream),
  printf(Stream,Format,[],[]).

printf(Format,ArgList) :-
  current_output(Stream),
  printf(Stream,Format,ArgList,[]).

printf_opt(Format,ArgList,Options) :-
  current_output(Stream),
  printf(Stream,Format,ArgList,Options).

printf(Alias_or_stream,Format,ArgList) :-
  printf(Alias_or_stream,Format,ArgList,[]).
```

`printf/4` is closely related to the C language printf function. Roughly, the formats supported by `printf/4` are the same as those allowed by the C language printf, with the inclusion of several additional combinations, In particular, '`%t`', which indicates that the corresponding Prolog term should be output at that point. And where one would call the C language function in the form

```
  printf(Format, A1, A2, ..., An),
```

one calls the Prolog `printf/2` in the form

```
  printf(Format, [A1,A2,...,An]).
```

More precisely, formats are specified as follows. An ***extent expression*** consist of either a sequence of digits, or of two sequences of digits separated by a period(.); in addition, an extent expression may be prefixed with a minus sign (-). If K is an extent expression, an ***active format element*** is one of the following expressions:

```
%t   %p   %Ks   %Kd   %Ke  %Kf  %Kg
```

The last five elements in this list are also called ***C format elements.*** A ***printf format*** is a quoted string, ie., and atom. (Using double quoted strings for formats is accepted for bacwards compatibility; however, it is much more wasteful of storage.) Any printf format contains zero or more active format elements, together with other text (possibly none).

The behavior of printf/[..] for the format elements `%Ks, %Kd, %Ke, %Kf,` and `%Kg` is completely in accord with the C printf, since in these cases, the argument (appropriately converted) is simply passed to the C printf. As noted above, for `%t`, the argument is printed on the output stream as a Prolog term. Finally, the format allows the programmer to take control of the formatting process as follows. Suppose that the format is `%p`, that `Stream` is the stream argument to `printf/4`, and that PArg is the argument corresponding to `%p.` Then the action of `printf/4` is determined by:

```
(PArg = Stream^PrintGoal0 ->
       call(PrintGoal0)
       ;
       (PArg = [Stream, Options]^PrintGoal0 ->
            call(PrintGoal0)
            ;
            call(PArg)
       )
).
```

`printf/4` is effectively defined as follows:

If Format = [],

    printf(Alias_or_stream, Format, ArgList, Options)

succeeds; otherwise,

    printf(Alias_or_stream, Format, ArgList, Options)

holds provided that:

If

    Format = ["%t" | FormatTail] and ArgList = [T | ArgListTail],

then

    print_term(Alias_or_stream, T, Options) and
    printf(Alias_or_stream,FormatTail,ArgListTail,Options)

else if

    Format = ["%p" | FormatTail] & ArgList = [T | ArgListTail],

```
then   if
         T = S^PG & S=Alias_or_stream
       then call(PG)
       else   if
                 T = [S,O]^PG & S=Alias_or_stream & O=Options
              then call(PG)
              else
                 call(T) and
                 printf(Alias_or_stream,FormatTail,ArgListTail,Options)
else if Format = ["%%" | FormatTail] ,
then
     output the character % to Alias_or_stream and
     printf(Alias_or_stream,FormatTail,ArgListTail,Options),
else if
     Format = [Head | FormatTail] & Head is a C active format string
     & ArgList = [T | ArgListTail],
then
     output T to Alias_or_stream in format Head in the manner of  C printf,
     & printf(Alias_or_stream,FormatTail,ArgListTail,Options)
else
     Format = [C | FormatTail] &
     put_char(Alias_or_stream, C) &
     printf(Alias_or_stream,FormatTail,ArgListTail,Options)
```

sprintf/3
sprintf(Alias_or_stream,Format,ArgList)
sprintf(+,+,+)

bufwrite/2
bufwrite(String,Term)
bufwrite(String,Term)

bufwriteq/2
bufwriteq(String,Term)

bufwriteq(String,Term)

These very useful convenience predicates are defined by

```
sprintf(Output,Format,Args)
  :-
  open(string(Output),write,Stream),
  printf(Stream,Format,Args),
  close(Stream).

bufwrite(String,Term) :-
  open(string(String),write,Stream),
  write_term(Stream,Term,
       [line_length(10000),quoted(false),
         maxdepth(20000), quoted_strings(false)]),
  close(Stream).

bufwriteq(String,Term) :-
  open(string(String),write,Stream),
  write_term(Stream,Term,
       [line_length(10000), quoted(true),
        maxdepth(20000), quoted_strings(false)]),
  close(Stream).
```

10.8 Operator Declarations

op/3
op(Priority, Op_specifier, Operator)
op(+, +, +)

`op/3` is used to specify Operator as a syntactic operator (for the Prolog parser) according to the specifications of Priority and Op_specifier.

current_op/3
current_op(Priority, Op_specifier, Operator)
current_op(?, ?, ?)

`current_op(Priority, Op_specifier, Operator)` is true iff `Operator` is an operator with properties defined by specifier `Op_specifier` and precedence `Priority`.

Examples

currentop(P, xfy, OP). Succeeds three times if the predefined operators have not been altered, producing the following bindings:

P $\longrightarrow$ **1100** **OP** $\longrightarrow$ **;**

P $\longrightarrow$ **1050** **OP** $\longrightarrow$ **->**

P $\longrightarrow$ **1000** **OP** $\longrightarrow$ **,**

The order in which the solutions are produced is implementation dependent.

10.9 DEC10-Style I/O Predicates

The full details of the definitions of the DEC10-style I/O predicates are presented in the file *sio_d10.pro* which is in the *alsdir* subdirectory. This file should be loaded whenever one wishes to use the DEC10- style I/O system (apart from simple calls to read/1 and write/1). Note that the predicates listed here as DEC10-style predicates have been added to the ALS Library, and so the file *sio_d10.pro* is automatically loaded by the development environment whenever one of them is called.

Below, we present conceptual definitions (which simply suppress some of the detail) of the DEC10 predicates.

see/1.
```
   see(Alias_or_stream) :-
     'is input stream'(Alias_or_stream,Stream),
     !,
     set_current_input(Stream).

   see(FileName) :-
     open(FileName,read,[alias(FileName)],Stream),
     set_input(Stream).
```

seeing/1.

```
   seeing(Alias) :-
     current_input(Stream),
     current_alias(Alias,Stream), !.

   seeing(Stream) :- current_input(Stream).
```

seen/0.

```
   seen :-
     current_input(Stream),
     close(Stream).
```

tell/1.

```
   tell(Alias_or_stream) :-
     'is output stream'(Alias_or_stream,Stream), !,
     set_current_output(Stream).

   tell(FileName) :-
     open(FileName,write,[alias(FileName)],Stream),
     set_current_output(Stream).
```

telling/1.

```
   telling(Alias) :-
     current_output(Stream),
     current_alias(Alias,Stream), !.

   telling(Stream) :- current_output(Stream).
```

told/0.

```
   told :-
     current_output(Stream),
     close(Stream).
```

get0/1.

```
   get0(Byte) :-
```

```
     current_input(Stream),
     get_code(Stream,Byte), !.
```

get/1.

```
   get(Byte) :-
     get0(Byte0),
     get_more(Byte0,Byte).

   get_more(Byte0,Byte) :-
     Byte0 =< 0' ', !,
     get0(Byte1),
     get_more(Byte1,Byte).

   get_more(Byte,Byte).
```

skip/1.

```
   skip(Byte) :-
     get0(Byte0),
     skip_more(Byte,Byte0).

   skip_more(Byte,Byte0) :-!.

   skip_more(Byte,_) :-
     get0(Byte0),
     skip_more(Byte,Byte0).
```

put/1.

```
   put(Byte) :-
     current_output(Stream),
     put_code(Stream,Byte), !.
```

tab/1.

```
   tab(N) :-
     N =< 0, !.

   tab(N) :- NN is N-1,
     put(0' '),
     tab(NN).
```

ttyflush/0.

```
   ttyflush :- flush_output.
```

display/1.

```
   display(X) :-
     write_term(X,[quoted(false),ignore_ops(true),numbe
     rvars(true)]).
```

10.10The user file

The file *user* represents both the keyboard (stream `user_input`) and the display (stream `user_output`). The system automatically opens stream `user_input` to be ***stdin***, and opens stream `user_output` to be ***stdout***. .

The above information is useful if you use operating system shell commands to change the standard input and output to be other than the keyboard and display. This will work properly if ALS Prolog was invoked with the `-g` and `-b` command line switches, and if the operating system supports such redirection (e.g., the Macintosh does not).

The *user* file (`user_input, user_output`) cannot be closed with `close/1.` However, you can signal end-of-file from the console on various operating systems as follows:

- On UNIX: **Control-D**
- On DOS and Win32: **Control-Z** followed by a return
- On the Macintosh: **Control-D**, or **Control-Z**.

11 Prolog Builtins: Non-I/O

11.1 Term Manipulation

11.1.1 Comparison predicates

@< /2
@> /2
@=< /2
@>= /2
== /2
\== /2

compare/3
compare(Relation, TermL, TermR)
compare(?, +, +)

@< /2, @> /2, @=< /2, @>= /2 perform comparisons on terms according to the standard order for Prolog terms. ==/2 and \==/2 perform limited identity (isomorphism) checks on their arguments. compare/3 subsumes both these comparison and identify checks.

11.1.2 Term Classification

atom/1
atomic/1
float/1
integer/1
number/1

These predicates classify terms according to the types expressed by their names.

11.1.3 Term Analysis & Synthesis

functor/3

functor(Term, Atom, Integer)
functor(?,?,?)

If `Term` is instatiated to a compound term (including an atom, which is viewed as a compound term of arity 0), then `Atom` and `Integer` are unified respectively with the functor of `Term` and the number of arguments of `Term`. Conversely, if `Atom` is an atom and `Integer` is a non-negative integer, then `Term` is unified with a compound term with functor `Atom`, and which has `Integer` number of arguments, all of which are uninstantiated variables.

arg/3
arg(Integer, Structure, Term)
arg(+, +, ?)

If `Structure` is a compound term of arity n, and `Integer` is an integer ≤ n, then `Term` is unified with the nth argument of `Structure`.

=../2
Term =.. List
? =.. ?

`Term =.. List` (pronouced ‘univ’) translates between terms and lists of their components. If `Term` is instantiated, List will be unified with a list of the form `[F,` A_1`,...,`A_n`]`, where `F` is the functor of `Term` and A_1`,...,`A_n are the arguments of `Term`. Conversely, if List is of the form `[F,` A_1`,...,`A_n`]` where `F` is an atom, then `Term` will be unified with the term whose functor is `F` and whose arguments are A_1`,...,`A_n.

mangle/3
mangle(N, Structure, Term)
mangle(+,+,+)

mangle/3, though related to arg/3, destructively updates the Nth argument of Structure to become Term.

var/1
var(Term)
var(+)

nonvar/1
nonvar(Term)
nonvar(+)

`var(Term)` succeeds iff `Term` is an uninstantiated variable, and `nonvar/1` behaves exactly opposite.

11.1.4 List manipultation predicates

append/3
append(LeftList,RightList,ResultList)
append(?,?,?)

dappend/3
dappend(LeftList,RightList,ResultList)
dappend(?,?,?)

dappend/3 is a determinate version of append/3.

member/2
member(Item, List)
member(?, ?)
dmember/2
dmember(Item, List)
dmember(?, ?)

dmember/2 is a determinate version of member/2.

reverse/2
reverse(List, RevList)
reverse(?, ?)
dreverse/2,
dreverse(List, RevList)
dreverse(?, ?)

dreverse /2 is a determinate version of reverse/2.

length/2
length(List, Length)

length(+, -)

length(List,Length) causes to be unified with the number elements of List.

sort/2
sort(List, SortedList)
sort(+, -)
keysort/2
keysort(List, SortedList)
keysort(+, -)

sort/2 sorts `List` according to the standard order, merging dentical elements as defined by `==/2,` and unifying the result with SortedList. `keysort/2` expects `List` to be a list of terms of the form: `Key-Data`, sorting each pair by `Key` alone. See also the ALS Library.

11.1.5 Term Database

recorda/3
recorda(Key,Term,Ref)
recorda(Key,Term,Ref)

recordz/3
recordz(Key,Term,Ref)
recordz(Key,Term,Ref)

recorded/3
recorded(Key,Term,Ref)
recorded(Key,Term,Ref)

11.2 Atom and UIA Manipulation

atom_length/2
atom_length(Atom,Length)
atom_length(+, -)

Determines the length of an atom.

atom_concat/3
atom_concat(Atom1,Atom2,Atom)
atom_concat(?, ?, ?)

Concatenates two atoms to form a third..

sub_atom/4
sub_atom(Atom,Start,Length,SubAtom)
sub_atom(+, ?, ?, ?)

Dissects atoms. When instatiated, `Start` and `Length` must be non-negative integers, and `SubAtom` must be an atom. Can be used to extract a `SubAtom` extending `Length` chars from `Start`, and to determine if a given candidate `SubAtom` occurs in `Atom`, etc.

'$uia_alloc'/2 and relatives provide an extensive collection of routines for allocating and manipulating UIAs. They are introduced in the Chapter: Working with Uninterned Atoms.

gensym/2
gensym(Prefix, Symbol)
gensym(+, -)

Creates families of unique symbols.

11.3 Type Conversion

atom_chars/2
atom_chars(Atom,CharList)
atom_chars(?,?)

atom_codes/2
atom_codes(Atom,CodeList)
atom_codes(?,?)

These predicates convert between atoms on the one hand, and on the other hand, either lists of (atomic) characters, or lists of ascii character codes (Prolog strings):

$$\begin{tikzcd} & \text{abc} \arrow[dl, leftrightarrow, "\texttt{atom\_chars}"'] \arrow[dr, leftrightarrow, "\texttt{atom\_codes}"] & \\ \text{[`a', `b', `c']} & & \text{[97, 98, 99]} \end{tikzcd}$$

number_chars/2
number_chars(Number,CharList)
number_chars(Number,CharList)

number_codes/2
number_codes(Number,CodeList)
number_codes(Number,CodeList)

In a manner exactly analogous to `atom_chars(codes)` above, these predicates convert between numbers, and lists of atomic characters or lists of ascii character codes.

term_chars/2
term_chars(Term,CharList)
term_chars(Term,CharList)

term_codes/2
term_codes(Term,CodeList)
term_codes(Term,CodeList)

In a manner exactly analogous to `atom_chars(codes)` above, these predicates convert between terms, and lists of atomic characters or lists of ascii character codes.

name/2
name(Constant,PrintName)
name(?,?)

`name/2` converts between constants and Prolog strings (lists of character codes). It is included primarily for backwards compatibility with older versions of Prolog; use of `[atom/number]_[chars/codes]` above is recommended.

11.4 Collectives

bagof/3
bagof(Template,Goal,Collection)
bagof(+, +, ?)

setof/3
setof(Template,Goal,Collection)
setof(+, +, ?)

findall/3
findall(Template,Goal,Collection)
findall(+, +, ?)

Methods of obtaining all solutions to Goal. Fail when there are no solutions.

bagOf/3
bagOf(Template,Goal,Collection)
bagOf(+, +, ?)

setOf/3
setOf(Template,Goal,Collection)
setOf(+, +, ?)

Like `bagof/3` and `setof/3`, respectively, but succeed when no solutions to `Goal` exist, unifying `Collection` with the empty list `[]`.

b_findall/4
b_findall(Template,Goal,Collection,Bound)
b_findall(+, +, -, +)

Like findall/3, except that it locates at most integer Bound > 0 number of solutions.

11.5 Prolog Database

assert/1
assert(Clause)

assert(+)

asserta/1
asserta(Clause)
asserta(+)

assertz/1
assertz(Clause)
assertz(+)

These predicates add a `Clause` to the Prolog database. If the principal functor and arity of `Clause` is `P/N`, then:

- `asserta/1` adds `Clause` before all previous clauses for `P/N`;
- `assertz/1` adds `Clause` after all previous clauses for `P/N`;
- `assert/1` adds `Clause` in some implementation-dependent position relative to all previous clauses for `P/N`.

clause/2
clause(Head, Body)
clause(+, ?)

Used to retrieve clauses `(A :- B)` [or, facts `A`] from the database where `A` unifies with `Head` and `B` unifies with `Body [true].`

retract/1
retract(Clause)
retract(+)

The current module is searched for a clause that will unify with `Clause`. The first such matching clause, if any, is removed from the database.

asserta/2
asserta(Clause, Ref)
asserta(+, -)

asserta/2
asserta(Clause, Ref)

asserta(+, -)

assertz/2
assertz(Clause, Ref)
assertz(+, -)

clause/3
clause(Head, Body, Ref)
clause(+, ?,?)

retract/2
retract(Clause, Ref)
retract(+, ?)

These predicates. all similar to their counter-parts above, add an extra argument `Ref` to the previous arguments, where Ref is an implementation-dependent ***data-base reference.*** A database reference obtained from `assert[a/z]/3` can be passed to `clause/3` to retrieve a clause, and to `retract/2` to delete a clause.

abolish/2
abolish(Name, Arity)
abolish(+, +)

All the clauses for the specified procedure `Name/Arity` in the current module are removed from the database

erase/1
erase(DBRef)
erase(+)

If `DBRef` is a database reference to an existing clause, `erase(DBRef)` removes that clause.

instance/2

$clauseinfo/3

$firstargkey/2

11.6 Global Variables

gv_alloc/1, make_gv/1 and relatives provide methods for manipulating global variables. See Chapter 8 (*Global Variables, Destructive Update & Hash Tables)* for a discussion.

11.7 Control

cut(!)
comma(,)
arrow (->)
semicolon (;)

abort/0
abort

The current computation is discarded and control returns to the Prolog shell

breakhandler/0
breakhandler

call/1
call(Goal)
call(+)

If `Goal` is instantiated to a structured term or atom which would be acceptable as the body of a clause, the goal `call(Goal)` is executed exactly as if that term appeared textually in place of the expression `call(Goal).`

:/2
Module:Goal
+ : +

Like call/1, but invokes Goal in the defining module Module. See Chapter 3 (*Modules*) .

catch/2
catch(Goal,Pattern,ExceptionGoal)
catch(+,+,+)

throw/0
throw(Reason)
throw(+)

These predicates provide a controlled abort mechanism, as well as access to the exception mechanism. They are introduced in Chapter 9.2 (*Exceptions.)*

fail/0

true/0

not/1
not(Goal)
not(+)

\+/1
\+(Goal)
\+(+)

`not/1` and `\+/1` are synonymous and implement negation by failure. If the `Goal` fails, then `not(Goal)` succeeds. If `Goal` succeeds, then `not(Goal)` fails.

repeat/0
repeat

`repeat/0` always succeeds, even during backtracking.

$findterm/5
'$findterm'(Functor,Arity,HeapPos,Term,NewHeapPos)
'$findterm'(+, +, +, ?, -)

A low-level predicate for searching the heap.

forcePrologInterrupt/0
callWithDelayedInterrupt/[1,2]
setPrologInterrupt/1
getPrologInterrupt/1

The predicates provide access to the ALS Prolog interrupt mechanism. See Chapter 9.3 (*Interrupts.)* .

11.8 Arithmetic

See is/2 in the Reference Manual.

11.9 Program and System Management

als_system/1
als_system(InfoList)
als_system(-)

sys_env/2
sys_env(OS, Processor)
sys_env(+, +)

Predicates for obtain system environmental information.

command_line/1
command_line(Switches)
command_line(+)

Provides access to the command line by which an ALS Prolog process was invoked (including packaged applications).

compile_time/0
compile_time

Controls compile-time vs load-time execution of `:-` goals in files.

consult/1
consult(File)
consult(+)

reconsult/1
reconsult(File)
reconsult(+)

consultq/1

consultq(File)
consultq(+)

consult_to/1
consult_to(File)
consult_to(+)

consultq_to/1
consultq_to(File)
consultq_to(+)

consuld/1
consultd(File)
consultd(+)

reconsultd/1
reconsultd(File)
reconsultd+)

Various ways of dynamically loading a `File` of Prolog clauses into a running ALS Prolog program. All versions are defined in the builtins file *blt_io.pro.*

consultmessage/1
consultmessage(OnOff)
consultmessage(+)

`consultmessage(on/off)` controls whether or not messages are printed when files are consulted.

curmod/1
curmod(Module)
curmod(-)

modules/2
modules(Module,Uselist)
modules(+, -)

Provides access to information concerning modules.

gc/0
gc

Manually invokes garbage collection/compaction.

halt/0
halt

hide/1

index_proc/3

listing/[0,1]
listing
listing(Form)
listing(+)

Provides source-codes listings of clauses in the current Prolog database.

statistics/[0,2]
statistics
statistics(runtime,X)
statistics(runtime,+)

Obtain system statistics at runtime.

system/1
system(Command)
system(+)

Issue a command to the OS command processor, when supported.

module_closure/[2,3]
:- module_closure(Name,Arity,Procedure).
:- module_closure(Name,Arity).

procedures/4
all_procedures/4
all_ntbl_entries/4

Retrieve information concerning all Prolog- or C-defined procedures.

’$procinfo’/5
’$nextproc’/3
’$exported_proc’/3
’$resolve_module’/4

Retrieve detailed information about a given procedure.

11.10 Date and Time

These predicates provide access to the date and time functions of the underlying operating system. They are designed to be portable across operating systems. As such, they utilize Prolog-oriented, os-independent formats for date and time. Dates are internally represented by terms of the form

```
    YY/MM/DD
```

where `YY`, `MM`, `DD` are integers representing, respectively, the year, the month (counted from 1 to 12) and the day (couunted from 1 to 31, as appropriate to the month). The format of dates can be controlled by the predicate `set_date_pattern/1`. Any permuation of `YY`, `MM`, and `DD` is permitted. The predicates are defined in the builtins file *fs_cmn.pro* together with the various system-specific files *fs_unix.pro, fs_dos.pro, fs_mac.pro.*

date/1.
date(Date)
date(-)

`date/1` returns the current date in the format set by `set_date_pattern/1`.

date_pattern/4.
date_pattern(YY,MM,DD,DatePattern).
date_pattern(+,+,+,-).

This predicate consists of a single fact which provides the mapping between the three integers representing the date and the pattern expressing the date; this fact is governed by `set_date_pattern/1`.

set_date_pattern/1.

set_date_pattern(Pattern).
set_date_pattern(+).

The acceptable arguments to `set_date_pattern/1` are ground terms built up out of the ***atoms*** `yy`, `mm`, and `dd`, separated by the slash ’/’, such as

`mm/dd/yy` or `dd/mm/yy.`

The action of `set_date_pattern/1` is to remove the existing `date_pattern/4` fact, and to install a new fact which implements the date pattern corresponding to the input argument.

date_less/2
date_less(Date0, Date1)
date_less(+, +)

If `Date0` and `Date1` are date terms of the form `YY/MM/DD`, this predicate succeeds if and only `Date0` represents a date earlier than `Date1`.

time/1.
time(Time)
time(-)

This predicate returns a term `Time` representing the current time; Time is of the form

`HH:MM:SS`

where `HH`, `MM`, `SS` are integers in the appropriate ranges.

time_less/2.
time_less(Time0, Time1)
time_less(+, +)

If `Time0` and `Time1` are terms of the form `HH:MM:SS` representing times, this predicate succeeds if and only if `Time0` is a time earlier than `Time1`.

datetime/2.
datetime(Date, Time)
datetime(-, -)

This predicate combines date/1 and time/1, computing both from the same operating system access call.

gm_datetime/2.
gm_datetime(Date, Time)
gm_datetime(-, -)

This predicate is similar to datetime/2, returning the Greenwich UTC date and time from the same call to the operating system clock.

11.11File Names

File names and paths are one of the unpleasant ways in which operating systems differ. The file name and path predicates described in this section provide a substntial degree of portability across operating systems. They do not claim to handle or support all possible names or path descriptions in each supported operating system. But they do deal with most normal file and path names encountered in practice. Consequently they make it possible to write fairly machine-independent code. The approach is to simply parse incoming path expressions into elementary lists, and to 'pretty-print' outgoing lists into the appropriate path expressions. The internal representations are simply lists consisting of the significant elements of the path and file name. These predicates are defined in the builtins file *filepath.pro.* When running on a particular operating system (Unix, Windows, Macintosh), the top-level predicates determine the running OS, and call the parameterized lower-level predicates. Thus, some calls involving OS-specific path names will succeed under one OS and fail under another. For Windows path names, it is important to remember that '\' is the ISO Prolog standard escape character in (quoted) atoms, and hence occurrences of '\' as a directory separator must generally be doubled, as in:

```
'C:\\star\\flow\\foo.pro'
```

The primary predicates described in this Section are the following:

file_extension/3.
path_elements/2.
path_directory_tail/3.
is_absolute_path/1.
path_type/2.
path_type/3.

split_path/2.
split_path/3.
join_path/2.
join_path/3.
tilda_expand/2.
directory_self/2.
directory_self/3.

file_extension/3.
file_extension(Name, File, Ext)
file_extension(?, ?, ?)

This predicate is used for splitting or composing file (and path) names around the dot which separates the extension. Examples:

```
file_extension('foo.bar', F, X)  => F = foo, X = bar.
file_extension('/star/flow/foo.bar, F, X)
                  => F = '/star/flow/foo', X = bar.
file_extension(silly, F, X) => F = silly, X = ''.
file_extension(N, foo, bar) => N = 'foo.bar'.
```

path_directory_tail/3.
path_directory_tail(Path, Directory, Tail)
path_directory_tail(?, ?, ?)

This predicate maps between file system paths and the pair consisting of the entire path up to the last (right-most) directory separator, and the tail following that final separator. This is defined by:

```
path_directory_tail(Path, Directory, Tail) :-
   var(Path),
   !,
   join_path([Directory, Tail], Path).
path_directory_tail(Path, Directory, Tail) :-
   split_path(Path, Elements),
   dreverse(Elements, [Tail | RevDirElements]),
   dreverse(RevDirElements, DirElements),
   (DirElements = [] -> directory_self(Directory) ;
   join_path(DirElements, Directory)).
```

Examples:

```
path_directory_tail('foo.bar', F, T)  => F = '.', X = 'foo.bar.'
path_directory_tail('/star/flow/foo.bar, F, T)
                 => F = '/star/flow', X = 'foo.bar'.
path_directory_tail('/star/flow/sirius, F, T)
                 => F = '/star/flow', X = sirius.
```

is_absolute_path/1.
is_absolute_path(Path)
is_absolute_path(+)

This predicate hold of its atomic argument Path exactly when Path describes a path in the file system starting at the root, or at a disk or drive. It is defined by:

```
is_absolute_path(Path) :-
  path_type(Path, PathType),
  PathType \= relative.
```

Examples which succeed when running on the appropriate OS:

```
is_absolute_path('/star/flow/foo.pro').
is_absolute_path('C:\\star\\flow\\foo.pro').
is_absolute_path('mozart:star:flow:foo.pro').
```

Examples which fail:

```
is_absolute_path('foo.pro').
is_absolute_path('../foo.pro').
is_absolute_path('..\\foo.pro').
is_absolute_path(':foo.pro').
```

path_type/2.
path_type(Path, Type)
path_type(+, -)

This predicate determines the type (absolute, relative) of a file system path. It is defined by:

```
path_type(Path, Type) :-
  sys_env(OS, _, _),
  !,
  path_type(OS, Path, Type).
```

path_type/3.
path_type(OS, Path, Type)
path_type(+, +, -)

This predicate determines the OS-specific type of a file system path. All paths are relative unless determined to be absolute. A path is absolute if:

Unix:	It begins with the character ‘/’;
MacOS:	It contains ‘:’ at some position after the initial character;
Windows:	One of the following character sequences ':/', ':\\' occurs beginning at the second character of the path, or one of the character sequences '//', '\\\\', '/\\', '\\/' occurs at the beginning of the path.

path_elements/2.
path_elements(Path, Elements)
path_elements(?, ?)

This predicate relates paths to lists composed of the elements of the path, split about the directory separators. It is defined by:

```
   path_elements(Path, Elements) :-
     var(Path),
     !,
     join_path(Elements, Path).
   path_elements(Path, Elements) :-
     split_path(Path, Elements).
```

split_path/2.
split_path(Path, List)
split_path(+, -)

This predicate splits an atomic file system Path into a List of its constitutent directory components, including any root or drive elements (of an absolute path) at the beginning, and including the file name (if any) at the end. It is defined by:

```
   split_path(Path, List) :-
     sys_env(OS, _, _),
     !,
     split_path(OS, Path, List).
```

join_path/2.
join_path(List, Path)
join_path(List, Path)

This predicate composes an atomic file system Path from a List of its constitutent directory components, possibly including root or drive elements (of an absolute path) at the beginning, and including a file name (if any) at the end. It is defined by:

```
   join_path(List, Path) :-
     sys_env(OS, _, _),
     join_path(OS, List, Path).
```

split_path/3.
split_path(OS, Path, List)
split_path(+, +, -)

join_path/3.
join_path(OS, List, Path)
join_path(+, +, -)

These two predicates implement the OS-specific mappings between file system paths and lists of their components. They function as inverses of each other.

Examples:

```
Unix:     ‘/star/flow/foo.pro’
                         <=> [‘/’,star,flow,’foo.pro’]
Windows: ‘C:\\star\\flow\\foo.pro’
                    <=>  ['C:\\',star,flow,'foo.pro']
MacOS:   ‘mozart:star:flow:foo.pro’
               <=> [‘mozart:’,star, flow, ‘foo.pro’]
```

Also:

```
    join_path(['/star/flow',sirius],X)
          =>   X= '/star/flow/sirius',
```

etc.

tilda_expand/2.
tilda_expand(TildaPath, Path)
tilda_expand(+, -)

This predicate expands occurrences of '~' in settings where this is meaninful, that is, when one of the two follow goals succeeds:

```
    getenv('HOME', Home) ; get_user_home(Name, Home)
```

directory_self/1.
directory_self(Self)
directory_self(-)

directory_self/2.
directory_self(OS, Self)
directory_self(+, -)

These predicates return the "current directory" expression for the appropriate OS. They are defined by:

```
   directory_self(Self) :-
     sys_env(OS, _, _),
     !,
     directory_self(OS, Self).

   directory_self(unix, '.').
   directory_self(macos, ':').
   directory_self(mswin32, '.').
```

same_path/2
same_path(Path1, Path2)
same_path(+, +)

If `Path1` and `Path2` are two lists denoting file paths, determines whether they denote the same path, allowing for identification of uppercase and lowercase names as appropriate for the OS.

same_disk/2
same_disk(Disk1, Disk2)
same_disk(+, +)

If `Disk1` and `Disk2` are atoms denoting disks, determines whether they are the same, allowing for identification of upper and lower case letters, as appropriate for the os.

11.12File System[1]

The most important aspects of access to the file system are described in Chapter 11 on Prolog I/O. However, there are a number of further useful operations which are described in this Section. The predicates discussed in this section are defined in the builtins file *fs_cmn.pro* together with the various system-specific files *fsunix.pro, fswin32.pro, fsmac.pro.* The primary predicates are the following:

Manipulating directories and files:

get_cwd/1	- returns the current working directory
change_cwd/1	- change the current working directory
make_subdir/1	- creates a subdirectory in the current working directory
remove_subdir/1	- removes a subdirectory from the current working directory
remove_file/1	- removes a file from the current working directory
exists_file/1	- determines whether or not a file exists
file_status/2	- returns status information concerning a file

Lists of files in subdirectories:

files/2	- returns a list of files, matching a pattern, in the current directory
files/3	- returns a list of files, matching a pattern, residing in a directory
subdirs/1	- returns the list of subdirectories of the current directory
subdirs_red/1	- returns the list of subdirectories of the current directory, sans '.' and '..'

1. The predicates in this Section are defined in the builtins files *fsunix.pro, fsdos.pro, fsmac.pro,* etc.

directory/3	- returns a list of files of a given type and matching a pattern

Manipulating Drives:

get_current_drive/1	- returns the current drive
change_current_drive/1	- changes the current drive

change_cwd/1
change_cwd(NewDir)
change_cwd(+)

Changes the current working directory being used by the program to become `NewDir` (which must be an atom). Under DOS, this does not change the drive.

get_cwd/1
get_cwd(Path)
get_cwd(-)

Returns the current working directory being used by the program as a quoted atom. Under DOS, the drive is included.

make_subdir/1
make_subdir(NewDir)
make_subdir(+)

If `NewDir` is an atom, creates a subdirectory named `NewDir` in the current working directory, if possible.

remove_subdir/1
remove_subdir(SubDir)
remove_subdir(+)

If `SubDir` is an atom, remove the subdirectory named `SubDir` from the current working directory, if it exists.

remove_file/1
remove_file(FileName)
remove_file(+)

If `FileName` is an atom (possibly quoted) naming a file in the current working directory, removes that file.

files/2
files(Pattern,FileList)
files(+,-)

Returns the list (`FileList`) of all ordinary files in the current directory which match `Pattern`, which can include the usual '*' and '?' wildcard characters.

files/3
files(Directory, Pattern,FileList)
files(+,+,-)

Returns the list (`FileList`) of all ordinary files in the directory `Directory` which match `Pattern`, which can include the usual '*' and '?' wildcard characters.

subdirs/1
subdirs(SubdirList)
subdirs(-)

Returns the list of all subdirectories of the current working directory.

subdirs_red/1
subdirs_red(SubdirList)
subdirs_red(-)

Returns the list of all subdirectories of the current working directory, omitting '.' and '..'

exists_file/1.
exists_file(File)
exists_file(+)

Determines whether a file exists in the current directory. Applies to subdirectories as well as regular files.

File Types and Status

Every OS classifies files into different types and provides them with various statuses. ALS Prolog provides abstract types for directories and regular files, together with the ability to utilize OS-specific types, as described in the following table. On OSs for which a given type does not exist, requests for files of such types simply fail, and of course, they are never returned.

Table 6:

Abstract Type	Unix Type	Wins Type	Mac Type
directory	1	16	1
character_special	2		
block_special	3		
regular	4	32	4
symbolic_link / alias	5		5
socket	6		
fifo_pipe	7		
unknown	0	0	0
read_only		2	
hidden		4	
system		8	
TEXT			30

Where applicable, permissions for files can be queried and manipulated. Permissions are lists of atoms representing the permission details. The following table presents the possible permissions (order is unimportant). On some systems, some sub-attributes such as ’execute’ are meaningless.

[]
[execute]

[write]
[write,execute]
[read]
[read,execute]
[read,write]
[read,write,execute]

file_status/2
file_status(FileName, Status)
file_status(+, -)

If `FileName` is an atom naming a file in the current directory, returns a list `Status` of equations of the form

```
Tag = Value
```

which provide information on the status of the file. The four equations included on the list are:

```
type=FileType
permissions=Permissions
mod_time=ModTime
size=ByteSize
```

where `FileType` and `Permissions` are as described above. On systems where meaningful, `ModTime` is the time of last modification, or else the creation time, while `ByteSize` is the size of the file in bytes.

directory/3
directory(Pattern,FileType,List)
directory(+,+,-)

If `Pattern` is a file name pattern, including possibly the ’*’ and '?' wildcard characters, and if `FileType` is a numeric (internal) file type or a symbolic (abstract) file type, `directory/3` unifies `List` with a sorted list of atoms of names of files of type `FileType`, matching `Pattern`, and found in the current directory.

get_current_drive/1
get_current_drive(Drive)
get_current_drive(-)

Returns the current logical drive. On Unix, returns the erzataz drive ''.

change_current_drive/1
change_current_drive(Drive)
change_current_drive(+)

If `Drive` is an atom describing a logical drive which exists, changes the current drive to become `Drive`. On Unix, simply succeeds with no side effects.

11.13I-Code Calls

$icode/4
$icode(ServiceNumber,Arg1,Arity,Arg2)

The builtin `$icode` is used to call the internal code generation function. The form of the call is

```
        $icode(ServiceNumber,Arg1,Arity,Arg2)
```

When `ServiceNumber` is non-negative, it represents an abstract machine instruction to put in the instruction buffer. Negative `ServiceNumber` values are interpreted as commands. The remaining arguments are service dependent and should be filled in with zeros when not applicable.

init_codebuffer (-1)	Resets the internal code buffer pointer to point to the beginning of the code buffer.
name_clause (-2)	Attaches a predicate name and arity to the code currently in the icode buffer. Arg1 is a symbol (or token number) of the predicate. Arity should be set to the desired arity.
math_start (-3)	Indicates the start of an inline math computation. This command should precede the emission of a

	`math_begin` instruction and causes the current buffer position to be stored for use in the relative address computation at `math_end`.
math_rbranch (-4)	This should precede an rbranch instruction. It is used for the relative address calculation associated with a `math_endbranch` command.
math_end (-5)	Fills in the relative address associated with the `math_begin` instruction (which was immediately preceded by a `math_start` command).
math_reset (-6)	Causes the internal buffer pointer to be reset to the point at which `math_start` was called. This is used internally to throw away some inline math code after the compiler has decided that it can't compile it (as in '`X is 2.3`' for example).
math_endbranch (-7)	Fills in the relative branch associated with an rbranch instruction which was immediately preceded by a `math_rbranch` command.
export (-8)	Exports the predicate designated by Arg1/Arity in the *current* module.
new_module (-9)	Creates/opens a (new) module whose name is given by Arg1. If the module does not already exist, it is created and `use` declarations to user and builtins are added to the module. In addition, the current module will become the new module. This means that assert commands will place clauses in this module and predicate references within clauses will be to this module so it is desirable to call `new_module before` asserting a clause. If the module already exists, the `current module` is simply set to the module whose name is given by

	Arg1.
end_module (-10)	Closes the current module and sets the current module to `user`.
change_module (-11)	Changes the current module to the module whose name is given by Arg1 without creating the default use declarations.
add_use (-12)	Adds a use declaration to the module given by Arg1 to the current module.
asserta (-13)	Allocates code space and inserts the code in the icode buffer at the beginning of the predicate. The predicate should first have been named by `name_clause`. Any first argument indexing that exists for the predicate will be thrown away.
assertz (-14)	Allocates code space and appends the code in the code buffer to the end of the predicate. The predicate should first have been named with `name_clause`. Any first argument indexing that exists for the predicate will be thrown away.
exec_query (-15)	Causes the code in the icode buffer to be executed as a query (Meaning, Answers will be displayed and yes or no will be printed.)
exec_command (-16)	Causes the code in the icode buffer to be executed as a command. Nothing will be printed regardless of success of failure.
set_cutneeded (-17)	Sets/resets the internal `cut_needed` flag. If the clause has any cuts, comma, semicolons or calls, but is not classified as a cut macro, this flag should be set. It will be set when

Arg1 != -1 && !Arg2

While this is rather arcane, there are good reasons for it internally. For consistent results, the cut-needed flag should be set for each clause sometime before asserting it. If the `cut_needed` flag is set for either assertz or asserta, an instruction to move the current choice point to the cut point will be inserted prior to creation of the first choice point.

reset_obp (-18)	Erases the the icode parameters in the .obp file back to the most recent `init_codebuffer`.
index_all (-19)	Causes indexing to be generated for all predicates. This is normally done after a consult or reconsult operation. Assert and retract operations, however, cause the indexing to be discarded, so this service may be called to redo indexing after the database has been changed via assert or retract.
index_single (-20)	not implemented
addto_autouse (-21)	Causes a module name to be added to the list of modules to be automatically used. By default, only the builtins module is automatically used by all other modules. Argument one should be the name of the module to add to the autouse list.
addto_autoname (-22)	Causes a procedure name/arity to be added to the autoname list. This is a list of procedures for which "stubs" are created when a module is initialized. By default, `call/1`, `','/2`, `';'/2`, are on this list. These stubs must exist for context dependent procedures such as `call` or `setof` to work properly. Arg1 should be set to the proce-

dure name and `Arity` should be set to the arity.

cremodclosure (-23) Creates a module closure . Procedures such as `asserta/1` and `bagof/3` are defined in `builtins` and yet need to know which module invoked them. The solution is to create a $n+1$ argument version of these procedures in the builtins.pro file (or elsewhere) and create a module closure. This module closure will link together the three argument version with the four argument version, installing the calling module in the fourth argument. `Arg1` should be the name of the n argument procedure. `Arity` should be n. `Arg2` should be the name of the $n+1$ argument procedure to execute after installing the module name in the $(n+1)$th argument.

hideuserproc (-24) Used to hide user defined procedures. The first service argument (i.e., the second argument of `$icode/4`) is the name of the procedure to hide, the second is the arity of the procedure, the last is the name of the module in which the procedure is defined. The following query will hide `user:p/0`.

?- $icode(-24, p, 0, user).

relinkdatabase (-25) Relinks the entire database. Relinking of the program is done automatically by Version 1.1 after each consult or reconsult. However, it may still be desirable to relink the program before certain calls to assert or abolish.

Icode calls and .obp files

A `.obp` file simply consists of parameters to icode calls (along with symbol table information). During the execution of a command, it is not always desirable to keep the command in the .obp file. A simple example of this is in the DCG expander where `expand/2` is called from the parser as a command. `expand/2` will transform the DCG rule and assert it into the database. This assert operation will cause the code to be asserted in the database in addition to being added to the `.obp` file. If the expand command were retained, the assert operation would be done twice. Note also that when the `.obp` version of the file is loaded, the `expand` predicate will not be called. Only the `assert` operations that the `expand` predicate created will be performed.

Icode Instructions

The non-negative icode service numbers cause WAM instructions to be installed in the icode buffer. In the current version, argument/temporary (Ai, Xn) registers may range from 1 thru 16. Permanent variable numbers (Yn and MaxYn and EnvSize) may range from 1 thru 62. Only arities 0 thru 15 are permitted. Specifying procedure names, functors, and symbols (ProcName, Functor, Sym) is accomplished by passing in the symbol or token number if known. Integers are signed 16-bit quantities. Because of the restriction on the size of structures, NVoids should be at most 15

```
% p.
assert_p :-
   $icode(-1,0,0,0),           % initialize icode
buffer
   $icode(1,0,0,0),            % proceed
  $icode(-17,-1,0,0),        % no need for cut_btoc
                               % instruction
  $icode(-2,p,0,0),           % want to assert into
p/0.
   $icode(-14,0,0,0).          % assert the clause
% p(x).
assert_px :-
   $icode(-1,0,0,0),           % initialize icode
buffer
   $icode(25,x,0,1),           % get_symbol
   $icode(1,0,0,0),                % proceed
   $icode(-17,-1,0,0),           % no need for cut_btoc
                                   % instruction
   $icode(-2,p,1,0),             % want to assert into
p/1.
   $icode(-14,0,0,0).              % assert the clause
% p(f(x),9).
assert_pfx9 :-
   $icode(-1,0,0,0),               % initialize icode
buffer
   $icode(28,f,1,1),             % get_structure f/1,A1
   $icode(44,x,0,0),               % unify_symbol  x
   $icode(26,9,0,2),              % get_integer   9,A2
   $icode(1,0,0,0),                % proceed
   $icode(-2,p,2,0),          % want to assert into p/2
   $icode(-17,-1,0,0),         % no need for a cut_btoc
                                   % instruction
   $icode(-14,0,0,0).             % assertz the clause
% succ(X,Y) :- Y is X+1.
assert_succ :-
   $icode(-1,0,0,0),               % initialize icode
buffer
   $icode(-3,0,0,0),            % save buffer position
for AFP
   $icode(54,0,0,0),               % math_begin
   $icode(50,1,0,0),               % push_integerA1
   $icode(52,1,0,0),               % push_integer1
   $icode(56,0,0,0),               % add
   $icode(53,1,0,0),               % pop_integerA1
   $icode(23,1,0,2),               % get_valueX1, A2
   $icode(1,0,0,0),                % proceed
   $icode(-5,0,0,0),               % fill in relative
address for
                                   % math_begin
   $icode(32,1,0,3),               % put_valueA1,A3
   $icode(32,2,0,1),              % put_valueA2,A1
  $icode(37,'+',2,2),         % put_structure'+'/2,A2
  $icode(47,3,0,0),           % unify_local_value A3
   $icode(45,1,0,0),              % unify_integer1
   $icode(3,is,2,0),              % execute is/2
   $icode(-2,succ,2,0),           % succ/2 is the
procedure name
  $icode(-17,-1,0,0),         % reset the cut_needed
flag
   $icode(-14,0,0,0).             % assert it
```

12 The ALS Library Mechanism

The ALS Library mechanism provides a sophisticated device for managing large libraries of code in an efficient and flexible manner. Many files of potentially useful code can be available to a program without the cost of loading these files at the time the program is initially loaded. Only if program execution leads to a need for code from a particular library file is that file in fact loaded. Thereafter, execution proceeds as if the file had already been loaded.. The library mechanism is essentially invisibile to the programmer, except for a possible momentary pause when a particuular group of library predicates is first loaded. Consequently, the line between the predicates which are called 'builtin' and those which are called 'library' is quite gray.

By its nature, the library is almost always under construction. Check the contents of the *...alsdir/library/* directory for new additions.

12.1 Overview of ALS Library Mechanism and Tools.

Normally, the units making up the library are various sized (small to large) files containing code defining certain useful predicates, or defining whole subsystems of a large program.. Some of the predicates in such a file will be exported. These are the predicates which are regarded as ***library predicates***, and it is a call on one of them which must cause the library file to be loaded.

Like most symbolic languages, ALS Prolog utilizes a ***name table*** which is a hash table recording the association between names of predicates and the internal addresses at which their executable code is stored. Quite simply, the ALS library mechanism replaces the normal name table entry for the library predicates by a special 'stub' name table entry which accomplishes three things:

- it indicates that the predicate in question is a library predicate;
- it indicates the file in which the library predicate resides;
- it issues an internal ALS Prolog interrupt which is regarded as a ***library interrupt***.

In essence, execution is interrupted before execution of the called predicate, say p, has actually commenced. During handling of the interrupt, the indicated file is loaded (really, reconsulted, which is important), and the interrupt is released, resuming normal execution at the call to p. However, since the library file reconsulted during the interrupt contains a definition of p, the special name table entry for p has been replaced by a normal name table entry p, so that execution proceeds as if the code for p had always been loaded. Note that there is no interpretive overhead for this mechanism. The sole cost is born by the predicates which are stored as library predicates. And the overhead for the library predicates is not measurably greater that their own portion of the loading time at program initialiation, were they to be loaded with the rest of the the system.

The primitive mechanisms which implement this approach to libraries are to be found in the builtins file *blt_sys.pro.* The acutal loading mechanism is defined by `load_lib/2`. The related predicate `force_libload_all/2` can be used to force the loading a list of library files. This can be useful during construction of a stand-alone package. The low level mechanism for installing a library-type name table entry is `libhide/3.` The ALS Prolog system uses the file blt_lib.pro to record information about files which are to be treated as library files. This allows great flexibility, and in particular allows users and developers to add their own packages as library files. A tool for managing this process is described in the ***ALS Development Tools Guide***.

The collection of library predicates is steadily developing. The library includes such facilities as the macro processing tools and the structure definition/abstracton tools. These are described in their own sections of this manual or the ALS Tools Guide. The survey below lists the remaining groups which have been installed as of the date of writing of this chapter.

12.2 Lists: Algebraic List Predicates (listutl1.pro)

append/2
append(ListOfLists, Result)
append(+, -)
-- *appends a list of lists together*

If ListOfLists if a list, each of whose elements is a list, Result is obtained by appending the members of ListOfLists together in order.

intersect/2
intersect(L,IntsectL)
intersect(+,-)
    -- *returns the intersection of a list of lists*

If L is a list of lists, returns the intersection IntsectL of all the list appearing on L.

intersect/3
intersect(A,B,AintB)
intersect(+,+,-)
    -- *returns the intersection of two lists*

If A and B are lists, returns the intersection AintB of A and B, which is the collection of all items common to both lists.

list_diff/3
list_diff(A, B, A_NotB)
list_diff(+, +, +)
    -- *returns the ordered difference of two lists*

If A and B are lists, returns the difference A-B consisting of all items on A, but not on B.

list_diffs/4
list_diffs(A,B,A_NotB,B_NotA)
list_diffs(+,+,-,-)
    -- *returns both ordered differences of two lists*

If A and B are lists, returns both the difference A-B together with the difference B-A.

sorted_merge/2
sorted_merge(ListOfLists, Union)
sorted_merge(+, -)
    -- *returns the sorted union of a list of lists*

If ListOfLists is a list of lists, Union is the sorted merge (non-repetitive union) of the members of ListsOfLists.

sorted_merge/3
sorted_merge(List1, List2, Union)
sorted_merge(+, +, -)

-- *returns the sorted union of two lists*

If List1 and List2 are lists of items, Union is the sorted merge (non-repetitive union) of List1 and List2.

symmetric_diff/3
symmetric_diff(A,B,A_symd_B)
symmetric_diff(+,+,-)

-- *returns the symmetric difference of two lists*

If A and B are lists, returns the symmetric difference of A and B, which is the union of A-B and B-A.

union/3
union(A,B, AuB)
union(+,+, -)

-- *returns the ordered union of two lists*

If A and B are lists, returns the ordered union of A and B, consisting of all items occurring on either A or B, with all occurrences of items from A occurring before any items from B-A; equivalent to:

```
append(A,B-A,AuB);
```

If both lists have the property that each element occurs no more than once, then the union also has this property.

12.3 Lists: Positional List Predicates (listutl2.pro)

at_most_n/3
at_most_n(List, N, Head)
at_most_n(+, +, -)

-- *returns initial segment of list of length =< N*

If List is a list and N is a non-negative integer, Head is the longest initial segment of List with length =< N.

change_nth/3
change_nth(N, List, NewItem)
change_nth(+, +, +)

-- *destructively changes the Nth element of a list*

If N is a non-negative integer, List isa list, and NewItem is any non-var object, destructively changes the Nth element of List to become NewItem; this predicate numbers the list beginning with 0.

deleteNth/3
deleteNth(N, List, Remainder)
deleteNth(+, +, -)

-- *deletes the Nth element of a list*

If N is a non-negative integer and List is a list, then Remainder is the result of deleting the Nth element of List; this predicate numbers the list beginning with 1.

get_list_tail/3
get_list_tail(List, Item, Tail)
get_list_tail(+, +, -)

-- *returns the tail of a list determined by an element*

If List is a list and Item is any object, Tail is the portion of List extending from the leftmost occurrence of Item in List to the end of List; fails if Item does not belong to List.

list_delete/3
list_delete(List, Item, ResultList)
list_delete(+, +, -)

-- *deletes all occurrences of an item from a list*

If List is a list, and Item is any object, ResultList is obtained by deleting all occurrences of Item from List.

nth/3
nth(N, List, X)
nth(+, +, -)

-- *returns the nth element of a list*

If List is a list and N is a non-negative integer, then X is the nth element of List.

nth_tail/4
nth_tail(N, List, Head, Tail)
nth_tail(+, +, -, -)
-- *returns the nth head and tail of a list*

If List is a list and N is a non-negative integer, then Head is the portion of List up to but not including the Nth element, and tail is the portion of List from the Nth element to the end.

position/3
position(List, Item, N)
position(+, +, -)
-- *returns the position number of an item in a list*

If List is a list and Item occurs in List, N is the number of the leftmost occurrence of Item in List; fails if Item does not occur in List.

position/4
position(List, Item, M, N)
position(+, +, +, -)
-- *returns the position number of an item in a list*

If List is a list and Item occurs in List, N-M is the number of the leftmost occurrence of Item in List; fails if Item does not occur in List.

sublist/4
sublist(List,Start,Length,Result)
sublist(+,+,+,-)
-- *extracts a sublist from a list*

If List is an arbitrary list, Result is the sublist of length Length beginning at position Start in List.

subst_nth/4
subst_nth(N, List, NewItem, NewList)
subst_nth(+, +, +, -)
-- *non-destructively changes the Nth element of a list*

If N is a non-negative integer, List is list, and NewItem is any non-var object, NewList is the result of non-destrctively changing the Nth element of List to become |NewItem; this predicate numbers the list beginning with 0.

12.4 Lists: Miscellaneous List Predicates (listutl3.pro)

check_default/4
check_default(PList, Tag, Default, Value)
check_default(+, +, +, -)

-- *looks up an equation on a list, with default*

PList is a list of equations of the form tag = value check_default(PList, Tag, Default, Value) succeeds if Tag=Value belongs to PList; otherwise, if Default=Value

encode_list/3
encode_list(Items, Codes, CodedItems)
encode_list(+, +, -)

-- *combines a list of items with a list of codes*

If Items and Codes are lists of arbitrary terms of the same length, then CodedItems is the list of corresponding pairs of the form Code-Item

flatten/2
flatten(List, FlatList)
flatten(+, -)

-- *flattens a nested list*

If List is a list, some of whose elements may be nested lists, FlatList is the flattened version of List obtained by traversing the tree defining List in depth-first, left-to-right order; compound structures other than list structures are not flattened.

merge_plists/3
merge_plists(LeftEqnList, RightEqnList, MergedLists)
merge_plists(+, +, -).

-- *(recursively) merges two tagged equation lists*

LeftEqnList and RightEqnList are lists of equations of the form tag = value MergedLists consists of all equations occurring in either LeftEqnList or RightEqn-

List, where if the equations Tag=LVal and Tag = RVal occur in LeftEqnList and RightEqnList, respectively, MergedLists will contain the equation Tag = MVal where: a)If both of LVal and RVal are lists, then MVal is obtained by recursively calling merge_plists(LVal, RVal, MVal); b)Otherwise, MVal is LVal.

n_of/3
n_of(N, Item, Result)
n_of(+, +, -)

-- *creates a list of N copies of an item*

Result is a list of length N all of whose elements are the entity Item.

nobind_member/2
nobind_member(X, List)
nobind_member(+, +)

-- *tests list membership without binding any variables*

nobind_member(X, List) holds and only if X is a member of List; if the test is successful, no variables in either input are bound.

number_list/2
number_list(List, NumberedList)
number_list(+, -)

-- *creates a numbered list from a source list*

If List is a list, NumberedList is a list of terms of the form N-Item, where the Item components are simply the elements of List in order, and N is a integer, sequentially numbered the elements of List.

number_list/3
number_list(Items, StartNum, NumberedItems)
number_list(+, +, -)

-- *numbers the elements of a list*

If Items is a list, and StartNum is an integer, NumberedItems is the list obtained by replacing each element X in Items by N-X, where N is the number of the position of X in Items.

output_prolog_list/1

output_prolog_list(List)
output_prolog_list(+)

-- *outputs items on a list, one to a line*

Outputs (to the current output stream) each item on List, one item to a line, followed by a period.

remove_tagged/3
remove_tagged(EqnList, TagsToRemove, ReducedEqnList)
remove_tagged(+, +, -).

-- *removes tagged equations from a list*

EqnList is a list of equations of the form tag = value and TagsToRemove is a list of atoms which are candidates to occur as tags in these equations. ReducedEqnList is the result of removing all equations beginning with a tag from TagsToRemove from the list EqnList.

struct_lookup_subst/4
struct_lookup_subst(OrderedTags, DefArgs, ArgSpecs, ArgsList)
struct_lookup_subst(+, +, +, -)

-- *performs substs for structs package constructors*

OrderedTags and DefArgs are lists of the same length; so will be ArgsList. ArgSpecs is a list of equations of the form Tag = Value where each of the Tags in such an equation must be on the list OrderedTags (but not all OrderedTags elements must occur on ArgSpecs); in fact, ArgSpecs can be empty. The elements X of ArgsList are defined as follows: if X corresponds to Tag on OrderedTags, then: if Tag=Val occurs on ArgSpecs, X is Val; otherwise, X is the element of DefArgs corresponding to Tag.

12.5 Tree Predicates (avl.pro)

avl_create/1
avl_create(Tree)
avl_create(-)

-- *create an empty tree.*

avl_create(Tree) creates an empty avl tree which is unified with Tree.

avl_inorder/2
avl_inorder(Tree,List)
avl_inorder(+,-)

-- *returns list of keys in an avl tree in in-order traversal*

If Tree is an avl tree, List is the ordered list of keys encountered during an inorder traversal of Tree.

avl_inorder_wdata/2
avl_inorder_wdata(Tree,List)
avl_inorder_wdata(+,-)

-- *returns list of keys and data in an avl tree in in-order traversal*

If Tree is an avl tree, List is the ordered list of terms of the form Key-Data encountered during an inorder traversal of Tree.

avl_insert/4
avl_insert(Key,Data,InTree,OutTree)
avl_insert(+,+,+,-)

-- *inserts a node in an avl tree*

Inserts Key and Data into the avl-tree passed in through InTree giving a tree which is unified with OutTree. If the Key is already present in the tree, then Data replaces the old data value in the tree.

avl_search/3
avl_search(Key,Data,Tree)
avl_search(+,?,+)

-- *searches for a key in an avl tree*

Tree is searched in for Key. Data is unified with the corresponding data value if found. If Key is not found, avl_search will fail.

12.6 Miscellaneous Predicates (commal.pro)

flatten_comma_list/2
flatten_comma_list(SourceList, ResultList)
flatten_comma_list(+, -)

-- *flattens nested comma lists and removes extraneous trues'*

If SourceList is a comma list (i.e., (a,b,c,...)), then ResultList is also a comma list which is the result of removing all extraneous nesting and all extraneous occurrences of true'.'

12.7 I/O Predicates (iolayer.pro)

12.8 Control Predicates (lib_ctl.pro)

bagOf/3
bagOf(Pattern, Goal, Result)
bagOf(+, +, -)

-- *Like bagof/3, but succeeds with empty list on no solutions*

bagOf/3 is just like bagof/3, except that if Goal has no solutions, bagof/3 fails, whereas bagOf/3 will succeed, binding Result to [].

max/3
max(A,B,M)
max(+,+,-)

-- *computes the maximum of two numbers*

If A and B are ground expressions which evaluate to numbers under is/2, the M will be their maximum value.

min/3
min(A,B,M)
min(+,+,-)

-- *computes the minimum of two numbers*

If A and B are ground expressions which evaluate to numbers under is/2, the M will be their minimum value.

setOf/3
setOf(Pattern, Goal, Result)
setOf(+, +, -)

-- *Like setof/3, but succeeds with empty list on no solutions* setOf/3 is just like setof/3, except that if Goal has no solutions, setof/3 fails, whereas setOf/3 will succeed, binding Result to [].

12.9 Prolog Database Predicates (misc_db.pro)

assert_all/1
assert_all(ClauseList)
assert_all(+)
-- *asserts each clause on ClauseList in the current module*

If ClauseList is a list of clauses, asserts each of these clauses in the current module.

assert_all0/2
assert_all0(ClauseList,Module)
assert_all0(+,+)
-- *asserts each clause on ClauseList in module Module*

If ClauseList is a list of clauses, asserts each of these clauses in module Module.

assert_all_refs/3
assert_all_refs(Module,ClauseList, RefsList)
assert_all_refs(+,+, -)
-- *asserts a list of clauses, in a module, returning a list of refs*

If Module is a module, and if ClauseList is a list of terms which can be asserted as clauses, then assert_all_refs/3 causes each term on ClauseList to be asserted in Module, and returns RefsList as the list of corresponding references to these asserted clauses.

erase_all/1
erase_all(RefsList)
erase_all(+)
-- *erases each clauses referenced by a list of clause references*

If RefsList is a list of clauses references, causes each clause corresponding to one of these references to be erased.

12.10I/O Predicates (misc_io.pro)

colwrite/4
colwrite(AtomList,ColPosList,CurPos,Stream)
colwrite(+,+,+,+)

-- *writes atoms in AtomList at column positions in ColPosList*

If AtomList is a list of atoms (symbols or UIAs), and if ColPosList is a list of monotonically increasing positive integers of the same length as AtomList, and if CurPos is a positive integer (normally 1), and Stream is valid output stream (in text mode), this predicate outputs the items on AtomList to Stream, starting each element of AtomList at the postition indicated by the corresponding element of ColPosList. If a given item would overflow its column, it is truncated. Normally, CurPos = 1 and ColPosList begins with an integer greater than 1, so that the first column position is implicit.

copyFiles/2
copyFiles(SourceFilesList, TargetSubDirPath)
copyFiles(+, +)

-- *copies files to a directory*

If SourceFilesList is a list of file names, and TargetSubDirPath is either an atom or an internal form naming a directory, copies all of the indicated files to files with the same names in TargetSubDirPath.

gen_file_header/[3,4]
gen_file_header(OutStream,SourceFile,TargetFile)
gen_file_header(OutStream,SourceFile,TargetFile,ExtraCall)
gen_file_header(+,+,+)
gen_file_header(+,+,+,+)

-- *output a header suitable for a generated file*

OutStream is a write stream, normally to file TargetFile. Given SourceFile = fooin, and TargetFile = fooout, gen_file_header/3 outputs a header of the following format on OutStream:

```
   /*================================================
             fooout
             --Generated from: fooin
             Date: 94/4/17   Time: 9:52:53
    *================================================*/
```

In gen_file_header/4, the argument ExtraCall is called just before the printing of the lower comment line. Thus, if ExtraCall were

```
    printf(OutStream,'         -- by zipper_foo\n',[]),
```

the output would look like:

```
   /*================================================
             fooout
             --Generated from: fooin
             Date: 94/4/17   Time: 9:52:53
             -- by zipper_foo
   *=================================================*/
```

putc_n_of/3
putc_n_of(Num, Char, Stream)
putc_n_of(+,+,+)
-- *output Num copies of the char with code Char to Stream*

Num should be a positive integer, and Char should be the code of a valid character; Stream should be an output stream in text mode. Outputs, to Stream, Num copies of the characater with code Char.

read_terms/1
read_terms(Term_List)
read_terms(-)
-- *reads a list of Prolog terms from the default input stream*

Reads a list (Term_List) of all terms which can be read from the default input stream

read_terms/2
read_terms(Stream,Term_List)

read_terms(+,-)

-- *reads a list of Prolog terms from stream Stream*

Reads a list (Term_List) of all terms which can be read from the stream Stream.

read_lines/[1,2]
read_lines(Stream,Line_List)
read_lines(+,-)

Reads a list (Line_List) of all lines which can be read from the stream Stream.

12.11I/O Predicates (simplio.pro)

12.12String Manipulation Predicates (strings.pro)

asplit/4
asplit(Atom,Splitter,LeftPart,RightPart)
asplit(+,+,-,-)

-- *divides an atom as determined by a character*

If Atom is any atom or UIA, and if Splitter is the character code of of a character, then, if the character with code Splitter occurs in Atom, LeftPart is an atom consisting of that part of Atom from the left up to and including the leftmost occurrence of the character with code Splitter, and RightPart is the atom consisting of that part of Atom extending from immediately after the end of LeftPart to the end of Atom.

asplit0/4
asplit0(AtomCs,Splitter,LeftPartCs,RightPartCs)
asplit0(+,+,-,-)

-- *divides a list of character codes as determined by a character code*

If AtomCs is a list of character codes, and if Splitter is the character code of of a character, then, if the character with code Splitter occurs in AtomCs, LeftPart is the list consisting of that part of AtomCs from the left up to and including the leftmost occurrence of Splitter, and RightPart is the atom consisting of that part of AtomCs extending from immediately after the end of LeftPart to the end of AtomCs.

head/4

head(Atom,Splitter,Head,Tail)
head(+,+,-,-)

-- *splits an list into segments determined by a character code*

If Atom is a list of character codes, splits Atom into Head and tail the way asplit would, using the first occurrence of Splitter; on successive retrys, usings the succeeding occurrences of Spliter as the split point.

head0/4
head0(List,Splitter,Head,Tail)
head0(+,+,-,-)

-- *splits a character code list into segments determined by a code*

If List is a list of character codes, splits List into Head and tail the way asplit0 would, using the first occurrence of Splitter; on successive retrys, usings the succeeding occurrences of Spliter as the split point.

12.13Miscellaneous Predicates (xlists.pro)

xlist_append/2
xlist_append(ListOfXLists, Result)
xlist_append(+, -)

-- *appends together an ordinary list of extensible lists*

If ListOfXLists is an ordinary list of xtensible lists, then Result is obtained by serially xappending each of the xlists occurring on ListOfXLists.

xlist_append/3
xlist_append(Left, Right, Result)
xlist_append(+, +, -)

-- *appends two extensible lists*

xlist_head/2
xlist_head(XList, Result)
xlist_head(+, -)

-- *returns the head of an extensible list*

xlist_init/1

xlist_init(Result)
xlist_init(-)

-- *creates a freshly initialized extensible list*

xtensible lists are carriedaround in the form (Head, Tail) The actual list may be a standard extensible list [a,b,c,d | T] or may be a comma separated list: (a, (b, (c, (d, T)))) It is up to the routines using these tools to bind the tail variable to the correct structure, or to createthe correct type of structure for xappending to another such xlist.

xlist_make/3
xlist_make(Head, Tail, Result)
xlist_make(+, +, -)

-- *Makes an extenstible list data structure from Head,Tail*

xlist_tail/2
xlist_tail(XList, Result)
xlist_tail(+, -)

-- *returns the tail of an extensible list*

xlist_unit_c/2
xlist_unit_c(First, Result)
xlist_unit_c(+, -)

-- *creates a freshly initialized comma-type xlist with first elt*

xlist_unit_l/2
xlist_unit_l(First, Result)
xlist_unit_l(+, -)

-- *creates a freshly initialized ordinary xlist with first elt*

ALS Prolog Development Tools

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Integrated Development Environment

13 ALS Integrated Development Environment

The ALS Integrated Development Environment (IDE) provides a GUI-based developer-friendly setting for developing ALS Prolog programs.   Start the ALS IDE either by clicking on its icon (Windows or Macintosh, or CDE versions of Unix), or

by issuing

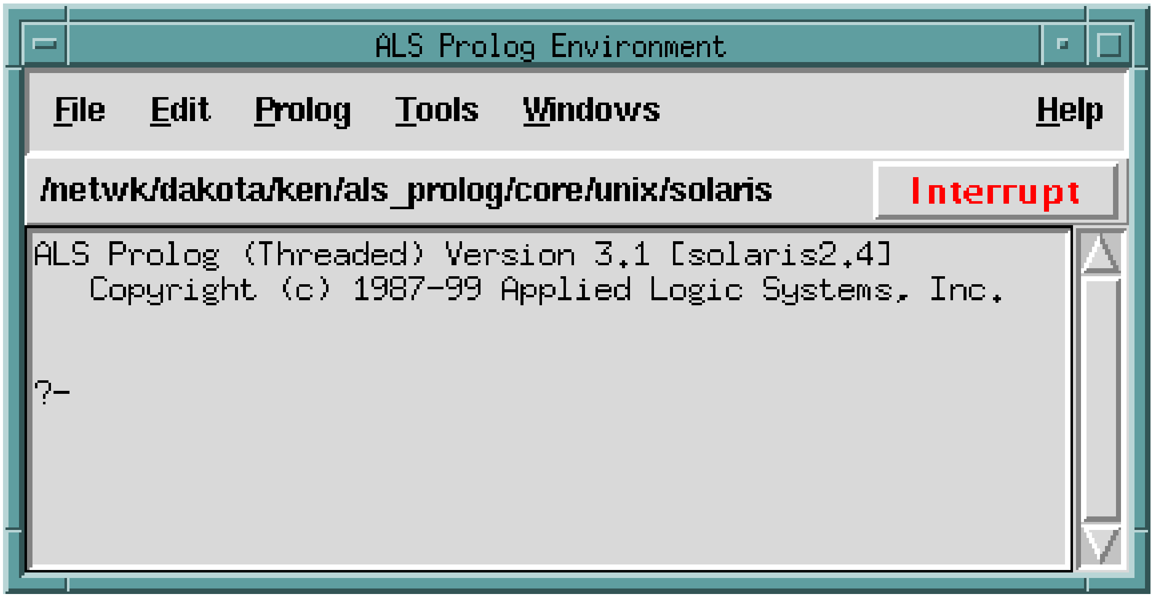
```
alsdev
```

in an appropriate command window. The IDE displays an initial spash screen

while it loads, and then replaces the spash screen with the main listener window.

13.1 Main Environment Window

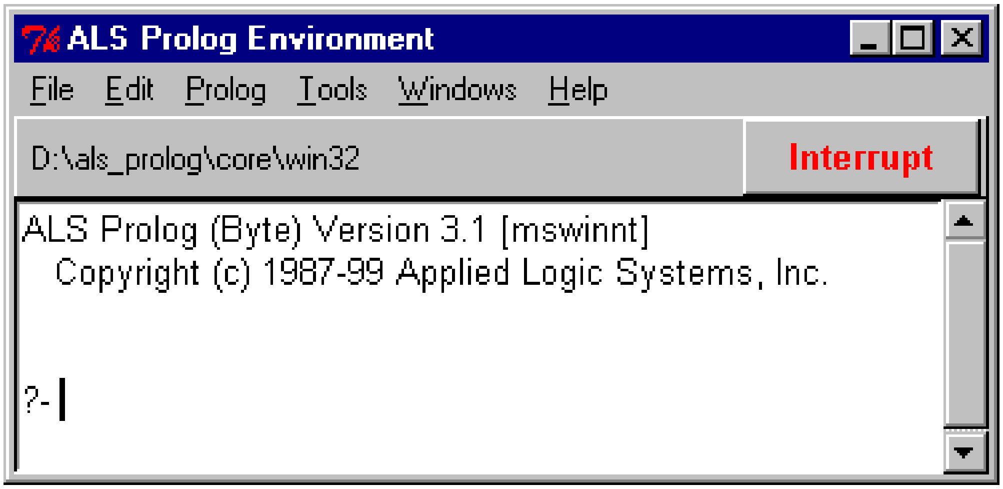
The details of the appearance of the ALS IDE windows will vary across the platforms. Here is what reduced-size versions of the main window look like on Unix::



```
ALS Prolog (Threaded) Version 3.1 [solaris2.4]
   Copyright (c) 1987-99 Applied Logic Systems, Inc.


?-
```

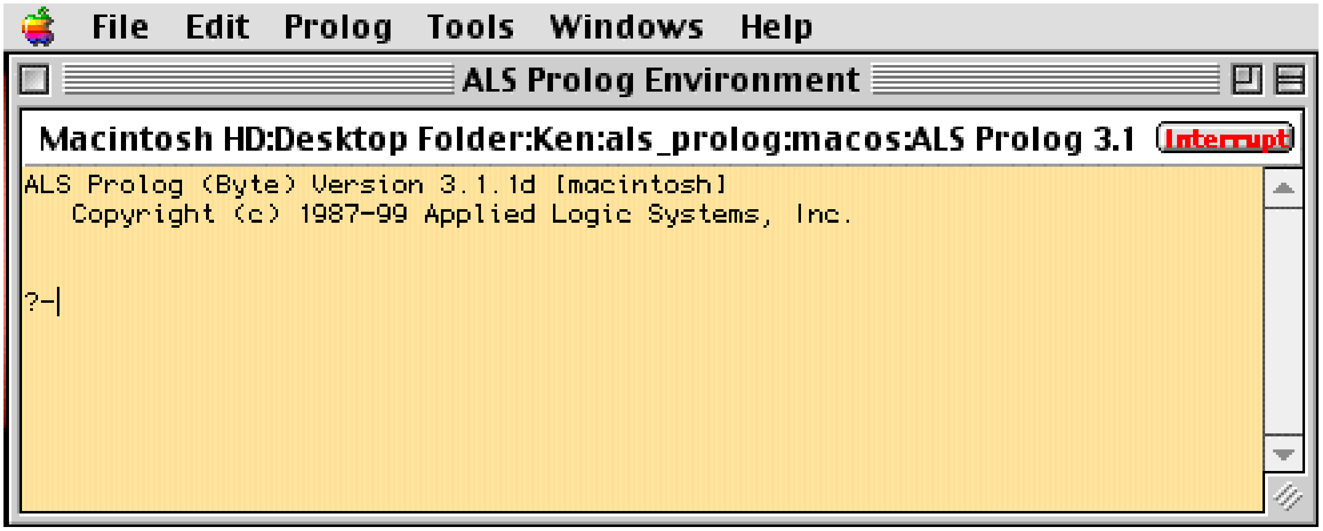
and on Windows:



```
ALS Prolog (Byte) Version 3.1 [mswinnt]
  Copyright (c) 1987-99 Applied Logic Systems, Inc.


?-
```

and on Macintosh:


File
Edit
Prolog
Tools
Windows
Help
ALS Prolog Environment
Macintosh HD:Desktop Folder:Ken:als_prolog:macos:ALS Prolog 3.1
Interrupt

```
ALS Prolog (Byte) Version 3.1.1d [macintosh]
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?-
```
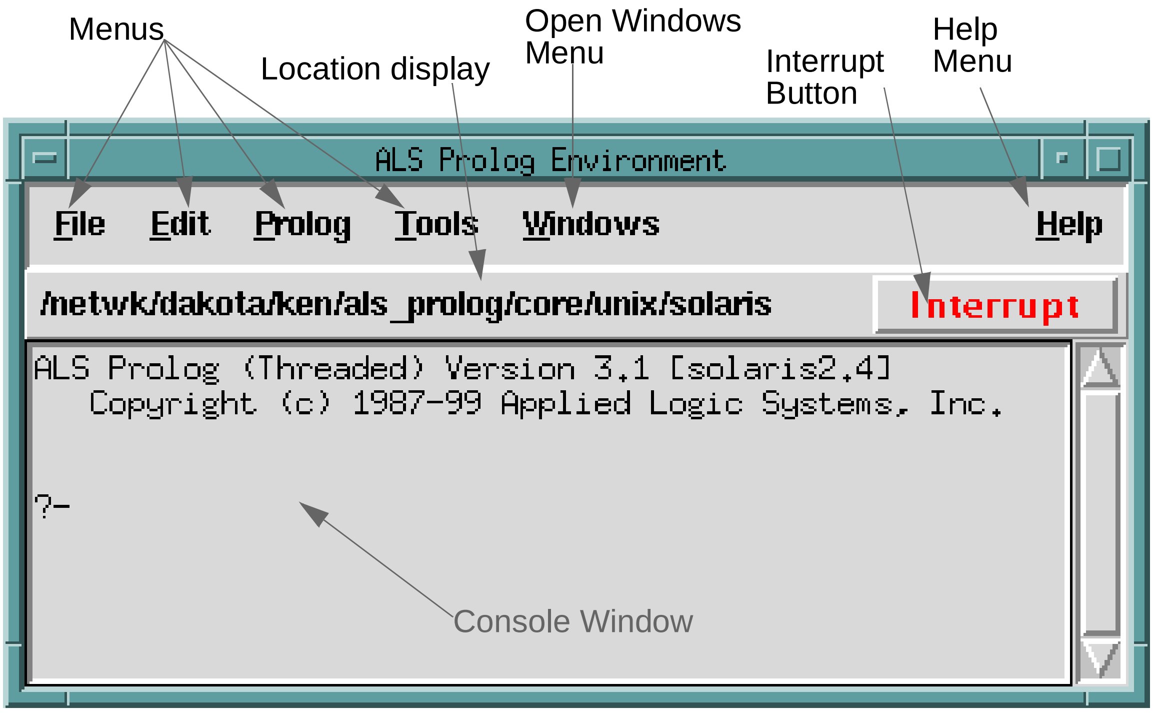

Throughout the rest of this section and others dealing with aspects of the ALS IDE, we will not attempt to show all three versions of each and every window or display. Since they are all quite similar, we will typically show just one, varying the display among Macintosh, Windows, and Unix (Motif).

The parts of the main window are:



/netwk/dakota/ken/als_prolog/core/unix/solaris

```
ALS Prolog (Threaded) Version 3.1 [solaris2.4]
   Copyright (c) 1987-99 Applied Logic Systems, Inc.


?-
```

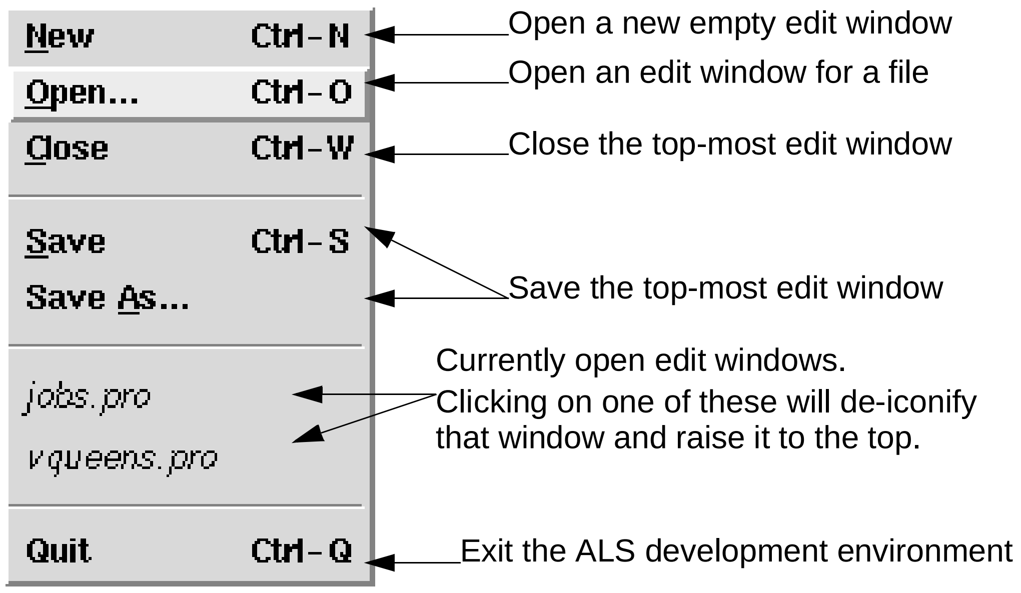
The Menus will be described below. The Location Display shows the current directory or folder. The Interrupt Button is used to interrupt prolog computations, while the Help Menu will in the future provide access to the help system (which can also be run separately). The Console Window is used to submit goals to the system and to view results.

13.2 Menus

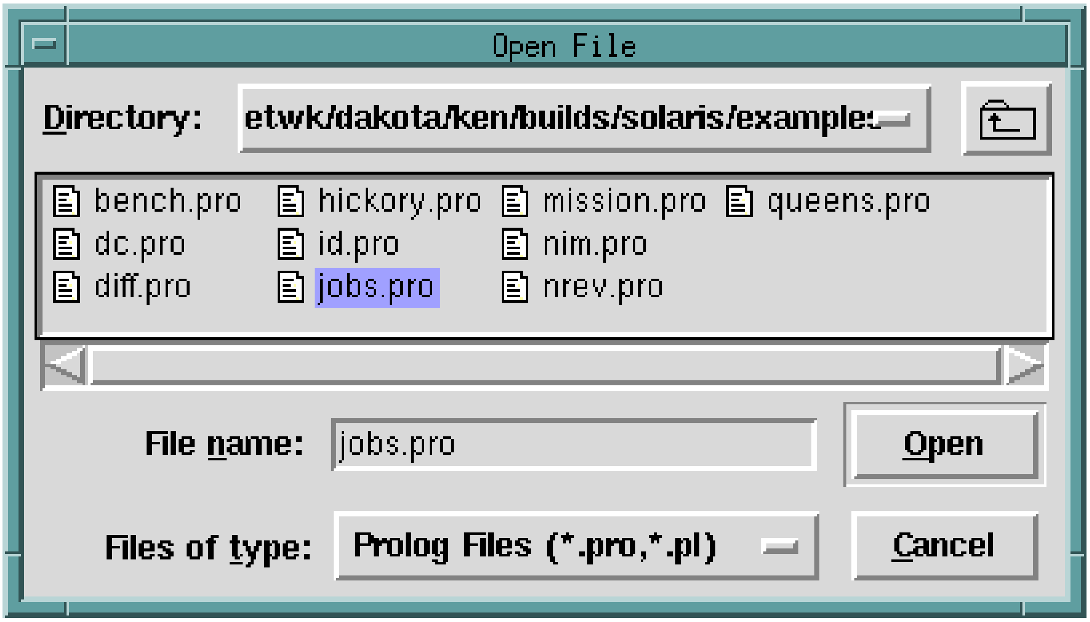
The options indicated by the accellerator keys on the menus apply when the focus (insertion cursor) is located over the main listener window, over the debugger window, or over any editor window.[1]

1. The ALS IDE is undergoing steady development. Some of the planned features are not yet implemented, and so menu items corresponding to them will show as grayed-out.

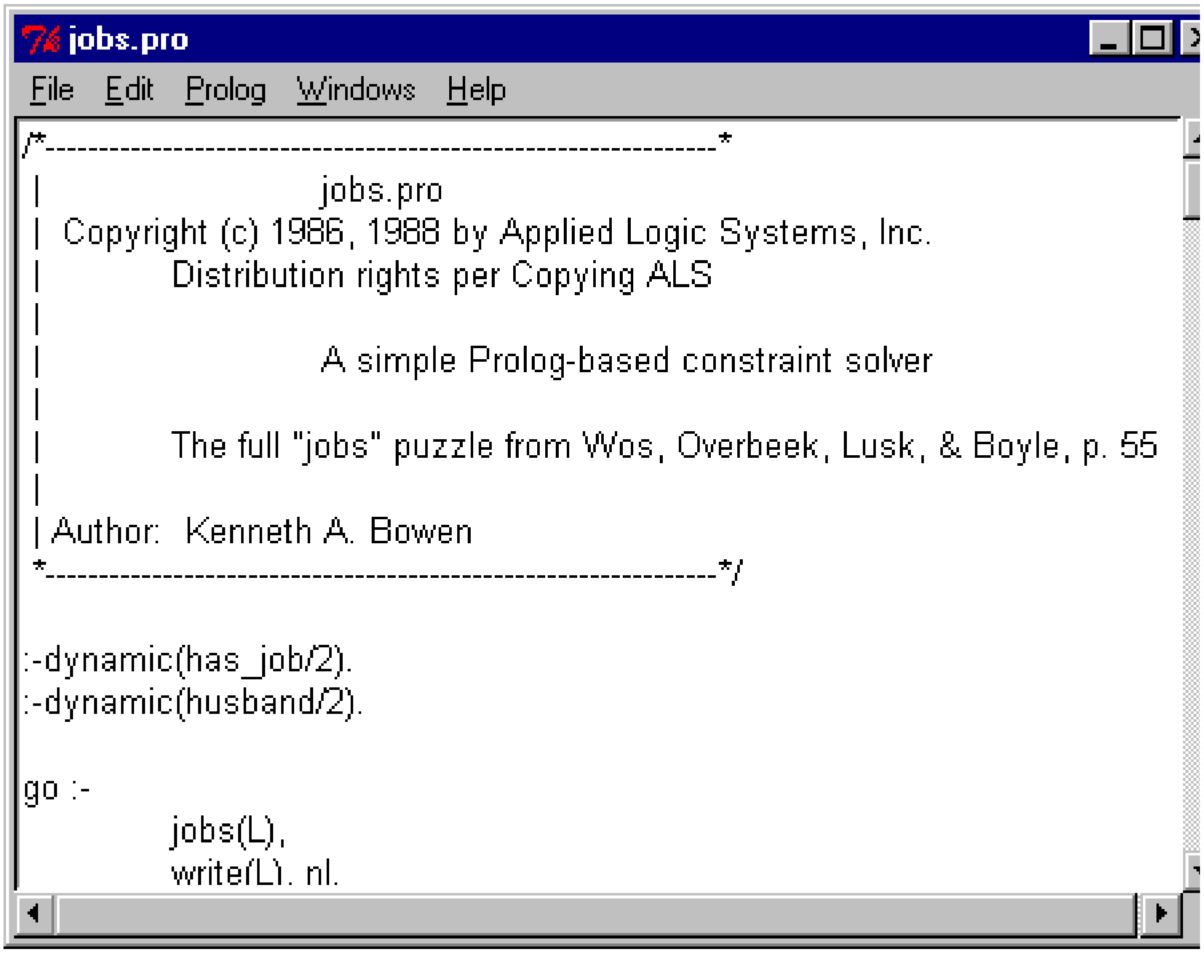
13.2.1 File Menu


New Ctrl-N
Open... Ctrl-O
Close Ctrl-W
Save Ctrl-S
Save As...
jobs.pro
vqueens.pro
Quit Ctrl-Q
Open a new empty edit window
Open an edit window for a file
Close the top-most edit window
Save the top-most edit window
Currently open edit windows.
Clicking on one of these will de-iconify that window and raise it to the top.
Exit the ALS development environment

New, Open, Close, Save, and SaveAs apply to editor windows, and have their usual meanings. New opens a fresh editor window with no content, while Open allows one to select an existing file for editing. The open file dialog looks like this : :



Selecting a file to open produces a window looking like the following:

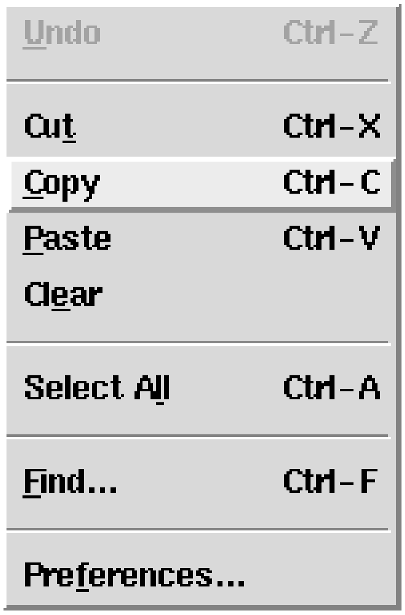


```
/*-------------------------------------------------------------*
 |                          jobs.pro
 |  Copyright (c) 1986, 1988 by Applied Logic Systems, Inc.
 |          Distribution rights per Copying ALS
 |
 |                          A simple Prolog-based constraint solver
 |
 |          The full "jobs" puzzle from Wos, Overbeek, Lusk, & Boyle, p. 55
 |
 | Author:  Kenneth A. Bowen
 *-------------------------------------------------------------*/

:-dynamic(has_job/2).
:-dynamic(husband/2).

go :-
          jobs(L),
          write(L), nl.
```

The Close, Save and SaveAs entries from the file menu apply to the edit window having the current focus.

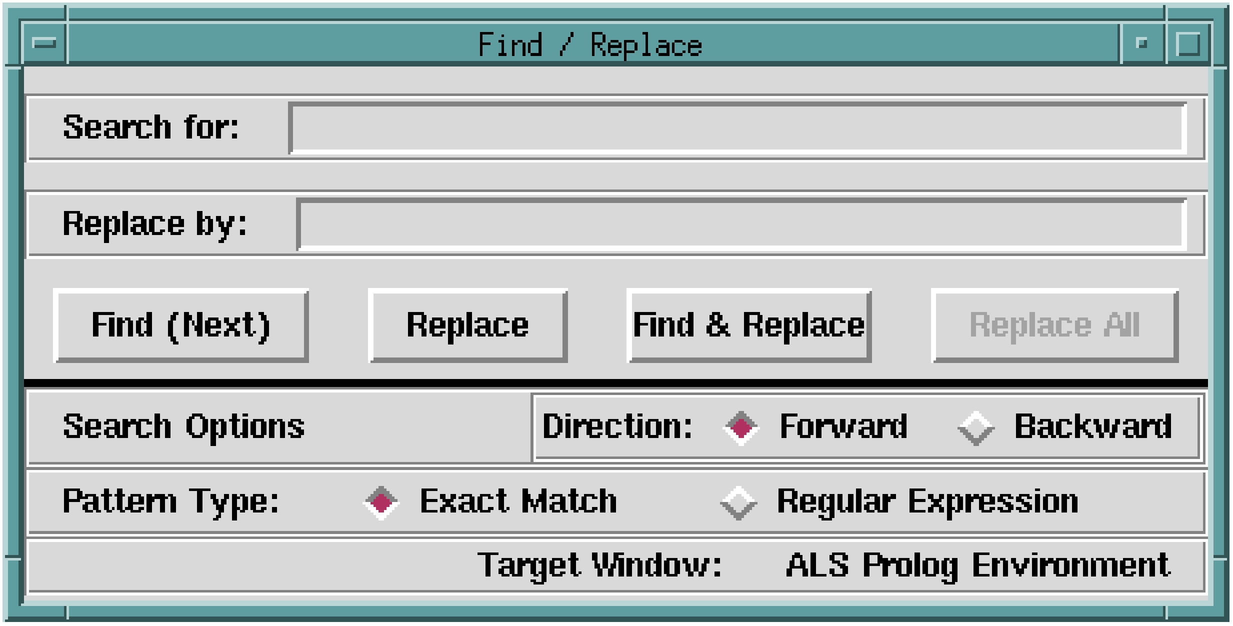
Quit allows you to exit from the ALS Prolog IDE.

13.2.2 Edit Menu



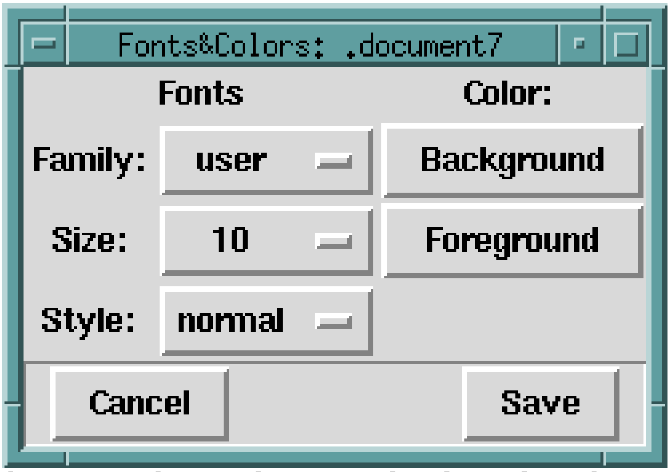
Cut, Copy, Paste, and Clear apply as usual to the current selection in an editor window. Copy also applies in the main llistener window. Paste in the main window always pastes into the last line of the window. Select All only applies to editor windows.

The Find button brings up the following dialog:

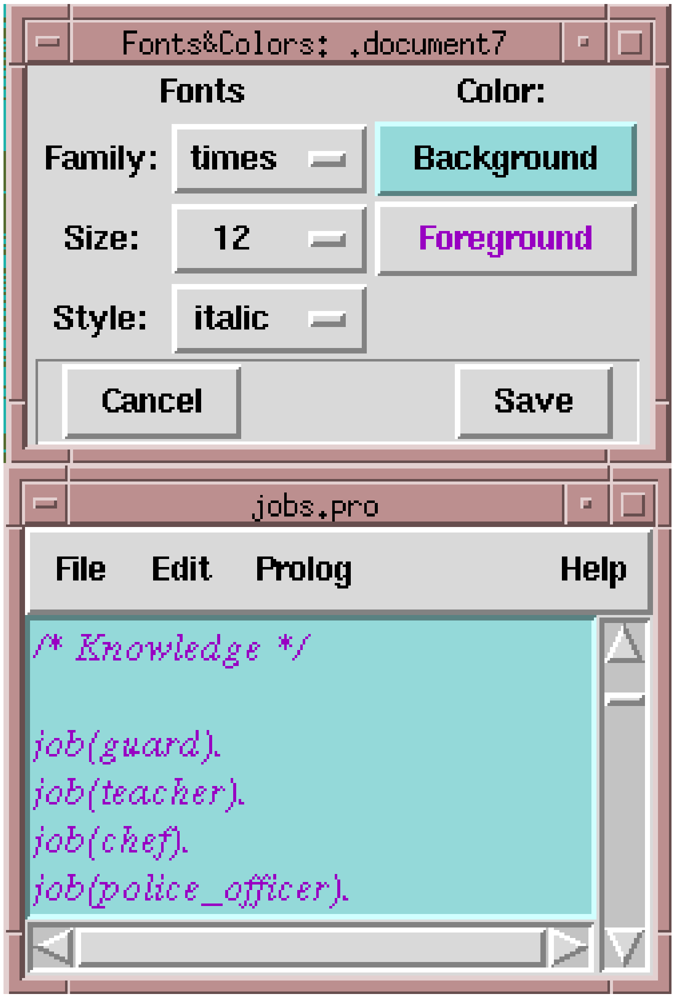

Find / Replace
Search for:
Replace by:
Find (Next)
Replace
Find & Replace
Replace All
Search Options
Direction: [✓ Forward] Backward
Pattern Type: [✓ Exact Match] Regular Expression
Target Window: ALS Prolog Environment

This dialog allows one to search in whatever window is top-most, and to carry out replacements in editor windows. If the text which has been typed into the Search for: box is located, the window containing it is adjusted so that the sought-for text is approximately centered vertically, and the text is highlighted.

The Preferences choice produces the following popup window: Selections made



using any of the buttons on this window immediately apply to the window (listener, debugger, or editor window) from which the Preferences button was pressed. For example:



Family: times

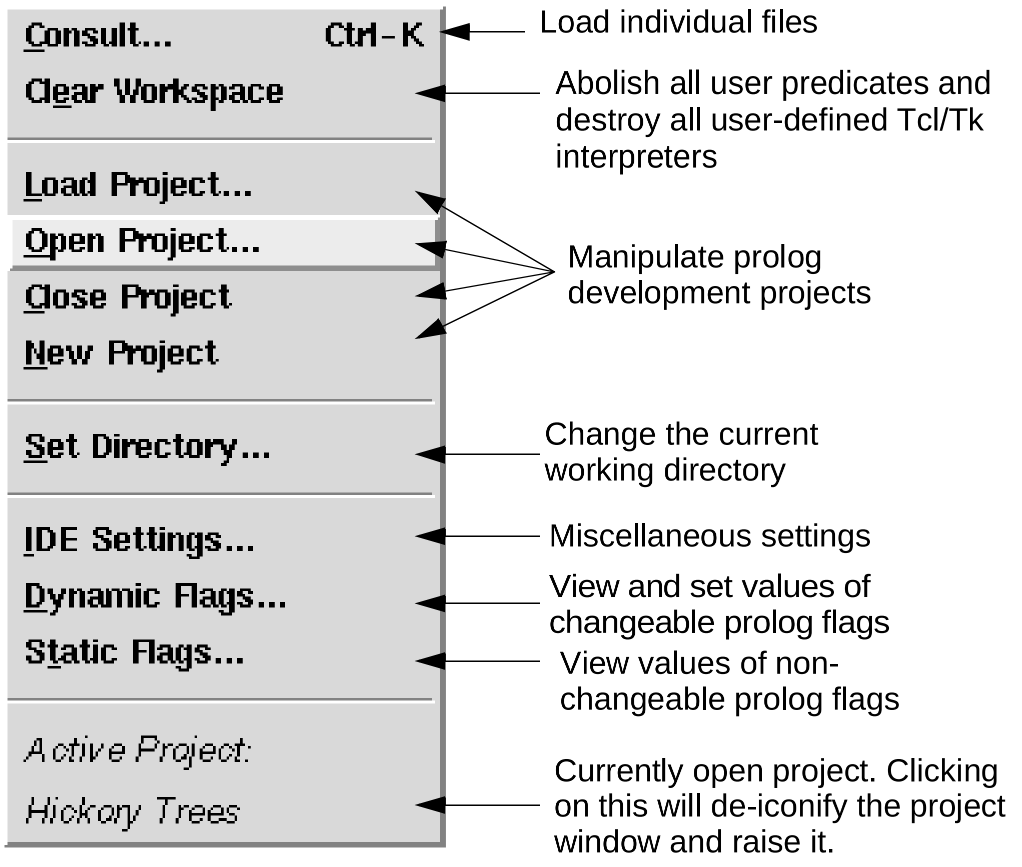
Size: 12

Style: italic

```
/* Knowledge */

job(guard).
job(teacher).
job(chef).
job(police_officer).
```

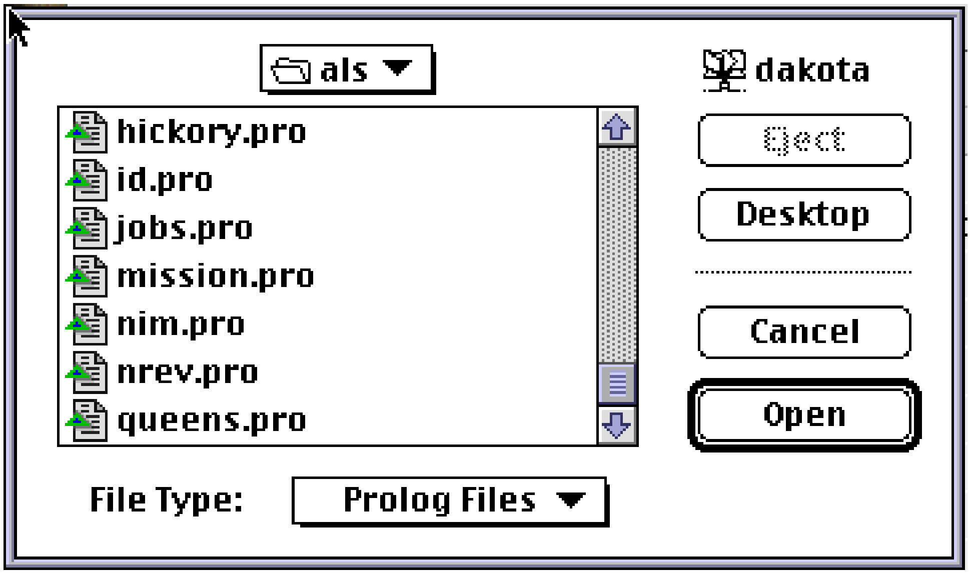
Selecting Cancel simply removes the Fonts & Colors window without undoing any changes. Selecting Save records the selected preferences in the inititialization file (*alsdev.ini*) which is read at start-up time, and also records the selections globally for the current session. Although no existing editor windows are changed, all new editor windows created will use the newly recorded preferences. Preferences for the main listener window and the debugger window are saved separately from the editor window preferences.

13.2.3 Prolog Menu


Consult... Ctrl-K
Clear Workspace
Load Project...
Open Project...
Close Project
New Project
Set Directory...
IDE Settings...
Dynamic Flags...
Static Flags...
Active Project:
Hickory Trees
Load individual files
Abolish all user predicates and destroy all user-defined Tcl/Tk interpreters
Manipulate prolog development projects
Change the current working directory
Miscellaneous settings
View and set values of changeable prolog flags
View values of non-changeable prolog flags
Currently open project. Clicking on this will de-iconify the project window and raise it.

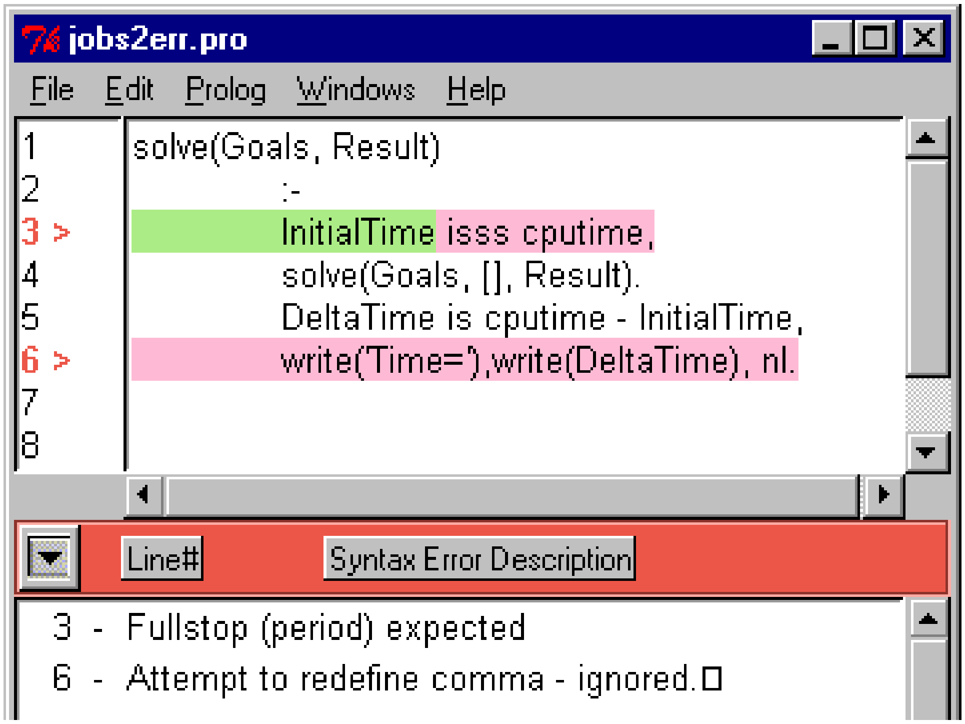
Choosing Consult produces two different behaviors, depending on whether the Prolog menu was pulled down from the main listener or debugger windows, or from an editor window. Using the accelerator key sequence (*Ctrl-K* on Unix and Windows, and *<AppleKey>K* on Macintosh) produces equivalent behaviors in the different settings. If Consult is chosen from the main listener or debugger windows, a file selection dialog appears, and the selected file is (re)consulted into the current

Prolog database:



In contrast, if Consult is selected from an edit window (or the *Ctrl/<apple>-K* accellerator key is hit over that window), the file associated with that window is (re)consulted into the Prolog database; if unsaved changes have been made in the editor window, the file/window is first Saved before consulting.

If a file containing syntax errors is consulted, these errors are collected, an editor window into the file is opened, and the errors are displayed, as indicated below:



```
1   solve(Goals, Result)
2           :-
3 >         InitialTime isss cputime,
4           solve(Goals, [], Result).
5           DeltaTime is cputime - InitialTime,
6 >         write('Time='),write(DeltaTime), nl.
7
8
```

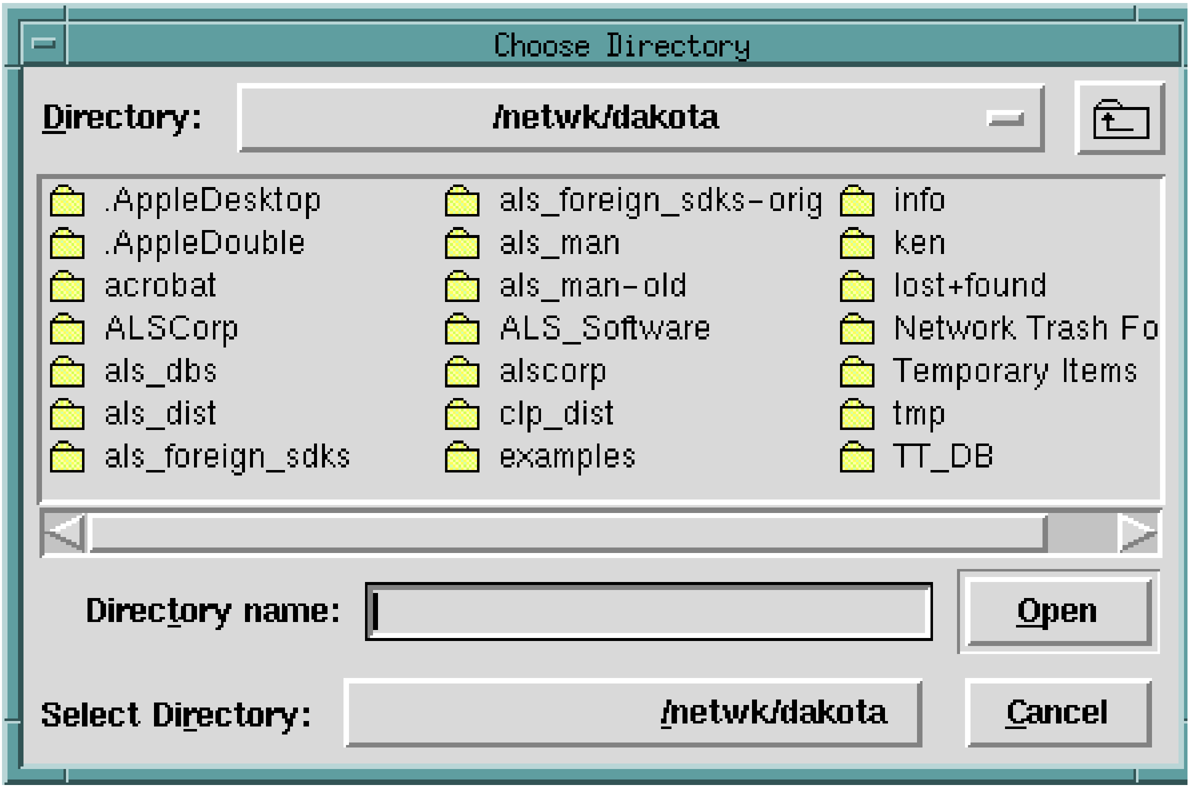
```
3  -  Fullstop (period) expected
6  -  Attempt to redefine comma - ignored.
```

Line numbers are added on the left, and the lines on which errors occur are marked in red. Lines in which an error occurs at a specified point are marked in a combination of red and green, with the change in color indicating the point at which the error occurs. Erroneous lines without such a specific error point, such as attempts to redefine comma, are marked all in red. A scrollable pane is opened below the edit window, and all the errors that occurred are listed in that pane. Double clicking on one the listed errors in the lower pane will cause the upper window to scroll until the corresponding error line appears in the upper pane. The upper pane is an ordinary error window, and the errors can be corrected and the file saved. Choosing Prolog> Consult, or typing ^K will cause the file to be reconsulted, and the error panes to be closed.

Clear Workspace causes all procedures which have been consulted to be abolished, , including clauses which have been dynamically asserted. In addition, future releases, all user-defined Tc/Tkl interpreters will also be destroyed.

The four Project-related buttons as well as the bottom entry on this menu are described in the next section.

Set Directory ... allows you to change the current working directory. Here is the Unix version of this dialog::


Choose Directory

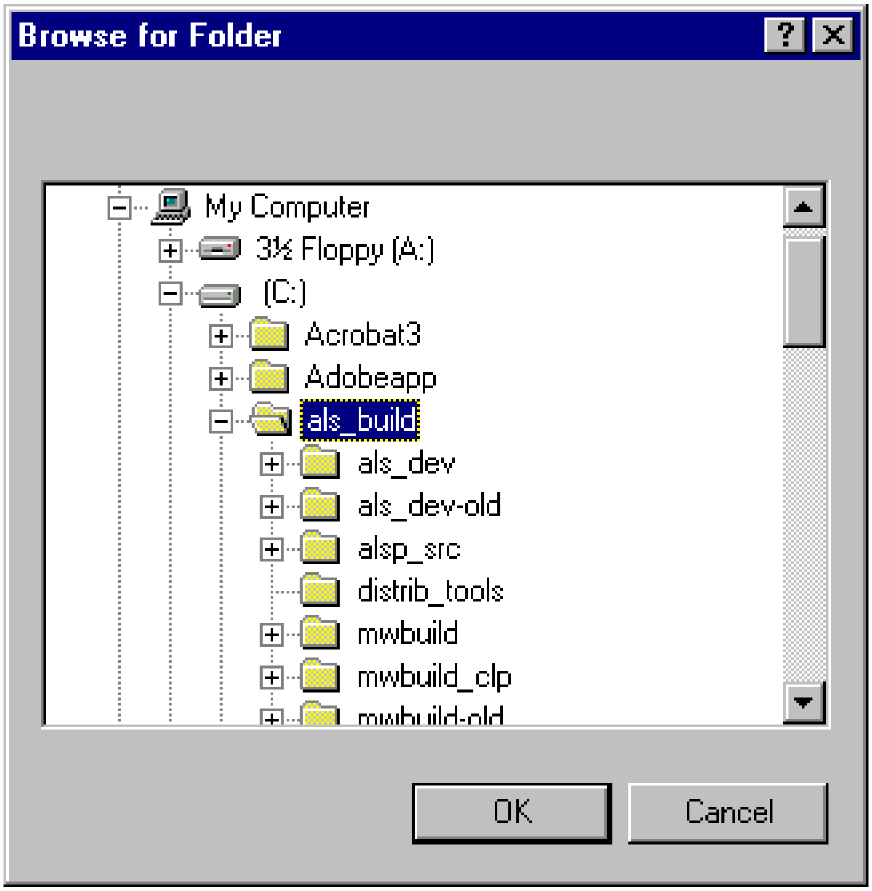
Directory: /netwk/dakota

.AppleDesktop	als_foreign_sdks-orig	info
.AppleDouble	als_man	ken
acrobat	als_man-old	lost+found
ALSCorp	ALS_Software	Network Trash Fo
als_dbs	alscorp	Temporary Items
als_dist	clp_dist	tmp
als_foreign_sdks	examples	TT_DB

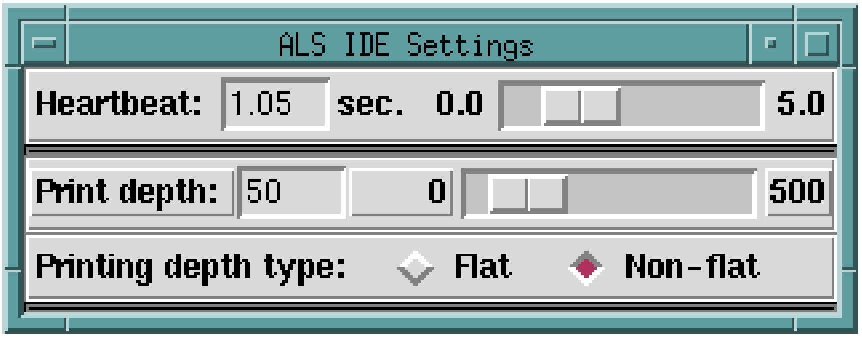
Directory name:

Select Directory: /netwk/dakota

And here is the Windows version:



Selecting IDE Settings raises the following dialog:


ALS IDE Settings

Heartbeat: 1.05 sec. 0.0 5.0

Print depth: 50 0 500

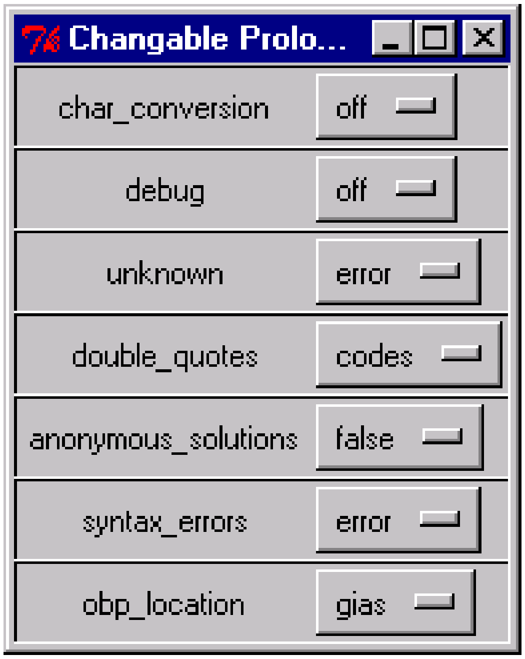
Printing depth type: Flat [✓ Non-flat]

The Heartbeat is the time interval between moments when a Prolog program temporarily yields control to the Tcl/Tk interface to allow for processing of GUI events, including clicks on the Interrupt button.

The Print depth setting contols how deep printing of nested terms will proceed; when the depth limit is reached, some representation (normally '*' or '...') is printed instead of continuing with the nested term.

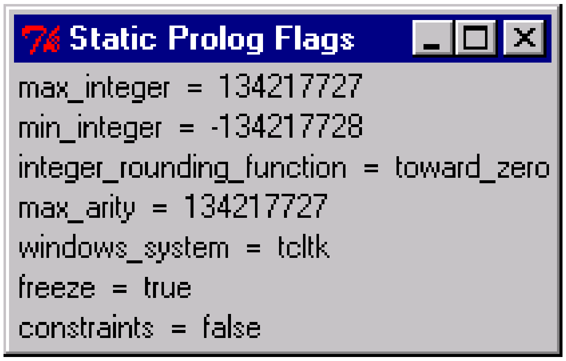
The Printing depth type setting determines whether traversing a list or the top-level arguments of a term increases the print depth counter. The Flat setting indicates that the counter will not increase as one traverses a list or the top level of a term, while Non-flat specifies that the counter will increase.

Selecting Dynamic Flags produces a popup window which displays the current values of all of the changable Prolog flags in the system, and allows one to reset any of those values:



char_conversion	off
debug	off
unknown	error
double_quotes	codes
anonymous_solutions	false
syntax_errors	error
obp_location	gias

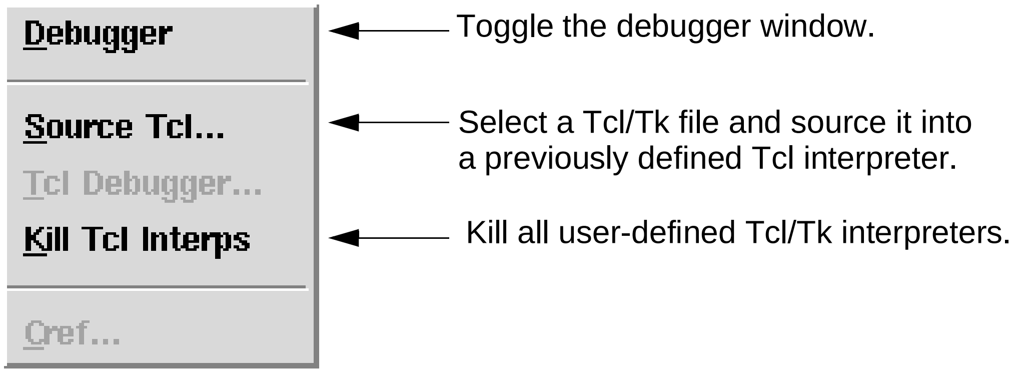
Selecting Static Flags producs a popup window displaying the values of all of the unchangable Prolog flags for the system:



```
max_integer = 134217727
min_integer = -134217728
integer_rounding_function = toward_zero
max_arity = 134217727
windows_system = tcltk
freeze = true
constraints = false
```

13.2.4 Tools Menu

This menu is expected to grow with new entries in future releases. Currently:


Debugger
Toggle the debugger window.
Source Tcl...
Select a Tcl/Tk file and source it into a previously defined Tcl interpreter.
Tcl Debugger...
Kill Tcl Interps
Kill all user-defined Tcl/Tk interpreters.
Cref...

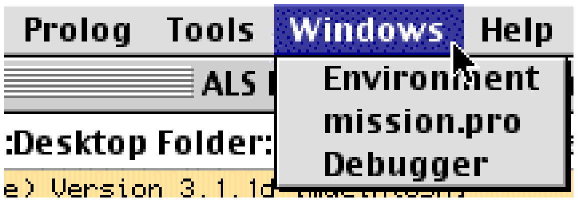
Selecting Debugger provides access to the GUI Debugger; this will be described in detail in Chapter 15 (*Using the ALS IDE Debugger*) .

Source Tcl allows one to "source" a Tcl/Tk file into a user/program-defined Tcl interpreter; the dialog prompts you for the name of the interpreter.

Kill Tcl Interps destroys all user-defined Tcl/Tk interpreters.

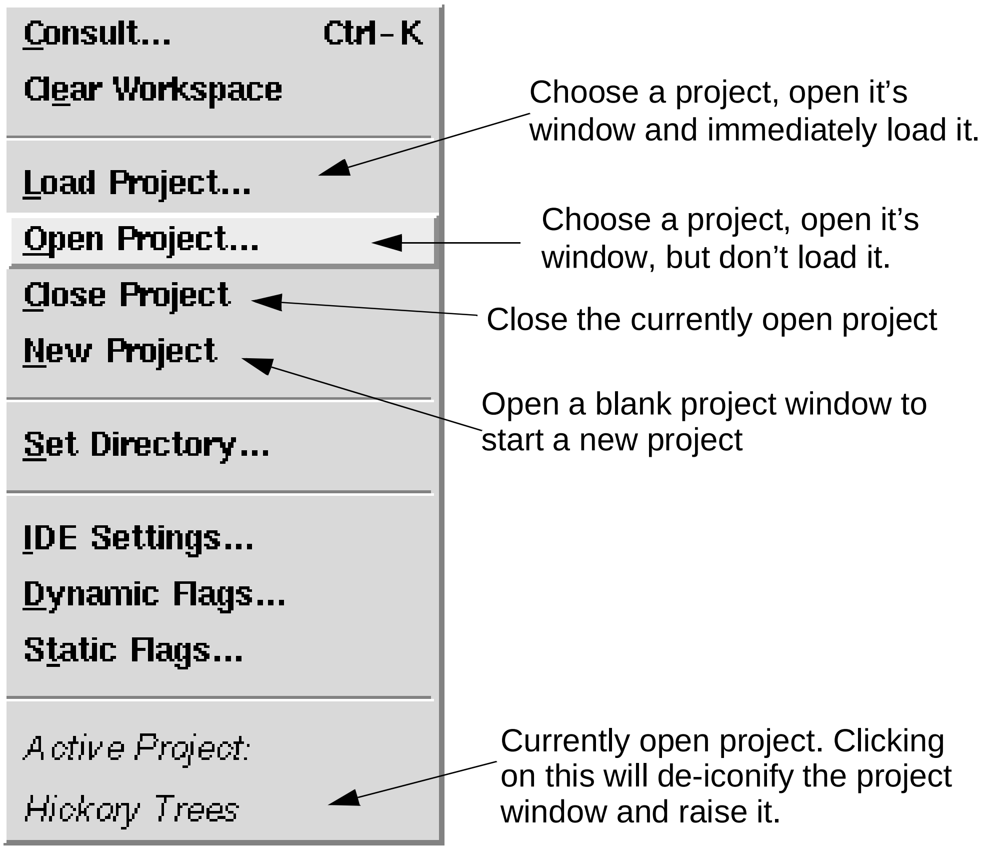
13.2.5 Windows Menu

This menu lists windows which have been opened. Double-clicking on an entry in this list will raise that window to the top of the desktop. Here is a typical situation:

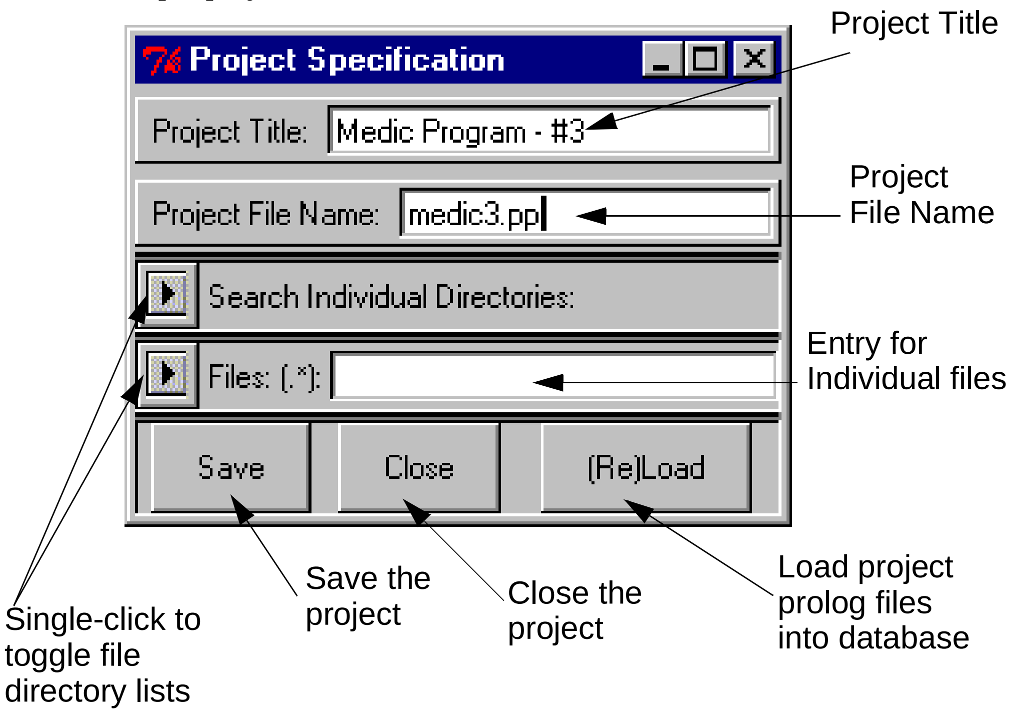


14 Prolog Development Projects

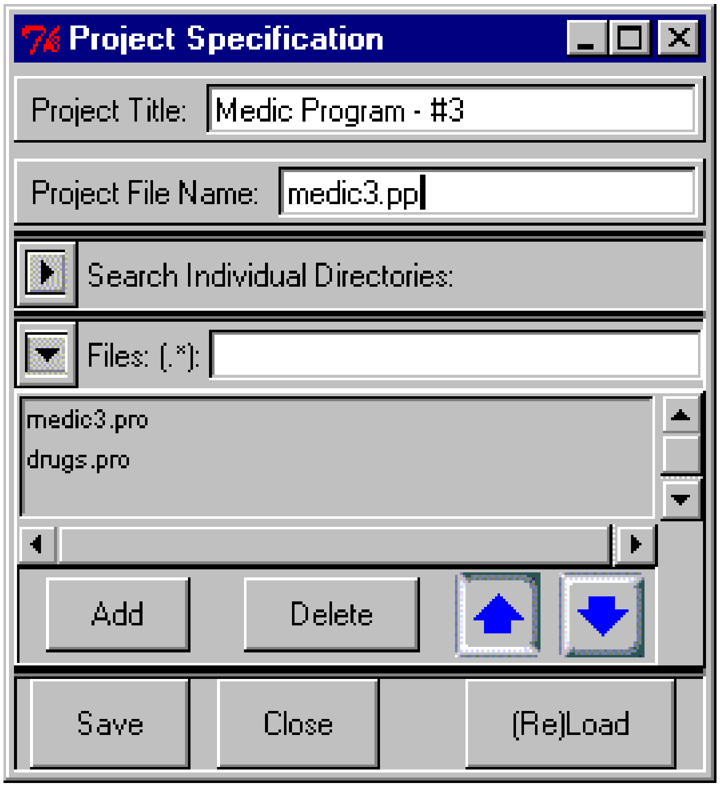
The ALS Prolog Development Environment (alsdev) supports a simple concept of development project which nonetheless, is quite useful. At it's most elementary, a project is just a named collection of files. Projects are accessed through the Prolog menu introduced in the preceeding section: Once again:


Consult... Ctrl-K
Clear Workspace
Load Project...
Open Project...
Close Project
New Project
Set Directory...
IDE Settings...
Dynamic Flags...
Static Flags...
Active Project:
Hickory Trees
Choose a project, open it's window and immediately load it.
Choose a project, open it's window, but don't load it.
Close the currently open project
Open a blank project window to start a new project
Currently open project. Clicking on this will de-iconify the project window and raise it.

Here is a sample project window:



Clicking on the triangular arrow button to the left of ‘Files:’ causes the list of files incorporated in the project to open, as shown below:


Project Specification

Project Title: Medic Program - #3

Project File Name: medic3.ppj

Search Individual Directories:

Files: (.*):

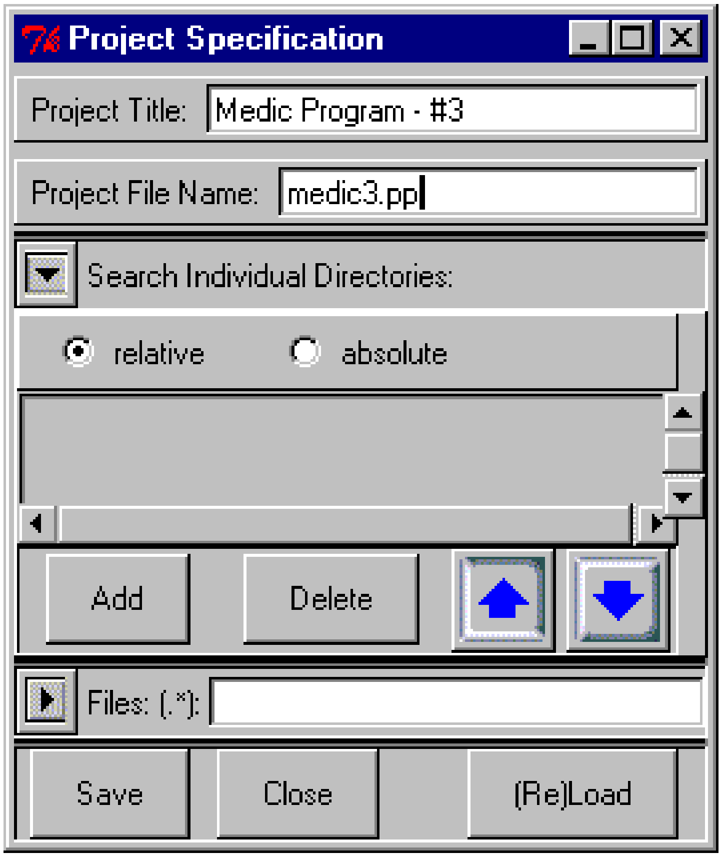
medic3.pro
drugs.pro

Files in the list can be deleted by selecting them, and the clicking the Delete button. New files may be added by clicking the Add button. This will raise a file selection dialog which allows you to select one or several files at the same time, from either the current directory, or other directories.

When the project is loaded, by clicking the (Re)Load button, the prolog files in the list (those with *.pro or *.pl extensions) are loaded in the order they appear. One can change the order of the files by single-clicking one to select it, and the using the blue up/down arrows to move it in the list.

Finally, double-clicking a file in the list will cause an editor window to be opened for that file.

Complex projects may incorporate files from several different directories. These can be specified using the Search Directories list, which is opened by toggling the other arrow button on the left:



Project Title: Medic Program - #3

Project File Name: medic3.ppj

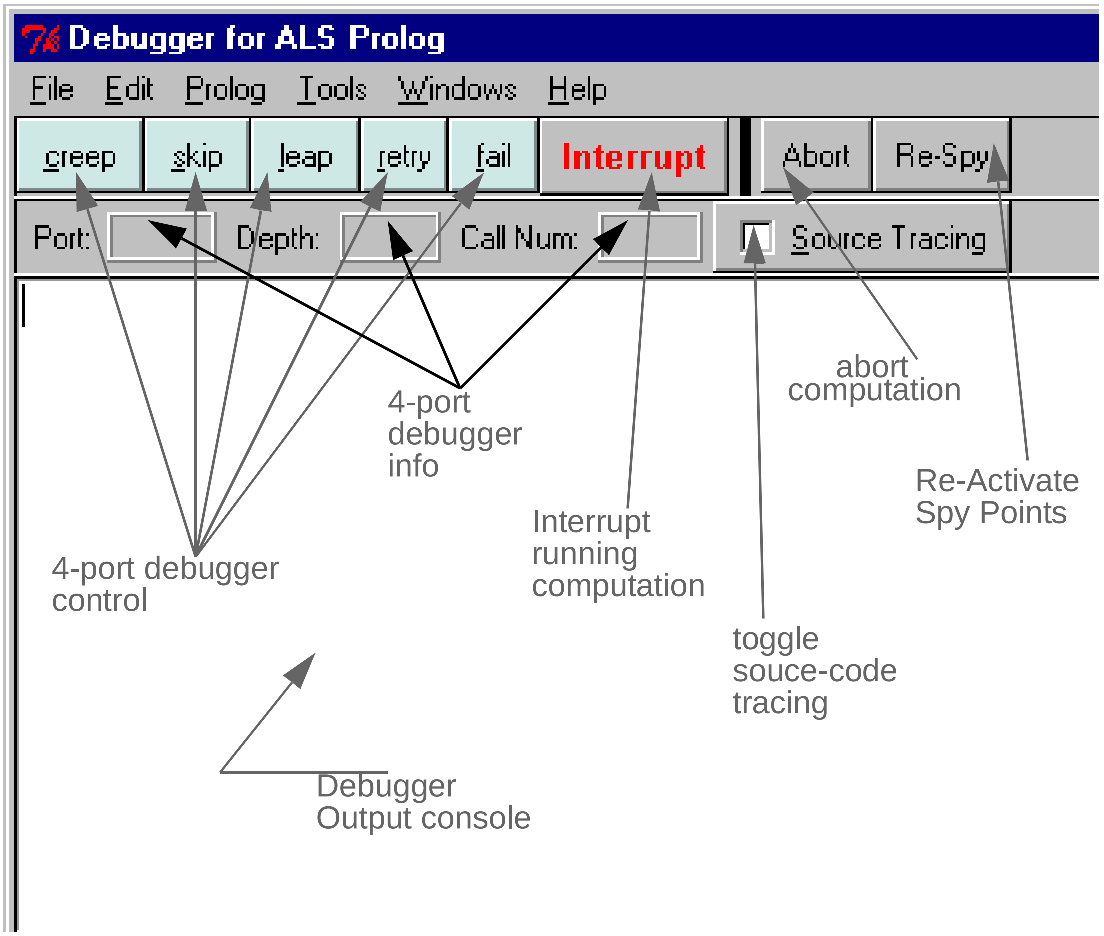
[✓ relative] absolute

Files: (.*):

As with files, one can single-click an entry in this list to select it, and remove it with the Delete button, or change its position using the blue up/down arrows. New directories are added by clicking Add, which raises a directory selection dialog. If the 'relative' radio button is checked, the new added path will be represented relative to the current working directory if this is possible. Otherwise, the path is represented in absolute form.

15 Using the ALS IDE Debugger

Selecting the Debugger entry from the Tools menu causes the primary debugger window to appear::



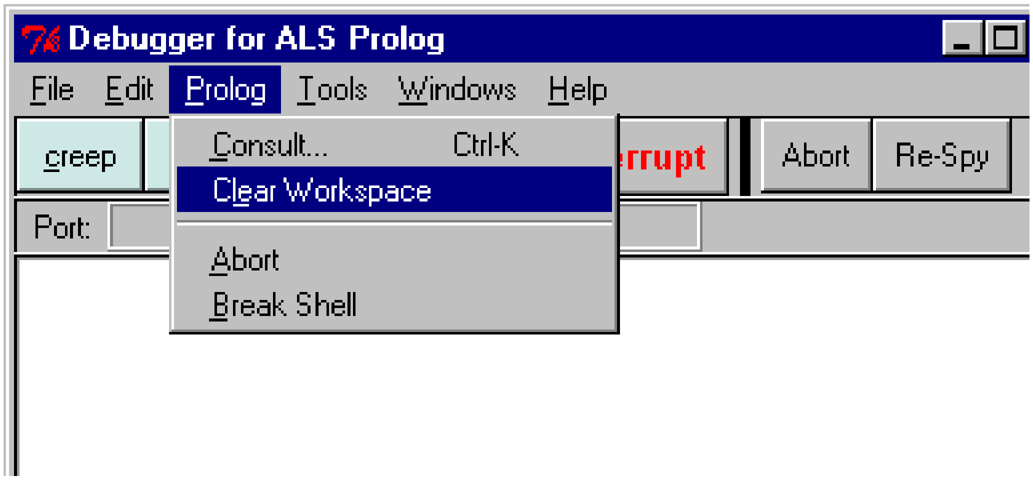
The debugger combines a traditional prolog four-port debugger (as described in Chapter 20 (*Using the Four-Port Debugger*)) with a source-code trace debugger. The details of the debugger action and the source trace will be described below. First we will examine the menus and buttons on the debugger window.

15.1 Debugger Window Menus.

The first two debugger menus, File and Edit, provide the same facilities as discussed for all other windows in Chapter 13 (*ALS Integrated Development Environment*) .

15.1.1 Prolog Menu.

The top two items of the Prolog menu are also the same as earlier:



However, the lower portion has been replaced with two debugger-related items:

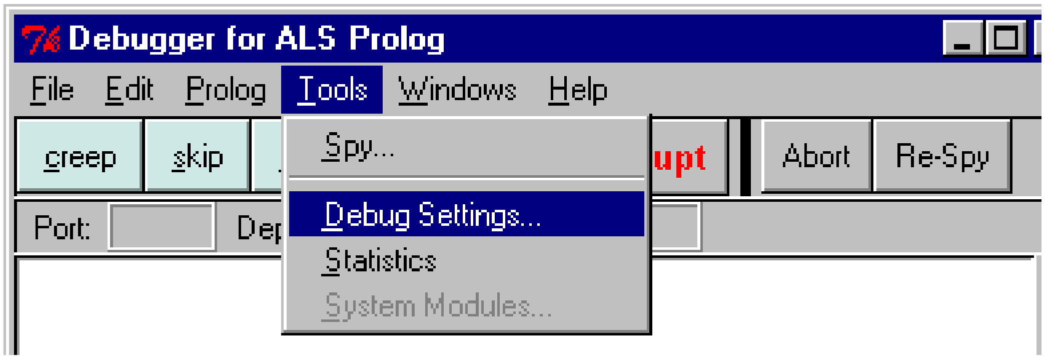
Abort -- choosing this causes the computation currently being traced to be aborted (effectively, abort/0 is invoked).

Break Shell -- choosing this causes a secondary break shell to be started without disturbing the current computation being traced.

If no computation is being traced, the Abort and Break choices have no effect.

15.1.2 Tools Menu

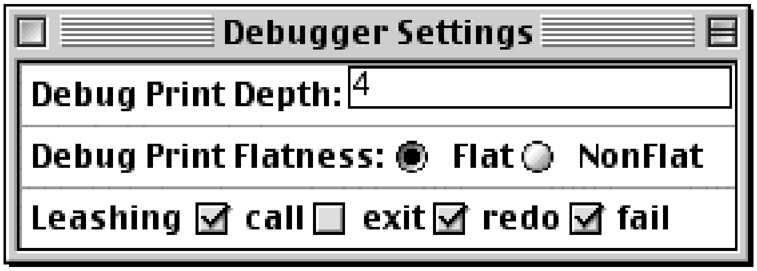
The Tools Menu



is completely specific to the debugger.

Choosing Spy allows one to selectively set and remove spy points. This will be discussed in detail below.

Choosing Debug Settings raise the following popup window:


Debugger Settings

Debug Print Depth: 4

Debug Print Flatness: [✓ Flat] NonFlat

Leashing [✓ call] exit [✓ redo] [✓ fail]

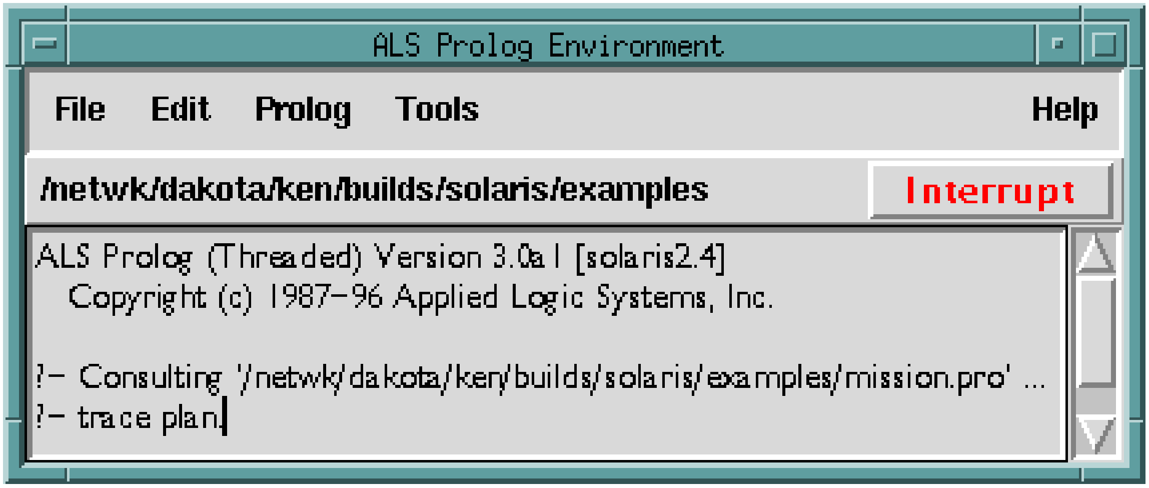
These settings control which debugger ports are shown, and also control the appearance of the lines printed for the ports which are show.

15.2 Tracing with the IDE Debugger.

Suppose we have raised the debugger, consulted the *mission.pro* example from the supplied example programs. Then begin tracing by typing

```
trace plan.
```

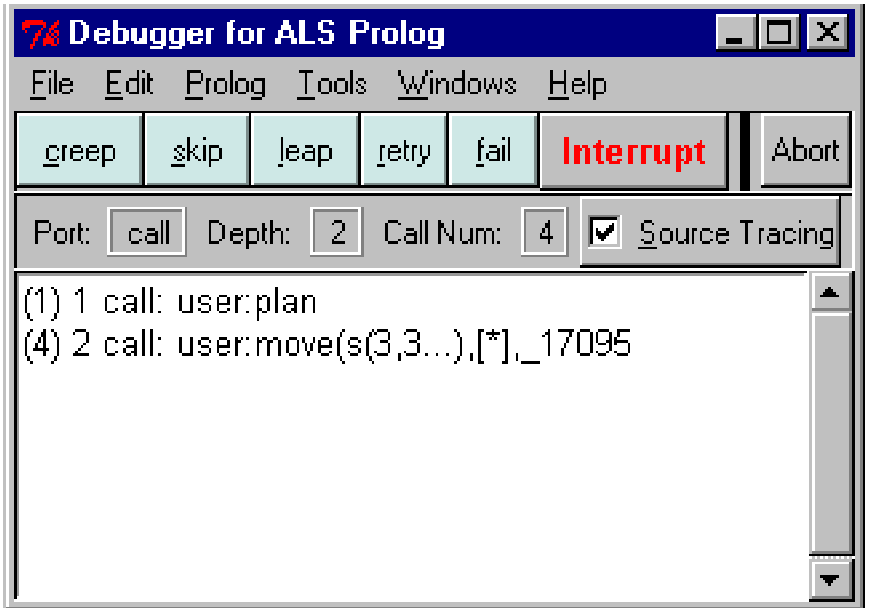
in the main listener window, as show below: :



/netwk/dakota/ken/builds/solaris/examples

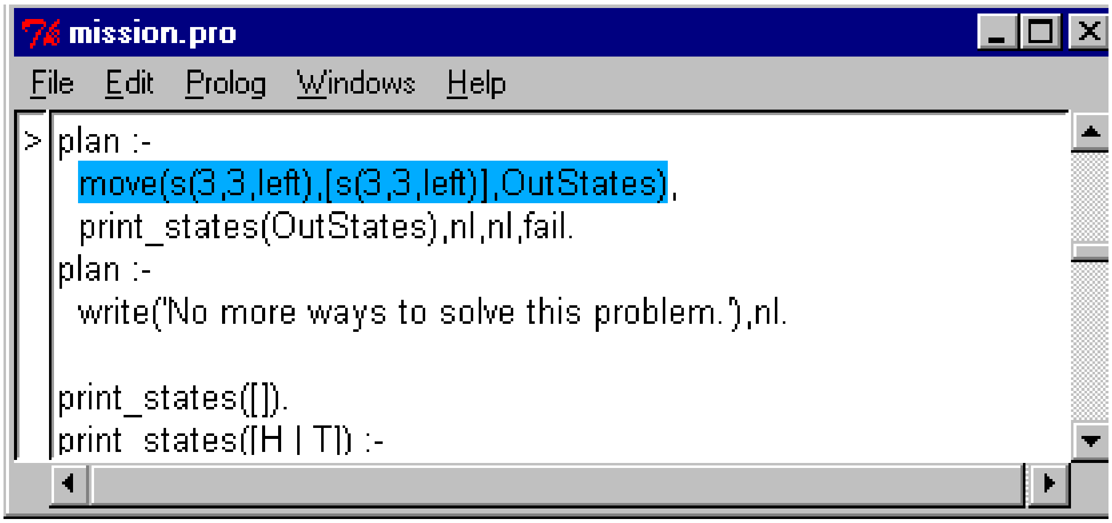
```
ALS Prolog (Threaded) Version 3.0a1 [solaris2.4]
   Copyright (c) 1987-96 Applied Logic Systems, Inc.

?- Consulting '/netwk/dakota/ken/builds/solaris/examples/mission.pro' ...
?- trace plan.
```

The debugger will immediately open an editor window containing the *mission.pro* file, while at the same time starting the four-port trace in the debugger window:


Debugger for ALS Prolog
File Edit Prolog Tools Windows Help
creep skip leap retry fail Interrupt Abort

Port: call Depth: 2 Call Num: 4 [✓ Source Tracing]

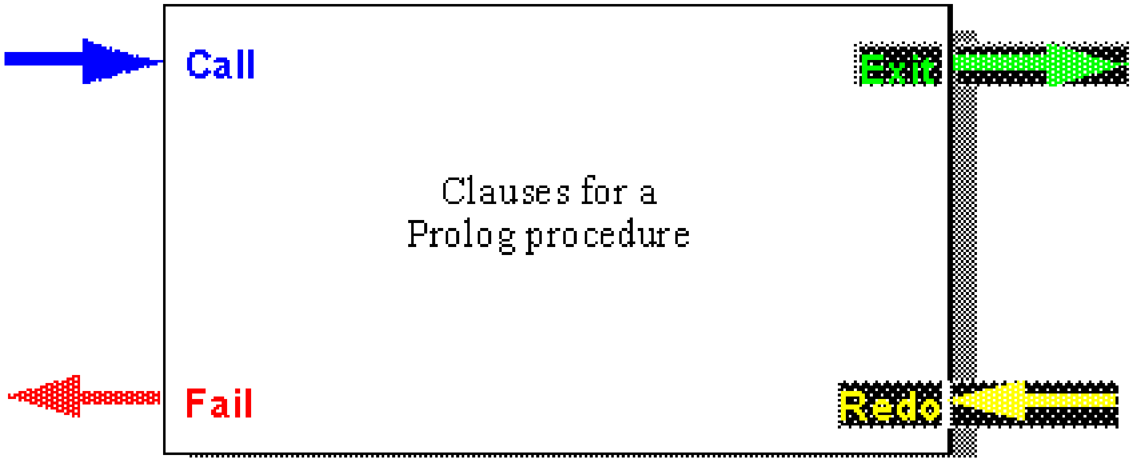
```
(1) 1 call: user:plan
(4) 2 call: user:move(s(3,3...),[*],_17095
```



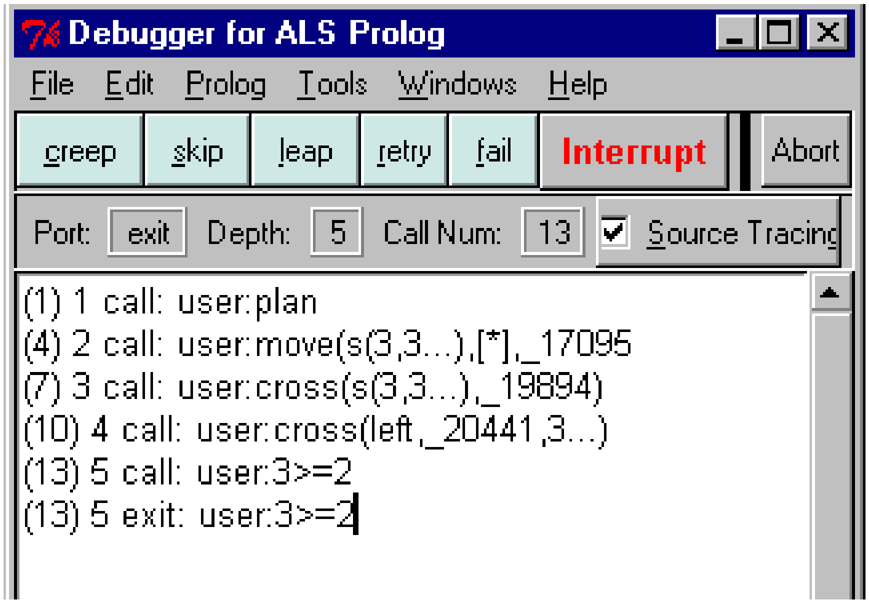
```
> plan :-
    move(s(3,3,left),[s(3,3,left)],OutStates),
    print_states(OutStates),nl,nl,fail.
  plan :-
    write('No more ways to solve this problem.'),nl.

  print_states([]).
  print_states([H | T]) :-
```

The call `move(...)` in the source code window which corresponds to the current call in the 4-port debugger window is highlighted in blue. Note that the window also automatically scrolled so that this code is now visible.

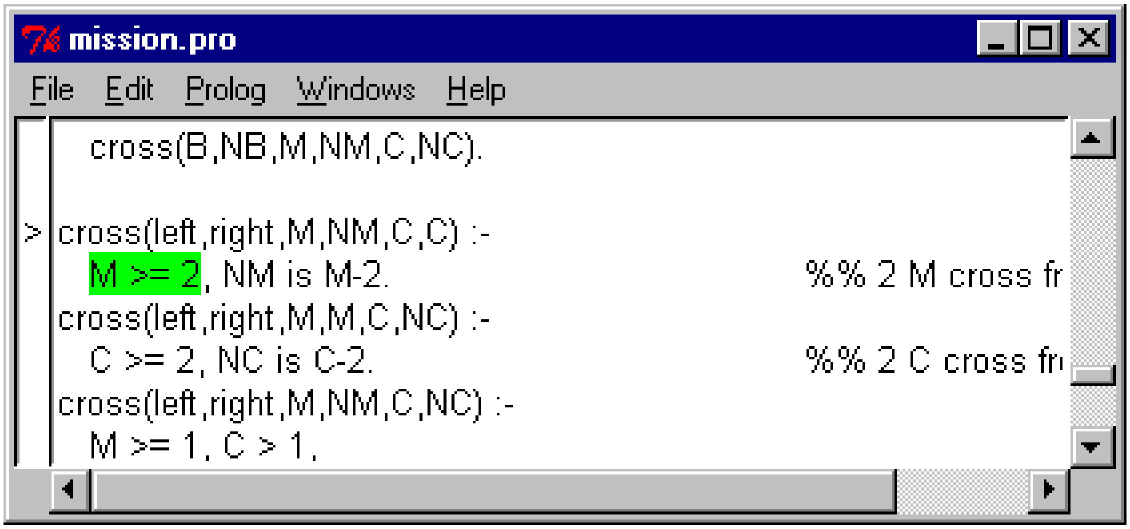
The coloring used in the source code window corresponds to the port colors shown in the four-port model diagram Figure 16 (*Generic Procedure Box.*), repeated here:



Click on creep four more times, and the situation is now:

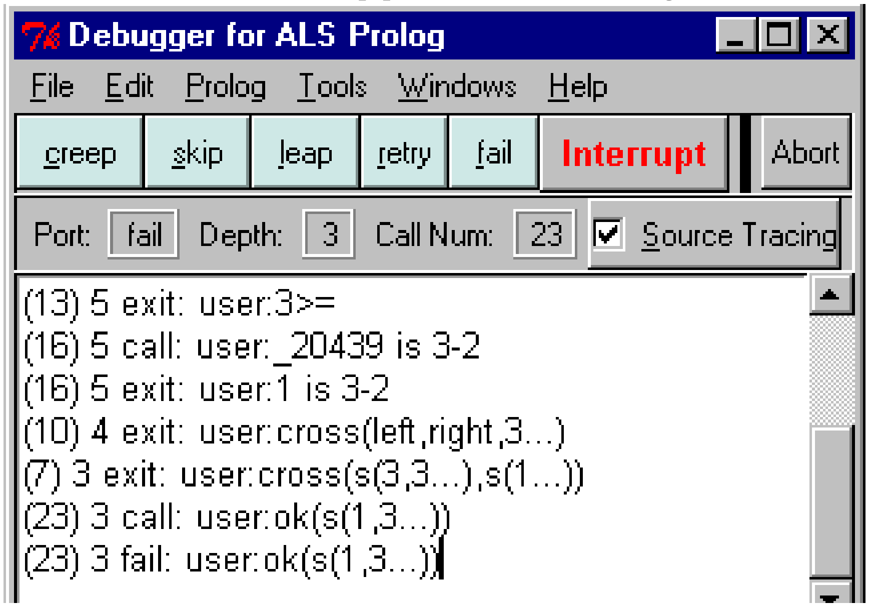

Debugger for ALS Prolog
File Edit Prolog Tools Windows Help
creep skip leap retry fail Interrupt Abort
Port: exit Depth: 5 Call Num: 13 [✓ Source Tracing]

```
(1) 1 call: user:plan
(4) 2 call: user:move(s(3,3...),[*],_17095
(7) 3 call: user:cross(s(3,3...),_19894)
(10) 4 call: user:cross(left,_20441,3...)
(13) 5 call: user:3>=2
(13) 5 exit: user:3>=2
```

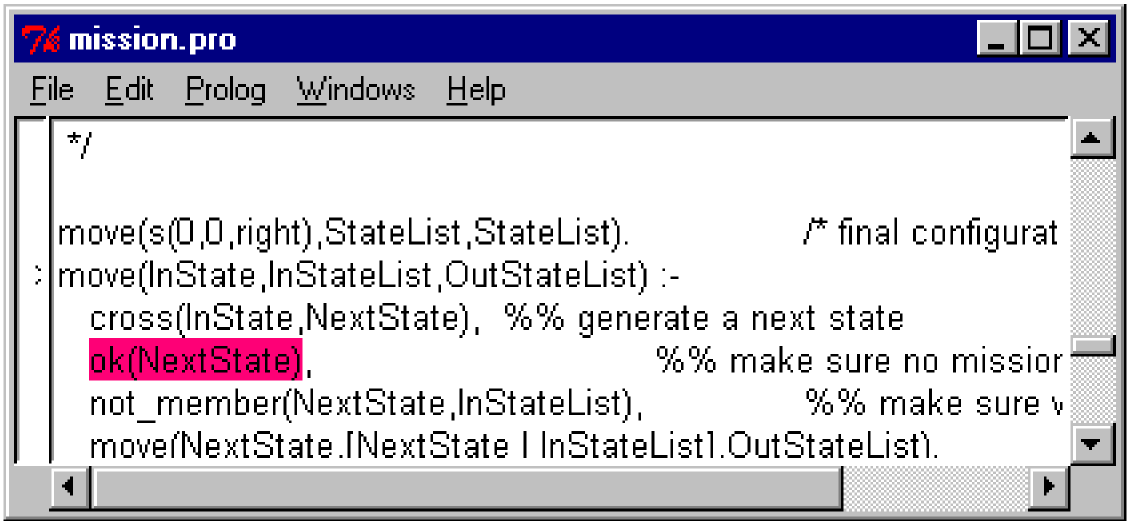


```
   cross(B,NB,M,NM,C,NC).

> cross(left,right,M,NM,C,C) :-
   M >= 2, NM is M-2.                    %% 2 M cross fr
  cross(left,right,M,M,C,NC) :-
   C >= 2, NC is C-2.                    %% 2 C cross fr
  cross(left,right,M,NM,C,NC) :-
   M >= 1, C > 1,
```

Seven more clicks on creep produces the following:

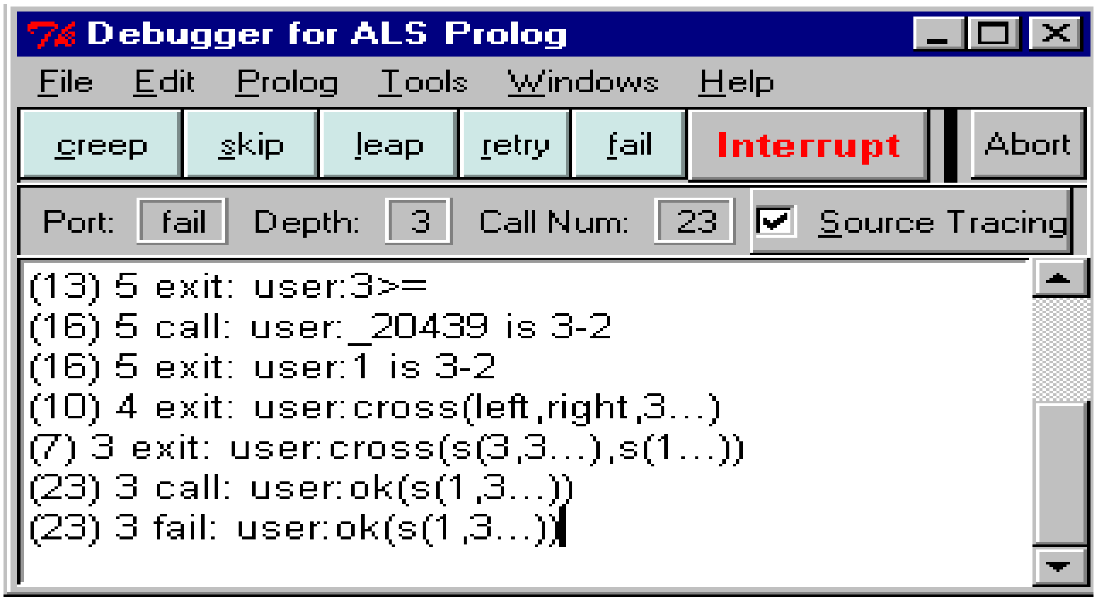

Debugger for ALS Prolog
File Edit Prolog Tools Windows Help
creep skip leap retry fail Interrupt Abort
Port: fail Depth: 3 Call Num: 23 Source Tracing

```
(13) 5 exit: user:3>=
(16) 5 call: user:_20439 is 3-2
(16) 5 exit: user:1 is 3-2
(10) 4 exit: user:cross(left,right,3...)
(7) 3 exit: user:cross(s(3,3...),s(1...))
(23) 3 call: user:ok(s(1,3...))
(23) 3 fail: user:ok(s(1,3...))
```



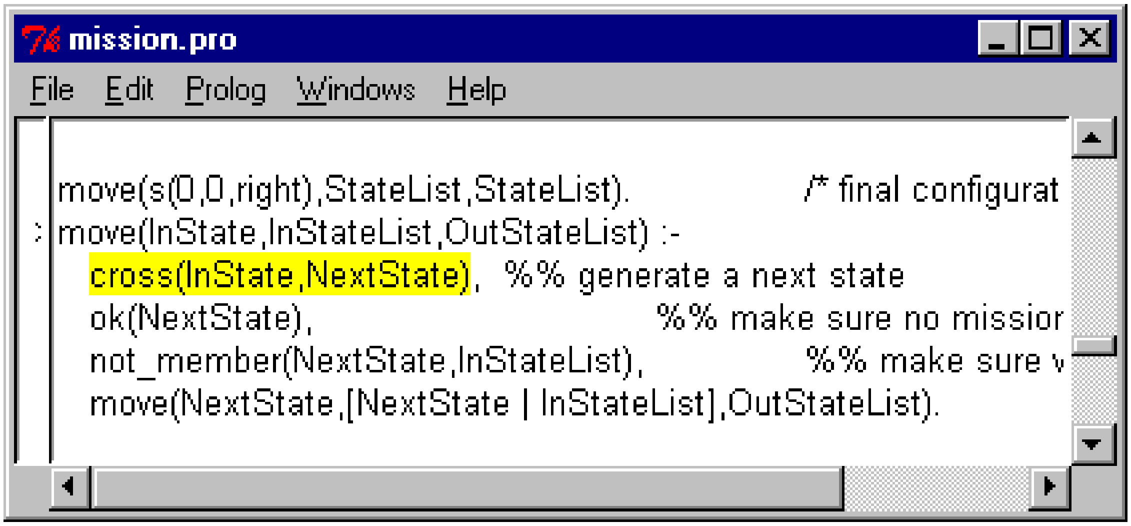
```
*/

move(s(0,0,right),StateList,StateList).             /* final configurat
move(InState,InStateList,OutStateList) :-
   cross(InState,NextState),  %% generate a next state
   ok(NextState),                          %% make sure no missior
   not_member(NextState,InStateList),             %% make sure v
   move(NextState,[NextState | InStateList],OutStateList).
```

One more click on creep produces:


Debugger for ALS Prolog
File Edit Prolog Tools Windows Help
creep skip leap retry fail Interrupt Abort

Port: fail Depth: 3 Call Num: 23 ✓ Source Tracing

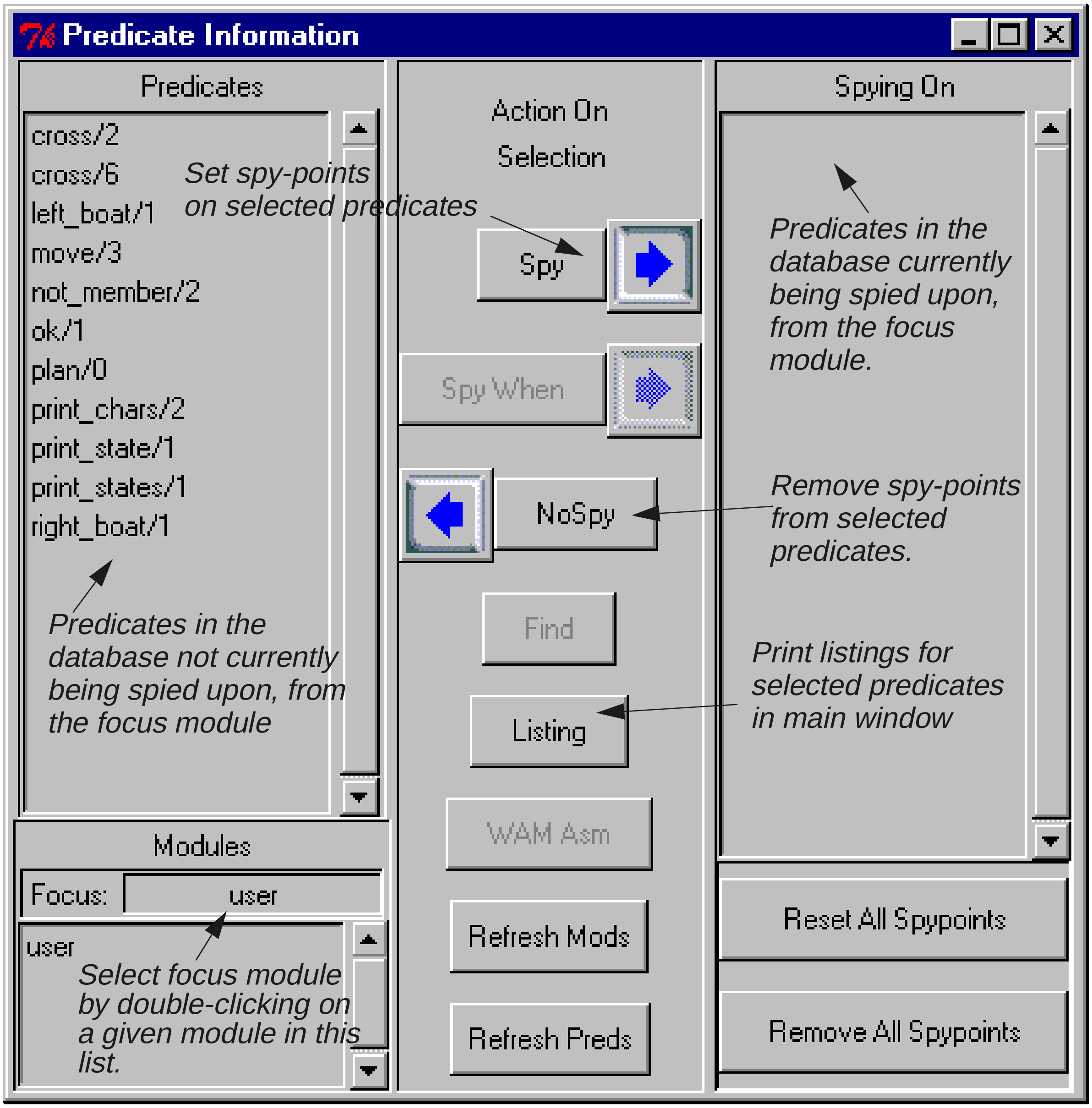
```
(13) 5 exit: user:3>=
(16) 5 call: user:_20439 is 3-2
(16) 5 exit: user:1 is 3-2
(10) 4 exit: user:cross(left,right,3...)
(7) 3 exit: user:cross(s(3,3...),s(1...))
(23) 3 call: user:ok(s(1,3...))
(23) 3 fail: user:ok(s(1,3...))
```



```
move(s(0,0,right),StateList,StateList).             /* final configurat
move(InState,InStateList,OutStateList) :-
   cross(InState,NextState),  %% generate a next state
   ok(NextState),                         %% make sure no missior
   not_member(NextState,InStateList),              %% make sure v
   move(NextState,[NextState | InStateList],OutStateList).
```

15.3 Spying with the ALS IDE

Choosing Spy... from the Debugger Tools menu raises the following dialog:



Predicate Information
Predicates
cross/2
cross/6
left_boat/1
move/3
not_member/2
ok/1
plan/0
print_chars/2
print_state/1
print_states/1
right_boat/1
Set spy-points on selected predicates
Predicates in the database not currently being spied upon, from the focus module
Modules
Focus:
user
user
Select focus module by double-clicking on a given module in this list.
Action On Selection
Spy
Spy When
NoSpy
Find
Listing
WAM Asm
Refresh Mods
Refresh Preds
Spying On
Predicates in the database currently being spied upon, from the focus module.
Remove spy-points from selected predicates.
Print listings for selected predicates in main window
Reset All Spypoints
Remove All Spypoints

All modules currently known are shown in the listbox in the lower left corner. One selects a focus module by double-clicking on one of the elements of this list. All of the predicates defined in the focus module are shown initially in the left-hand large listbox headed Predicates. Occasionally, when files have been reconsulted, one must use the Refresh Mods and Refresh Preds buttons to update these lists.

Selecting one or more predicates in the Predicates listbox, and then clicking on the Spy (or the right-pointing blue arrow) button will cause spy points to be placed on each of the selected predicates. Each of the selected predicates will also be moved from the left listbox to the right listbox labelled Spying On. Double-clicking on a single predicate from the left column will also cause it to be spied upon and moved to the right column. Similarly, spy points can be removed by selecting one or more predicates from the right column and clicking on the No Spy (or the left-pointing blue arrow) button. Double-clicking a single predicate in the right column also removes its spy-point.

If one or more predicates have been selected, clicking on Listing will cause their definitions to be printed in the main listener window.

Various actions, such as consulting, can cause spy-points to be disabled. The Reset All Spypoints causes all current spy-points to be re-activated. The Remove All Spypoints button causes all current spypoints to be removed.

16 Using the GUI Library

The ALS library includes a growing collection of routines designed to make it easy to utilize various GUI constructs easly from ALS Prolog.

16.1 Initializing the GUI library.

In order to make use of these routines, one must first initialize the library. This is accomplished with the predicate `init_tk_alslib/0`. This initializes a Tcl/Tk interpreter named `tcli` (see the next Chapter), and sources (loads) the associated Tcl/Tk code into that interpreter. This call is really defined as

```
init_tk_alslib :- init_tk_alslib(tcli, _).
```

If `Interp` is an atom intended to name a Tcl/Tk interpreter, then

```
init_tk_alslib(Interp, Path)
```

creates a Tcl/Tk interpreter named `Interp`, locates the adjunct TclTk code, returns the path to the directory containing that code in `Path`, and sources that code into `Interp`.

All of the calls in the library are organized in a similar style: there is a default version which references the default interpreter `tcli`, and there is a general version allowing one to use the same functionality with any other interpreter.

16.2 Dialogs.

16.2.1 Information dialogs.

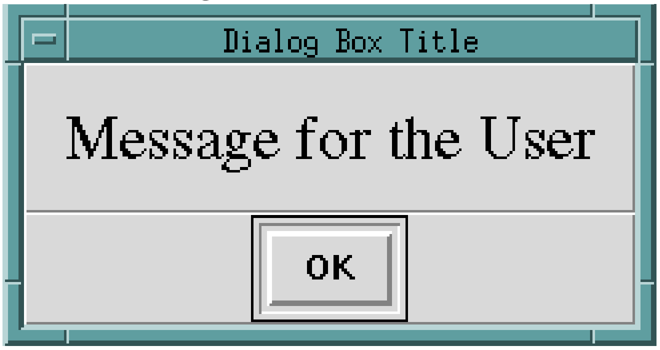
```
 info_dialog(Msg) :-
    info_dialog(Msg, 'Info').
 info_dialog(Msg, Title) :-
    info_dialog(tcli, Msg, Title).
```

`info_dialog(Interp, Msg, Title)`

The call

```
?-info_dialog('Message for the User',
             'Dialog Box Title').
```

produces the information dialog:



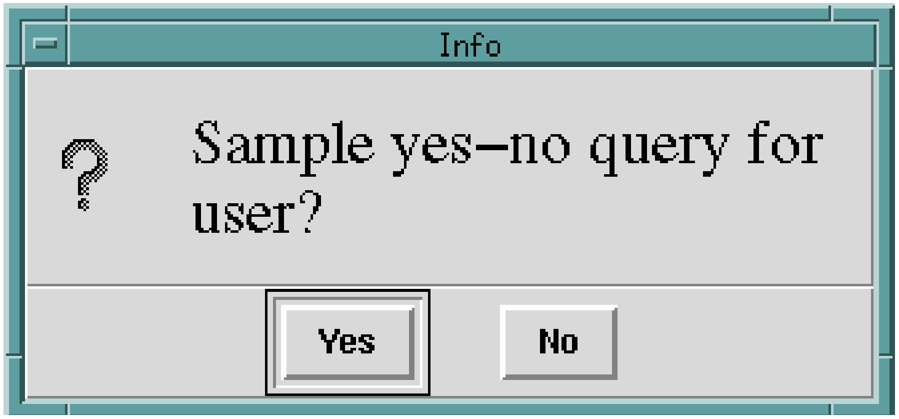
16.2.2 Yes-no dialogs.

```
yes_no_dialog(Msg, Answer)
    :-
    yes_no_dialog(Msg, 'Info', Answer).
yes_no_dialog(Msg, Title, Answer)
    :-
    yes_no_dialog(tcli, Msg, Title, Answer).
yes_no_dialog(Interp, Msg, Title, Answer)
    :-
    yes_no_dialog(Interp, Msg, Title, 'Yes', 'No', Answer).
```
`yes_no_dialog(Interp, Msg, Title, YesLabel, NoLabel, Answer)`

The call

```
?- yes_no_dialog('Sample yes-no query for user?',
                    Answer).
```

produces the following popup dialog:



If the user clicks “Yes”, the result is

```
   Answer = Yes
```

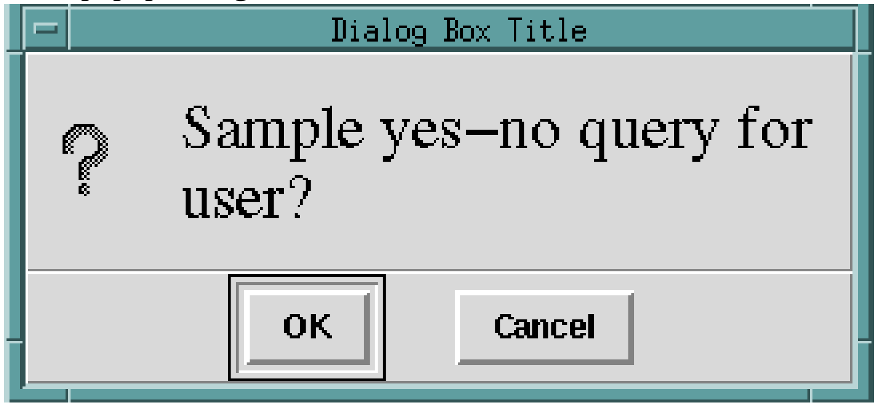
while clicking “No” yields

```
   Answer = No.
```

The call

```
   yes_no_dialog(tcli,
                    ‘Sample yes-no query for user?’,
                    ‘Dialog Box Title’,
                    ‘OK’, ‘Cancel’, Answer).
```

produces the popup dialog



Clicking “OK” yields

```
   Answer = OK
```

while clicking “Cancel” yeilds

```
   Answer = Cancel.
```

16.3 Choices from lists.

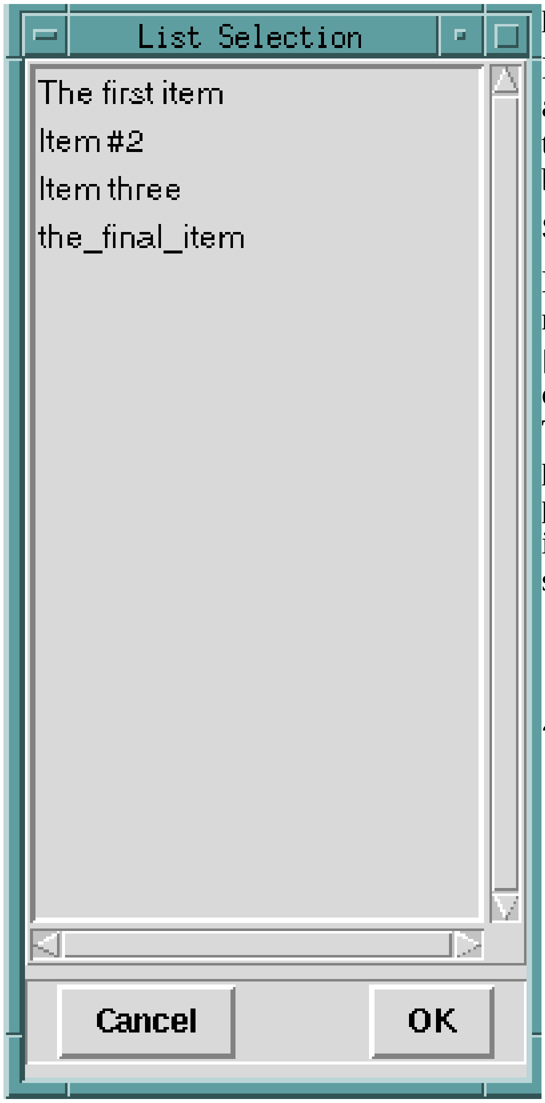
popup_select_items(SourceList, ChoiceList)

popup_select_items(SourceList, Options, ChoiceList)

popup_select_items(Interp, SourceList, Options, ChoiceList)

The call

```
   ?- popup_select_items(
          [‘The first item’,’Item #2’,
           ‘Item three’, the_final_item],
        Selection).
```



produces the popup shown at the left.:

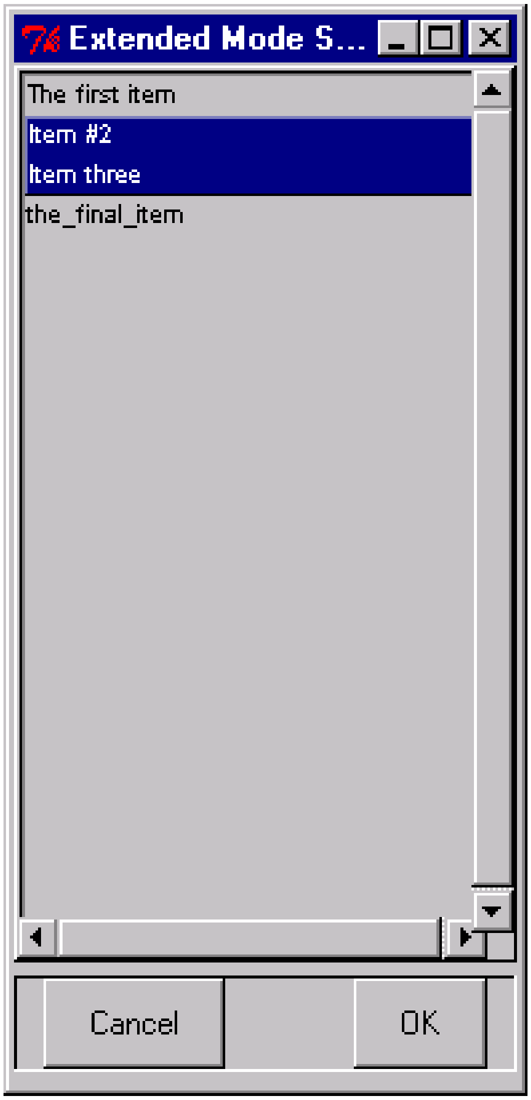
In this case, the user is allowed to select a single item; if the user selected “Item three” and clicked OK, the result would be:

```
Selection = [Item three].
```

Even though in this case the user was restricted to selection of one item, the `popup_select_items/_` predicate returns a list of the selected items. The `Options` argument for popup_select_items/[3,4] allows the programmer to place the popup list box in any of the other standard Tk listbox selection modes. For example, the call

```
?- popup_select_items(
  [‘The first item’,
   ’Item #2’,
   ‘Item three’,
   the_final_item],
  [mode=extended,
   title=
’Extended Mode Selection’
  ],
   Selection).
```

will popup a list box whose appearance is identical (apart from the different title requested) to the previous listbox. However, it will permit selection of ranges of elements, as seen below:



The result of clicking OK will be:

```
Selection =
   [Item #2, Item three]
```

The standard Tk listbox modes are described (on the Tcl/Tk man/help pages as follows)::

If the selection mode is *single* or *browse*, at most one element can be selected in the listbox at once. In both modes, clicking button 1 on an element selects it and deselects any other selected item. In *browse* mode it is also possible to drag the selection with button 1.

If the selection mode is *multiple* or *extended*, any number of elements may be selected at once, including discontiguous ranges. In *multiple* mode, clicking button 1 on an element toggles its selection state without affecting any other elements. In *extended* mode, pressing button 1 on an element selects it, deselects everything else, and sets the anchor to the element under the mouse; dragging the mouse with button 1 down extends the selection to include all the ele ments between the anchor and the element under the mouse, inclusive.

16.4 Inputting atoms (answering questions).

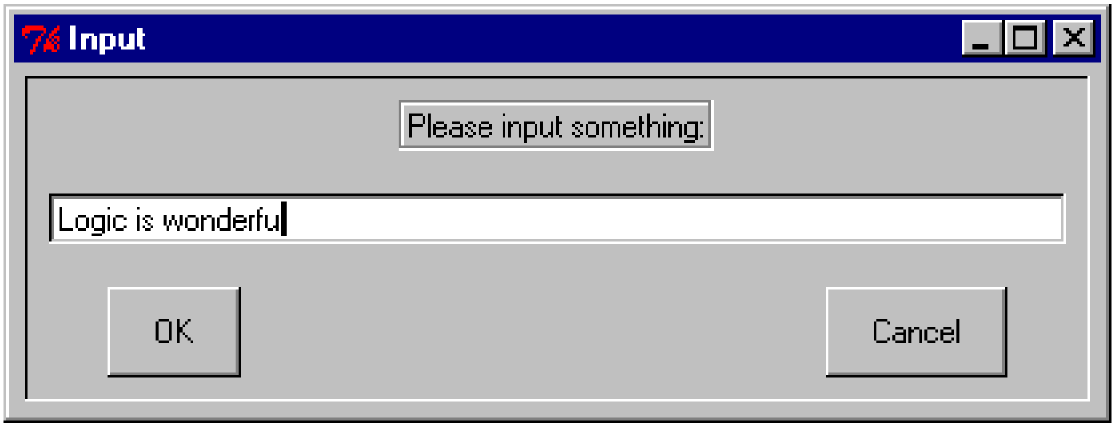
```
atomic_input_dialog(Msg, Atom)
    :-
    atomic_input_dialog(Msg, 'Input', Atom).
atomic_input_dialog(Msg, Title, Atom)
    :-
    atomic_input_dialog(tcli, Msg, Title, Atom).
```

`atomic_input_dialog(Interp, Msg, Title, Atom)`

This is a useful method of obtaining input from users. For example, the call

```
?- atomic_input_dialog('Please input something:',
  Atom).
```

will popup the following window:



If the user types

Logic is wonderful

then the result would be

```
Atom = Logic is wonderful
```

16.5 File selection dialogs

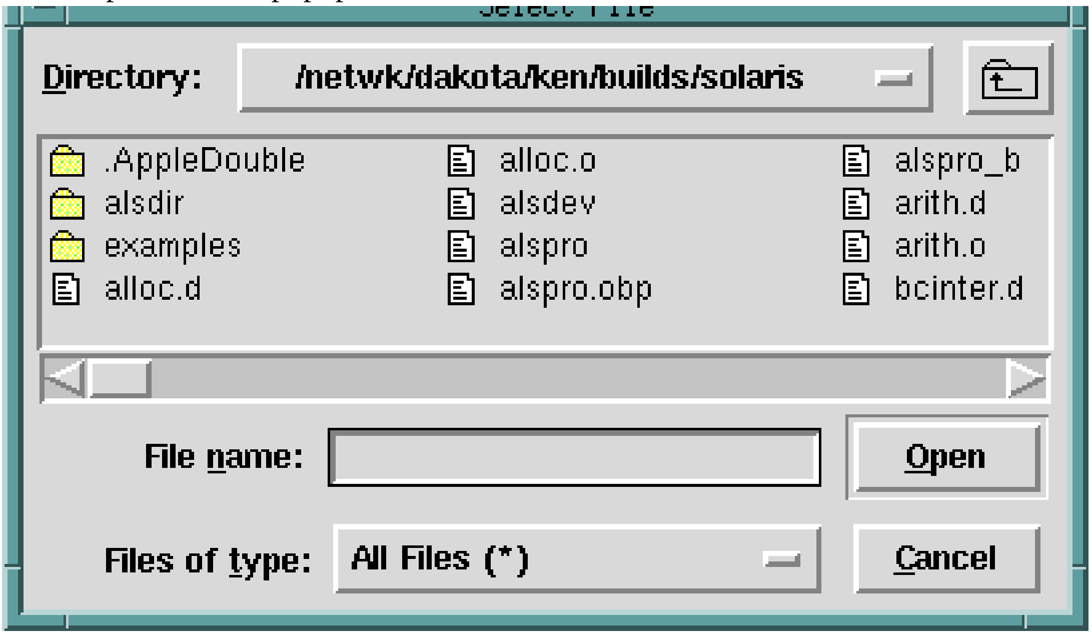
```
file_select_dialog(FileName)
    :-
    file_select_dialog(tcli, [title='Select File'],
  FileName).
file_select_dialog(Options, FileName)
    :-
    file_select_dialog(tcli, Options, FileName).
```

`file_select_dialog(Interp, Options, FileName)`

The call

```
?- file_select_dialog(File).
```

would produce this popup:


Directory: /netwk/dakota/ken/builds/solaris

```
.AppleDouble    alloc.o       alspro_b
alsdir          alsdev        arith.d
examples        alspro        arith.o
alloc.d         alspro.obp    bcinter.d
```

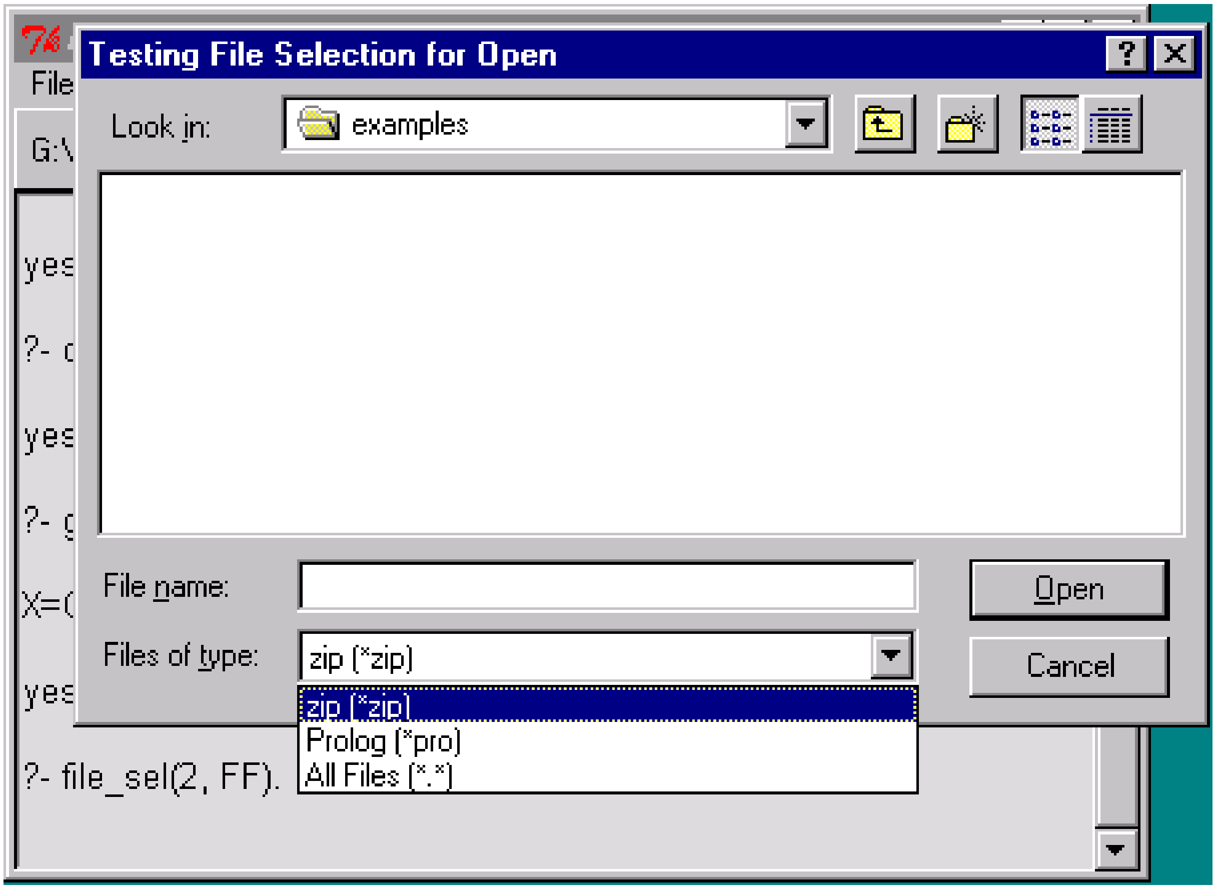
File name:

Files of type: All Files (*)

The call

```
?- file_select_dialog(
            [title='Testing File Selection for Open',
             filetypes= [[zip,[zip]],
                         ['Prolog',['pro']],
                         ['All Files',['*']] ]
             ],   File).
```

would produce



16.6 Displaying Images.

These routines provide simple access from ALS Prolog to the image routines of Tk.

They will be extended. The current versions support gif images, but the routines can be extended to any of the types Tk supports. To display images, one must specify a path to the image file, and must first produce an internal Tk form of the image. This is done with:

```
create_image(ImagePath, ImageName)
    :-
    create_image(tcli, ImagePath, ImageName).
```
`create_image(Interp, ImagePath, ImageName)`

Assume that

pow_wow_dance.gif

is a file in the current directory. Then the call

?- create_image('pow_wow_dance.gif', pow_wow).

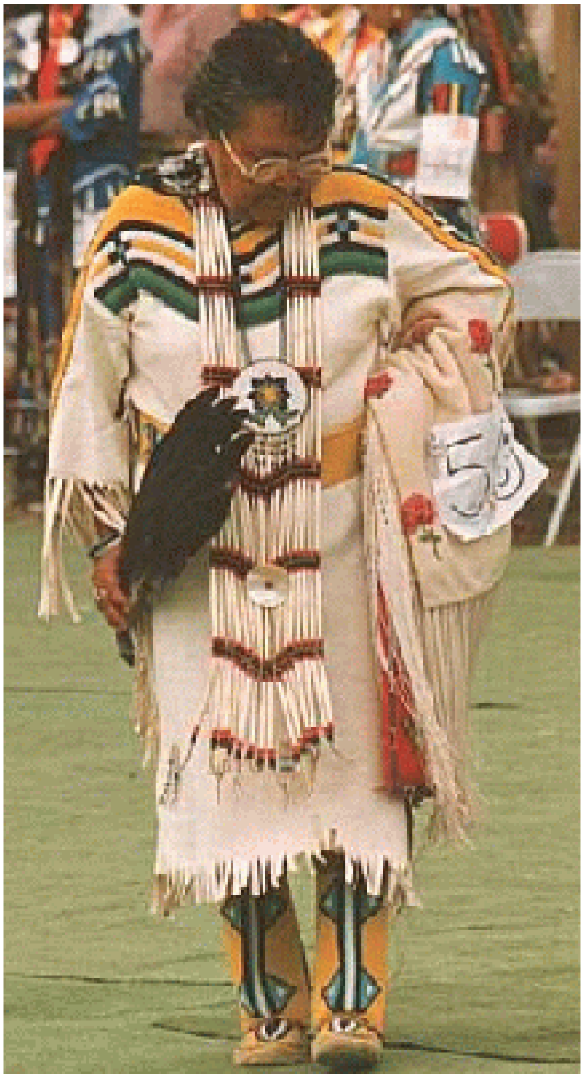
will create the internal form of this image and associate the name pow_wow with it. Display of images which have been created is accomplished with:

```
display_image(ImageName)
    :-
    display_image(tcli, ImageName, []).
display_image(Interp, ImageName, Options)
```

Thus, the call

?-display_image(pow_wow).

produces



16.7 Adding to the ALS IDE main menubar.

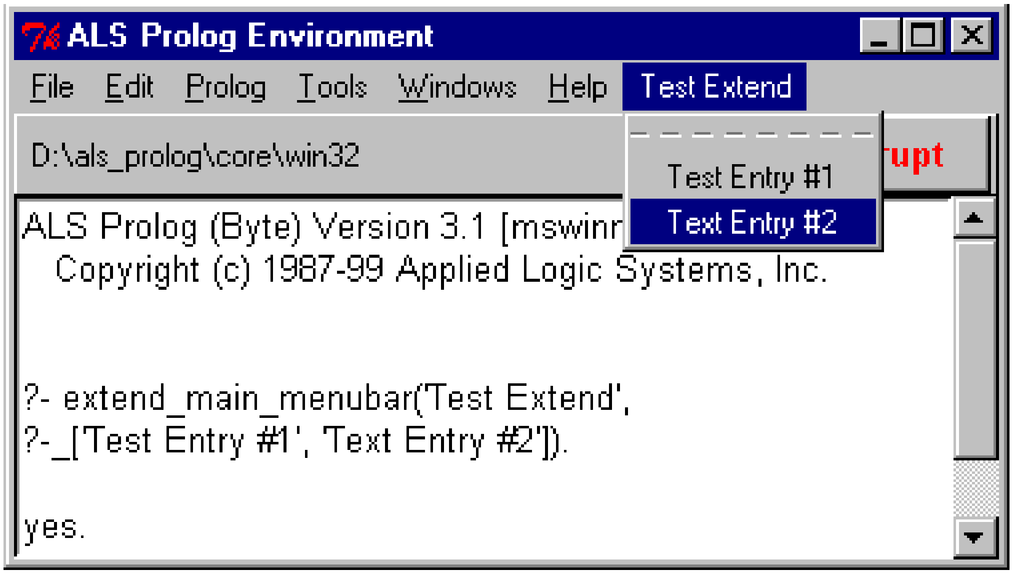
Simple additions to the main menubar are often useful. The general call to accomplish this is:

```
    extend_main_menubar(Label, MenuEntriesList)
```

`Label` should be the label which will appear on the menu bar, and `MenuEntriesList` is a Prolog list describing the menu entries. The simplest list consists only of labels which will occur on the pull-down menu. Thus, after executing the call

```
    ?- extend_main_menubar('Test Extend',
                    ['Test Entry #1', 'Test Entry #2']).
```

the main listener window would look like this when clicking on the newly added menubar entry:



```
ALS Prolog (Byte) Version 3.1 [mswinr
   Copyright (c) 1987-99 Applied Logic Systems, Inc.


?- extend_main_menubar('Test Extend',
?-_['Test Entry #1', 'Text Entry #2']).

yes.
```

This is somewhat uninteresting, however, since these menu items won't do anything. To add simple behaviors to the menu entry, one uses expressions of the form

Label + Behnavior

where Label is the menu label which will appear, and Behavior is either a ground Prolog term, or is a prolog term of the form

tcl(Expr)

where Expr is a quoted atom describing a Tcl/Tk function call. Thus, if we replace the call considered above by the following,

```
?- extend_main_menubar('Test Extend',
            ['Test Entry #1' + tcl('bell'),
             'Test Entry #2' + test_write
            ]),
```

where

```
test_write
    :-
    printf(user_output, 'This is a test ...\n', []),
    flush_input(user_input).
```

then the appearance of the main menu and the new pulldown will be the same, but chooseing Test Entry #1 will cause the bell to ring, and choosing Test Entry #2 will cause

```
This is a test ...
```

to be written on the listener console.

To summarize thus far, the main menu bar can be extended by calling:

```
extend_main_menubar(Label, MenuEntriesList)
```

where:

- `Label` is an atom (suitable for extending a Tk window path);
- `MenuEntriesList` is a list of menu entry descriptors.

And a *menu entry descriptor* is either an `Atom` alone, or an expression of the form

```
Atom + Expr
```

where `Atom` is a prolog atom which will serve as the new menu entry, and `Expr` is a *menu entry action expression,* which can be one of the following:

- `tcl(TclExpr)`
- `cascade(SubLabel, SubList)`
- `PrologCall`

Here, `TclExpr` can be any Tcl/Tk expression for evaulation, and `PrologCall` is any ground Prolog goal. The new entry

```
cascade(SubLabel, SubList)
```

allows one to create menu entries which are themselves cascades. In this case, `SubLabel` must be an atom which will serve as the entry's label, and `SubList` is (recursively) a list of menu entry descriptors.

Here are several useful predicates for working with menus and menu entries:

```
menu_entries_list(MenuPath, EntriesList)
  :-
  menu_entries_list(tcli, MenuPath, EntriesList).
```
`menu_entries_list(Interp, MenuPath, EntriesList)`

If `MenuPath` is a Tk path to a menu (top level or subsidiary), then `EntriesList` will be the list of labels for the entries on that menu, in order. For example,

```
?- menu_entries_list(shl_tcli,
            '.topals.mmenb', EntriesList).
EntriesList = [File, Edit, Prolog, Tools, Help].
```

When one indexes menu entries, the indicies are integers beginning at 0.

```
path_to_main_menu_entry(Index, SubMenuPath)
    :-
    path_to_menu_entry(shl_tcli, '.topals.mmenb',
                                Index, SubMenuPath).

path_to_menu_entry(MenuPath, Index, SubMenuPath)
    :-
```

```
        path_to_menu_entry(tcli, MenuPath, Index, SubMenuPath).
```

`path_to_menu_entry(Interp, MenuPath, Index, SubMenuPath)`

If `MenuPath` is a Tk path to a menu (top level or subsidiary), and if `Index` is an integer >= 0, and if the `Index'th` entry of `MenuPath` is a cascade, so that it has an associated menu, then `SubMenuPath` is a path to that associated menu. Thus,

```
?- path_to_main_menu_entry(4, SubMenuPath).
SubMenuPath = .topals.mmenb.help
```

Finally, one can add new entries at the ends (bottoms) of existing menu cascades, as follows:

```
add_to_main_menu_entry(Index, Entry)
    :-
    path_to_main_menu_entry(Index, MenuPath),
    extend_cascade(Entry, MenuPath, shl_tcli).
```
`extend_cascade(Entry, MenuPath, Interp)`

For example,

```
?- add_to_main_menu_entry(3,,
                 'My Entry' + test_write).
```

will add an entry at the end of the Tools cascade. The predicate

```
extend_cascade(Entry, MenuPath, Interp)
```

accomplishes adding the `Entry` to the end of menu `MenuPath` under interpreter `Interp`.

17 ALS Prolog - TCL/TK Interface

17.1 Introduction and Overview

The interface between ALS Prolog and Tcl/Tk allows prolog programs to create, manipulate and destroy Tcl/Tk interpreters, to submit Tcl/Tk expressions for evaulation in those interpreters, and to allow expressions being evaluated to make calls back into Prolog. Computed data can be passed in both directions:

- A Tcl/Tk function called from Prolog can return a value to Prolog;
- A Prolog goal called from Tcl/Tk can bind Tcl variables to computed values.

The conversions between the datatypes of the two languages are described in the next section. In general, one cannot count on the interface to automatically handle all situations. One must either assure that the originating code (Prolog or Tcl) creates a data entity which coverts into the the desired target type, or one must explictly coerce the entity after it has passed through the interface (e.g., with tcl_coerce).

17.2 Prolog to Tcl Type Conversion

17.3 Prolog to Tcl Interface Predicates

17.3.1 tcl_new(?Interpreter) tk_new(?Interpreter)

`tcl_new/1` creates a new Tcl interpreter. If the `Interpreter` argument is an uninstantiated (Prolog) variable, then a unique name is generated for the interpreter. If `Interpreter` is a atom, the new Tcl interpreter is given that name.

`tk_new/1` functions in the same manner as `tcl_new/1`, except that the newly-created Tcl interpreter is initialized with theTk package.

Examples

tcl_new(i). Succeeds, creating a Tcl interpreter named i.

tcl_new(X). Succeeds, unifying X with the atom ‘interp1’.

Errors

- Interpreter is not an atom or variable.

  type_error(atom_or_variable).
- The atom Interpreter has already been use as the name of a Tcl interpreter.

  permission_error(create,tcl_interpreter,Interpreter)
- Tcl is unable to create the interpreter.

  tcl_error(message)

17.3.2 tcl_call(+Interpreter, +Script, ?Result) tcl_eval(+Interpreter, +ArgList, ?Result)

Tcl_call and Tcl_eval both execute a script using the Tcl interpreter and returns the Tcl result in Result. Tcl_call passes the Script argument as a single argument toTcl’s eval command. Tcl_eval passes the elements of ArgList as arguments to the Tcl’s eval command, which concatenates the arguments before evalating them.

Tcl_call’s Script can take the following form:

- List - The list is converted to a Tcl list and evaluated by the Tcl interpreter. The list may contain, atoms, numbers and lists.
- Atom - The atom is converted to a string and evaluated by the Tcl interpreter.

Tcl_eval’s ArgList may contain atoms, numbers or lists.

Examples

tcl_call(i, [puts, abc], R). Prints ‘abc’ to standard output, and bind R to ‘’.

tcl_call(i, [set, x, 3.4], R). Sets the Tcl variable x to 3.4 and binds R to 3.4.

tcl_call(i, ‘set x’, R). Binds R to 3.4.

tcl_eval(i, [‘if [file exists ‘, Name, ‘] puts file-found’], R).

Errors

- Interpreter is not an atom.
- Script is not an atom or list.

- Script generates a Tcl error.

  tcl_error(message)

17.3.3 tcl_coerce_number(+Interpreter, +Object, ?Number)

17.3.4 tcl_coerce_atom(+Interpreter, +Object, ?Atom)
tcl_coerce_list(+interpreter, +Object, ?List)

These three predicates convert the object Object to a specific Prolog type using the Tcl interpreter Interpreter. Object can be an number, atom or list. If the object is already the correct type, then it is simple bound to the output argument. If the object cannot be converted, an error is generated.

Examples

tcl_coerce_number(i, ‘ 1.3’, N) Succeeds, binding N to the float 1.3

tcl_coerce_number(i, 1.3, N) Succeeds, binding N to the float 1.3

tcl_coerce_number(i, ‘abc’, N) Generates an error.

tcl_coerce_atom(i, [a, b, c], A) Succeeds, binding A to ‘a b c’

tcl_coerce_atom(i, 1.4, A) Succeeds, binding A to ‘1.4’

tcl_coerce_list(i, ‘a b c’, L) Succeeds, binding L to [a, b, c]

tcl_coerce_list(i, 1.4, L) Succeeds, binding L to [1.4]

tcl_coerce_list(i, ‘’, L) Succeeds, binding L to []

Errors
- Interpreter is not an atom.
- Object is not a number, atom or list.
- Object cannot be converted to the type.

  tcl_error(message)

17.3.5 tcl_delete(+Interpreter)
tcl_delete_all

Tcl_delete deletes the interpreter name Interpreter.

Tcl_delete_all deletes all Tcl interpreters created by tcl_new/1.

17.4 Tcl Prolog Interface

17.4.1 prolog - call a prolog term

Synopsis

prolog *option ?arg arg... ?*

Description

The prolog command provides methods for executing a prolog query in ALS Prolog. Option indicates how the query is expressed. the valid options are:

prolog call *module predicate ?-type arg ...?*

Directly calls a predicate in a module with type-converted arguments. The command returns 1 if the query succeeds, or 0 if it fails. The arguments can take the following forms:

-number arg

Passes arg as an integer or floating point number.

-atom arg

Passes arg as an atom.

-list arg

Passes arg as a list.

-var varName

Passes an unbound Prolog varaible. When the Prolog variable is bound, the Tcl variable with the name varName is set to the binding.

prolog read_call *termString ?varName ...?*

The string termString is first read as a prolog term and then called. The command returns 1 if the query succeeds, or 0 if it fails. The optional variables named by the varName arguments are set when a Prolog variable in the query string is bound. The prolog variables are matched to varNames in left-to-right depth first order.

Examples

prolog call builtins append -atom a -atom b -var x

Returns 1, and the Tcl variable x is set to {a b}.

prolog read_call “append(a, b, X)” x

Returns 1, and the Tcl variable x is set to {a b}.

17.5 Stand-Alone TCL

Normally Tcl/Tk is installed in a system independent of ALS Prolog. Typically the Tcl/Tk shared/dynamic libraries are stored in a system directory (/usr/local/lib on Unix, \winnt\system32 on Windows NT, and “System Folder:Extensions” on MacOS). Tcl/Tk support libraries are similarly stored in a global location.

When creating a stand alone Prolog/Tcl-Tk application, it is sometimes convienient to create a package which includes Tcl/Tk so that the application will run correctly even on systems without Tcl/Tk.

Basicly this is done by moving the Tcl/Tk shared/dynamic libraries and support libraries into the same directory as ALS Prolog. Here are sample directories for MacOS, Unix and Win32:

MacOS

- ALS Prolog
- Tcl8.0.shlb
- Tk8.0.shlb
- MWRuntimeLib
- tcl8.0 (support library folder)
- tk8.0 (support library folder)

Unix

- alspro
- libtcl8.0.so or libtcl8.0.sl
- libtk8.0.so or libtk8.0.sl
- lib (directory containing:)

  tcl8.0 (support library directory)

tk8.0 (support library directory)

Win32

- alspro.exe
- tcl80.dll
- tk80.dll
- lib (directory containing:)

tcl8.0 (support library directory)

tk8.0 (support library directory)

On Solaris, unlike other Unix systems, the search path list for shared objects does not include the executable’s directory. To ensure that the Tcl/Tk shared objects are found, the current directory ‘.’ must be added to the LD_LIBRARY_PATH environment variable.

18 Packaging for Delivery

A typical complex ALS Prolog application involves the following elements:

- the ALS Prolog system
- various ALS Prolog source files
- various foreign C language source files

During development, the object versions of the foreign C language files may be dynamically loaded into a running ALS Prolog image (in the versions of ALS Prolog which support this), or may be statically linked with the ALS Prolog run-time library to create an extended ALS Prolog image. The total application under development is started by invoking either the basic ALS Prolog image or the extended image, loading the foreign C language object files if necessary, and dynamically consulting the ALS Prolog files. However, for delivery of application programs to users, it is desirable to be able to package all these elements of the program together in one single executable file. ALS Prolog provides packaging tools for achieving this goal. These tools are available on all platforms except the Macintosh.

The packaging tools are very straight-forward to use. Simply proceed through the following steps:

1. Start the image (either the basic ALS Prolog image, or an extended image);
2. Load the Prolog files constituting the application.
3. Invoke save_image/2.

Apart from the details necessary to flesh out step 3, this is all there is to it! The information necessary for step 3 is the following:

A. The name of the file in which the executable image is to be stored (e.g., my_app, or your_app.exe, etc.).

B. The name of a 0-ary Prolog predicate which is the entry point to the application (e.g., `start_my_app/0`).

C. The list of names of library files (if any) to be included in the application.

For example, suppose that the application is to be stored in the file *my_app*, that its entry point is the 0-ary predicate `start_my_app/0`, and that the list of library files which the application uses is

```
[cmdline, listutl1, listutl2, misc_db, misc_io,
  objs_run, strings]
```

Then, for step 3, simply issue the following goal:

```
?- save_image(my_app,
       [start_goal( start_my_app ),
        select_lib([cmdline, listutl1, listutl2,
                    misc_db, misc_io, objs_run,
                    strings] ) ] ).
```

You will see a number of cryptic messages, and eventually, the goal will succeed. If you exit the running prolog image, and perform a listing of your working directory, you will find a file *my_app*. Running this file is roughly equivalent to (i.e., will have the same effect as) the following ALS Prolog command-line:

```
alspro <my_app component files> -g start_my_app
```

or, if you are using an extended image,

```
my_ex_alspro <my_app component files> -g start_my_app
```

However, none of the component files need be consulted nor do the library files have to be loaded: they are all pre-packaged into the *my_app* image. This image is suitable for distribution (assuming your program `my_app` is ready for its debut to the outside world).

To explain how this works, let's assume that you are using a statically linked extended image `my_ex_alspro` as your starting point. Then, from start to finish, here is what happens.

1. You issue the command to run `my_ex_alspro` , and it is loaded and running.
2. You issue a consult to load the files making up your application `my_app`.
3. Your submit the goal

```
?- save_image( my_app,
                [start_goal( start_my_app ),
                 select_lib([cmdline, listutl1,
    listutl2,
                              misc_db, misc_io,
    objs_run,
                               strings] ) ] ).
```

4. ALS Prolog loads the library files

```
[cmdline, listutl1, listutl2, misc_db, misc_io,
  objs_run, strings]
```

5. ALS Prolog changes the usual Prolog shell startup to run your goal `start_my_app` instead. For the curious, the definition of the 0-ary predicate `‘$start’/0` at the end of the builtins file *builtins.pro* is retracted, and the following clause is asserted in module `builtins:`

```
‘$start’ :- start_my_app.
```

6. The entire (Prolog) code space is copied out in appropriate format to a temporary file, call it *TF.*
7. The file *my_app* is opened, and the original image `my_ex_alspro` is copied into the file *my_app,* which is left open.
8. The entire temporary file *TF* is copied onto the end of the file *my_app.*
9. A fixup to a certain global variable (call it G) is made and *my_app* is closed.

The ‘copying’ which is carried out is really writing the various code and data elements in the executable object file format appropriate to the given machine and operating system (e.g., a.out, coff, elf, etc.) So the final file *my_app* is really an executable file whose initial segment is the original image `my_ex_alspro`, followed by some ‘extra stuff’. Moreover, the entry point for `my_app` is the original entry point for `my_ex_alspro`, which is just a version of the ALS Prolog image.

When any such image (be it plain ALS Prolog or an extended image) starts up, at a point very early in its initialization, it looks at the global variable G. In the plain ALS Prolog image, or one which has simply been statically linked with some additional C code, G = 0. But in a ‘packaged application’ such as `my_app`, G contains a number effectively telling the system where the end of the image `my_ex_alspro` lies, and where the 'extra stuff', the packaged Prolog code, starts. The system uses this to appropriately allocate memory, and then to load the packaged ALS Prolog code from the application, from the builtins, and from the loaded library files, into the approprate code area. (This is a block move, so it happens very quickly. The difference in the startup times for alspro_b and alspro reflects the difference between loading the builtins *.obp files from disk, and this simple block move of the builtins code. Why? Because alspro is just a packaged version of alspro_b, packaging the builtins.)

Note that the 3-step process of building the application can be combined into a single-step operating system shell command-line action:

```
my_ex_alspro <my_app component files> \
  -g save_image( my_app, [start_goal( start_my_app ),
  \
  select_lib([cmdline, listutl1, listutl2, \
  misc_db, misc_io, objs_run, strings] ) ] ).
```

Such approaches are especially suitable for use in makefiles. (Note the continuation characters '\' at the end of each line except the final one.)

Like the ALS Prolog environments themselves, some packaged applications will want to accept command line arguments. Two predicates can be used in this regard. To obtain the complete original command line, including the name of the program being run, use `pbi__get_command_line/1`. For example, if the packaged application is named foo, then issuing the following operating system command line,

```
foo zipper -f zap
```

would cause any call

```
pbi__get_command_line(X)
```

to yield the value

```
X = [foo,zipper, '-f', zap].
```

If you want the packaged version ("foo") of the application to co-ordinate with the "unpackaged version" developed under the ALS environment, you can use `setup_cmd_line/0`. If the packaged application "foo" starts with start_my_app/0, simply ensure that start_my_app/0 makes a call on setup_cmd_line/0 any time before any call is made on command_line/1.

19 TTY Development Environment

The TTY Development interface for ALS Prolog is similar to the original DEC-10 system constructed in Edinburgh.

19.0.1 Starting up ALS Prolog

Starting up ALS Prolog varies from system to system. Under some systems such as ordinary Unix shells or DOS, one starts ALS Prolog by typing a shell command such as

```
C:> alspro
wizard% alspro
```

or

```
$ alspro
```

or

```
C:\> alspro
```

On others, such as the Macintosh, one clicks on an icon, which opens a windows.

The various versions usually show a startup banner such as the followingt:

```
ALS-Prolog Version 1.7
  Copyright (c) 1987-95 Applied Logic Systems
?-
```

19.0.2 Exiting Prolog

There are several ways to exit ALS Prolog. The normal way to exit is to submit the goal

```
?- halt.
```

from the Prolog shell or from a Prolog program. The second way to exit can only be accomplished from the top level of the Prolog shell. There, you can type a character (such as **Control-D** on Unix) or sequence. of characters (such as **Control-Z** followed by a return on DOS. or # at the beginning of a line on the Mac) which signifies closing the default input stream. See `halt/0` in the reference section. Finally, under the GUI or windowed interfaces, one can select an Exit menu button.

19.1 Asking Prolog to Do Something

The most common way of telling Prolog what you want it to do is to submit a ***goal***. If you are in the Prolog shell, and `?-` is the prompt, then anything you type is considered to be a goal. A goal must end with a period, ‘ . ’, followed by a white space character (carriage return, blank, etc.). This is called a ***full stop***. Goals must be correct Prolog terms. See Chapter 1 of the User Guide for a discussion concerning the construction of correct Prolog terms. The following is an example of a goal submitted from the ALS Prolog shell:

```
?- length([a,b,c],Answer).
Answer = 3
```

The goal issued was `length([a,b,c],Answer)`. The system responded by showing that the variable `Answer` was instantiated with the number `3`, and that the goal succeeded. The Prolog user had to press the `return` key after the

```
Answer = 3
```

was displayed, in order to get the `yes.` printed. Not all goals succeed, of course. For example the following goal fails:

```
?- length([a,b,c], 4).
no.
```

This goal fails because the list `[a,b,c]` is not four elements long.

After submitting a goal in the Prolog shell, if any variables have become instantiated, their values will be displayed to you as in the first example above with `length/2`. When this occurs, the shell waits for you to type either a ‘`;`’ followed by a `return`, or just a `return`. The two choices have the following effect:

- `;` — Forces the goal to fail, thus causing backtracking and retrying of the goal.
- `return` — Causes the goal to succeed.

If a recursive data structure is created, such as is done by the following goal

```
        ?- X = f(X).
```

the part of the Prolog shell which prints answers will go into a loop, and continue writing the data structure onto your screen until the structure gets too deep. When this happens, an ellipsis (`...`) is eventually displayed as shown below:

```
X = f(f(f(f(f(f(f(...)))))))
yes.
```

The actual depth of the structure shown by the answer printer is much deeper than is shown above.

Goals can also be submitted from within a file. There are two forms of submitting goals from files:

- Commands
- Queries

Commands are specified by the `:-` prefix, while queries are specified by the `?-` prefix. The only difference between the two is that queries write the message '`yes.`' to the screen if the goal succeeds, and '`no.`' if the goal fails, while commands do not write any result on the screen.

19.2 How to Load Prolog Programs

There are basically two ways of loading Prolog programs into the ALS Prolog system:

1. When you start `alspro` from the command line you can give a list of files for the Prolog system to load as programs.
2. If you want to load Prolog predicates from inside a program, or from the Prolog shell, you can use the consult/1 builtin in the following manner:

```
?- consult(File).
```

where `File` is *instantiated* to a Prolog program's file name. Alternatively, one can use

```
?- reconsult(File).
```

Finally, one can use the top-level list-as-reconsult construct:

?- [File1, File2,...].

For more information on how to use the consulting predicates, see Section 9.2.1 (*Consulting Program Files*) in the User Guide.

19.3 Stopping a Running Prolog Program

If you wish to interrupt a running ALS Prolog program, simply press the interrupt key (e.g., the Control-C key on Unix, the Control-Break key on DOS, the Apple-Period key combination on the Mac) for your system. You will be returned to the top level of the ALS Prolog shell.

19.4 How ALS Prolog Finds Prolog Files

When a request that a file be loaded is made (such as reconsult(myfile)), ALS Prolog looks for the file in the following manner:

19.4.1 Complex Pathnames

If the file is not a simple pathname, that is, any file with a ‘file-slash’ character (‘/’) in it (on Unix or DOS), or the ’file-color’ character (":") (on the Mac), the file will be loaded as specified. Some examples are:

```
?- consult('/usr/gorilla/banana.pro').
Consulting /usr/gorilla/banana.pro...
.../usr/gorilla/banana.pro consulted.
yes.

On the Mac:
?- consult('Usr:gorilla:banana.pro').
Consulting Usr:gorilla:banana.pro...
...Usr:gorilla:banana.pro consulted.
yes.
```

19.4.2 Simple Pathnames

If the file name is a simple pathname, then the file will be searched for in several directories, as follows:

1. The current directory is searched first;
2. Next, the directories listed on the `ALSPATH` environment variable (if it is defined) are searched in order of their left-to-right appearance;
3. Next, the directory named in the `ALSDIR` environment variable (if it is defined) is searched;
4. Finally, the directory in which the current image resides is searched.

If the specified file is located in any of the indicated directories, it will be loaded into ALS Prolog, and no further search is made for this file. (Thus, if multiple versions of a file exist in some of the indicated directories, only the first will be loaded.) The following example uses the Unix C shell to illustrate the use of the ALS Prolog pathlist. We assume for this example that ALS Prolog was installed in */usr/prolog*. Then the file *dc.pro* (which is one of ALS Prolog examples) will be contained in the directory */usr/prolog/alsdir/examples*. The following illustrates the use of `ALSPATH`:

```
wizard%setenv ALSPATH /usr/prolog/alsdir/examples:/
  usr/gorilla
wizard% alspro
ALS-Prolog Version 1.0
Copyright (c) 1987-90 Applied Logic Systems, Inc.

?- consult(dc).
Consulting dc...
.../usr/prolog/alsdir/examples/dc consulted.
yes.
```

The method used to implement the use of the `ALSPATH` pathlist actually provides greater flexibility than the foregoing discussion indicates. When ALS Prolog is initialized, it reads the Unix `ALSPATH` environment variable (if it is defined), together with the `ALSDIR` environment variable, and uses them to create a set of facts in the builtins module. These facts all have the following form:

```
searchdir(".../.../").
```

The expression within the quotes can be any meaningful Unix path describing a directory (hence the terminal ('/'). At startup time, the assertions correspond to the expressions found on the `ALSPATH` pathlist. Thus, the facts corresponding to the example above would be:

```
searchdir("/usr/prolog/alsdir/examples/").
searchdir("/usr/gorilla/").
searchdir("/usr/prolog/alsdir/").
searchdir("/usr/prolog/").
```

Note that the current directory (or '.' to represent it) does not appear among these facts; however, it is always automatically searched first. Additional entries can be made to this collection of facts by using `assert/1` (or `asserta/1` or `assertz/1`). For example, the goal

```
:-builtins:asserta(searchdir("chimpanze/")).
```

would cause the subdirectory *chimpanze* of the current directory to be searched immediately after the current directory and before any other directories. And

```
:-builtins:asserta(searchdir("../widget/")).
```

would cause the sibling subdirectory *widget* of the current directory to be searched immediately after the current directory and before any other directories. Assertions such as these can be placed in the ALS Prolog startup file (described below) to customize search paths for particular directries. See the User Guide for more information concerning loading files.

19.5 Controlling the Search Path

If you want to be able to consult some of your files that are not in your current directory, and you don't want to use absolute pathnames, you can put the directories where those files reside on a path searchlist called `ALSPATH`. In additon, you can add directories using the comannd-line switch -S at start-up time (see Section 19.7 (*ALS Prolog Command Line Options*)). The following is an example use of the `ALSPATH` variable on Unix or DOS:

```
setenv ALSPATH /usr/eddie/programs:/usr/sue/src/
  prolog
```

If you want to also automatically search the ALS Prolog directory, you could use the following:

```
setenv ALSPATH /usr/eddie/programs:/usr/sue/src/
  prolog:\
            /usr/prolog/alsdir
```

The definition of the `ALSPATH` variable can also be placed in your *.cshrc* startup file. Combining the examples above, your *.cshrc* startup file might include the following lines:

```
setenv ALSPATH /usr/eddie/programs:/usr/sue/src/
  prolog:\
            /usr/prolog/alsdir
```

On DOS, this would look like:

```
set ALSPATH /usr/eddie/programs:/usr/sue/src/
  prolog:\
            /usr/prolog/alsdir
```

Note that even though it is running under DOS, ALS Prolog utilizes Unix-style directory separators.

On the Macintosh, environment variables do not exist. However, one can still utilize the effects of the ALSPATH variable. As noted in Section 1.4, ALS Prolog uses the value of the ALSPATH variable to create and assert facts for the predicate builtins:searchdir/1. The predicate which processes this is called `builtins:ss_init_searchdir/1.` In fact, the reading and processing of ALSPATH, when it exists, is done as follows (in *blt_shl.pro*):

```
ss_init_searchdir
  :-
  getenv('ALSPATH',ALSPATH),
  ss_init_searchdir(ALSPATH).
```

What really happens in the code is that `ss_init_searchdir`/1 takes apart the value it has obtained for ALSPATH, and produces a list of atoms representing the individual directories in the path. It then calls a subsidiary predicate, `ss_init_searchdir0`/1 which recurses down this list, asserting the fact

```
builtins:searchdir(SDir)
```

for each atom `SDir` on the list. So on the Mac, there are two approaches. On the one hand, one can directly make assertions on builtins:searchdir/1 as above to set up the search path. Or, one can directly call `ss_init_searchdir0`/1 with an appropriate argument. So one of the animals examples from the last section would work like this:

```
:-builtins:ss_init_searchdir0(
  ['usr:prolog:alsdir:examples',
    'usr:gorilla']).
```

Such a call can be placed in the Prolog startup file or in one of your source files to occur automatically, as descirbed in the next section.

19.6 Using the Prolog Startup File

When ALS Prolog starts up, it looks first in the current directory and then in your home directory for a file named either *.alspro* (on Unix or the Mac) or *alspro.pro* (on DOS). After the Prolog builtins are loaded the *.alspro* (or *alspro.pro*) file is consulted if it exists. The purpose of the Prolog startup file is to allow you to automatically load various predicates and files which you routinely use, and to carry out possible customizations of your environment such as the modifications to the standard search path described in the previous section.

19.7 ALS Prolog Command Line Options

There are a number of options that can be included on the operating system shell command line when starting ALS Prolog. The following is a list of the options:

-g The option `-g` followed by an arbitrary Prolog goal, instructs ALS Prolog to run the goal when it starts up as if it was the first goal typed to the Prolog shell after the system is started. The goal might have to be quoted depending on the rules of the operating system shell you are running in, and if the goal contains any of your shell's special characters. You do not have to put a *full stop* after a goal, and you can submit multiple goals, provided there is no white space anywhere in the given goals. When the submitted goal finishes running (with success or failure), control is passed to the normal Prolog shell unless the `-b` command line option has also been used, in which case control returns to the operating system shell.

-b The option `-b` prevents the normal the Prolog shell from running. This means control will return to the operating system shell when all command line processing is complete, including processing of source files and execution of `-g` goals.

-q The option `-q` causes all standard system loading messages to be suppressed, including the banner. One of the uses of `-q` is to permit you to use ALS Prolog as a Unix filter. Note that this does not turn off prompts issued by the Prolog shell.

-v The option `-v` turns on verbose mode. This causes all system loading messages, including some which are normally suppressed, to be printed.

-gic The option `-gic` ("generated in current") causes the **.obp* files which are generated for consulted files to be created in the current working directory of the running image when the files are consulted.

-gis The option `-gis` causes the **.obp* files which are created for consulted files to be created in the same directory as the source file from which they were generated.

-giac The option `-giac` causes the **.obp* files which are created for consulted files to be stored in a subdirectory of the current working directory of the running image when the files are consulted; the subdirectory corresponds to the architecture of the running ALS Prolog image. Thus, for example, **.obp* files generated by a Solaris2.4 image will be stored in a subdirectory named *solaris2.4*, etc.

-gias The option `-gias` causes the **.obp* files which are created for consulted files to be stored in a subdirectory of the directory containing the source **.pro* files when the files are consulted; the subdirectory corresponds to the architecture of the running ALS Prolog image. Thus, for example, **.obp* files generated by a Solaris2.4 image will be stored in a subdirectory named *solaris2.4*, etc.

-w The option `-w` causes calls to non-existent predicates to print an error message. This is useful for debugging, but can be annoying otherwise.

-p The option `-p` is used by ALS Prolog to distinguish between command line switches intended for the system and those switches intended for an application (whether invoked with the `-g` command line switch or from the Prolog shell). The `-p` divides the command line into two portions: *All* switches to the left of the `-p` are interpreted as being for the ALS Prolog system, while *all* switches to the right of the `-p` are interpreted as being intended for a Prolog application. To make the latter available to Prolog applications, when ALS Prolog is initialized, a list `SWITCHES` of atoms and UIAs representing the items to the right of the `-p` is created, and a fact command_line(SWITCHES`)` is asserted in module `builtins`. For example, the command line

```
alspro -g my_appl -b applfile -p -k fast -s
initstate foofile
```

would result in the following fact being asserted in module `builtins`:

```
    command_line(['-k',fast,'-s',initstate,foofile]).
```

This assertion is always made, even when `-p` is not used, in which case the argument of `command_line/1` is the empty list. It is important to note that `command_line/1` is *not* exported from module `builtins`, so that accesses to it from other modules must be prefixed with '`builtins:`' as in

```
    ...,builtins:command_line(Cmds),...
```

-s This switch must be followed by a space and a path to a directory. The path is added to the `searchdir/1` sequence. Multiple occurrences of -s with a path may occur on the command line; the associated paths are processed and added to the searchdir/1 facts in order corresponding to their left-to-right occurrence on the command line. All paths occurring with -s on the command line are added to the searchdir/1 facts before any paths obtained from the ALSPATH environment variable.

-A, -a This switch must be followed by a space and a Prolog Goal (enclosed in single quotes if necessary to defeat the OS shell) and is used to force one or more assertions, as follows:

If `Goal` is of the form `M:(H1, ...Hk),` then each of `H1, ..., Hk` is asserted in module `M`. Thus,

```
     alspro -A 'ice_cream:(jerry, ben)'
```

would cause the two facts facts `jerry` and `ben` to be asserted in module `ice_cream`..

If `Goal` is of the form `M:H`, then `H` is asserted in module `M`.

If `Goal` is of the form `(H1, ...Hk)`, then each of `H1, ..., Hk` is asserted in module user. Thus,

```
     alspro -A '(jerry, ben)'
```

would cause the two facts facts `jerry` and `ben` to be asserted in module `user.`

Otherwise, `Goal` is asserted in module user.

Note that occurrences of the `-A (or -a)` switch must occur to the left of any occurrence of the `-p` switch. (This switch was designed for use in makefiles.)

-heap

The option `-heap` followed immediately by space and a number *w* sets the size of the ALS Prolog *heap* to

w *1024,

where *w* is the number of K bytes to allocate. Heap overflow will cause exit to the operating system.

-stack

The option `-stack` followed immediately by a space and a number *w* sets the size of the ALS Prolog *stack* to

w *1024,

where *w* is the number of K bytes to allocate. Stack overflow will cause exit to the operating system.

These two options were formerly only controlled by the use of an environment variable, `ALS_OPTIONS`. Now, either or both the command-line and environment variable method can be used. Use of one of the command-line options overrides use of the corresponding option with the environment variable.

The `ALS_OPTIONS` environment variable is used as follows. If w1 and w2 are similar to the value w described above for -h and -s, then:

Under Bourne shell, Korn shell, and Bash:

```
ALS_OPTIONS=stack_size:w1,heap_size:w2
export ALS_OPTIONS
```

Under csh:

```
setenv ALS_OPTIONS stack_size:w1,heap_size:w2
```

Under MS Windows:

```
ALS_OPTIONS=stack_size:w1,heap_size:w2
```

[Under MS Windows 95, such a line is placed in the AUTOEXEC.BAT file. Under Windows NT, one uses the Environment section of the System Properties control panel.]

20 Using the Four-Port Debugger

The ALS Prolog Debugger allows you to debug a faulty program with the standard four-port model of Prolog execution. You can use the debugger to find where your program is faulty by looking at how procedures are being called, what values they are returning, and where they fail.

The debugger is written in Prolog, so it can be consulted like any other program. If a debugger command is issued and the debugger is currently not loaded, it will be automatically consulted. The debugger is contained in the file *debugger.pro*, which resides in the ALS directory *alsdir*. (On the Macintosh, the debugger is contained in the file *debugger* which resides in the folder *Interfaces*.)

On the Macintosh and the original (real mode) ALS Professional and Student Prologs for the PC, the debugger is an interpretive debugger; i.e., the debugger program implements a complete interpreter for Prolog (in Prolog) which decompiles and interprets the (compiled) code which has been loaded. On all other versions of ALS Prolog, the debugger is a much more sophisticated program (written in ALS Prolog) that utilizes the interrupt facilities of ALS Prolog to directly debug the compiled (native) code produced by the ALS Prolog compiler. It does this without requiring you to set any special flags during compilation (loading).

20.1 The Four-Port Model

The four-port model of Prolog execution provides a conceptual point of view for analyzing the flow of control during execution of a Prolog program. Think of each procedure in your Prolog program as having a box around it with four ports for getting in and out of the procedure.

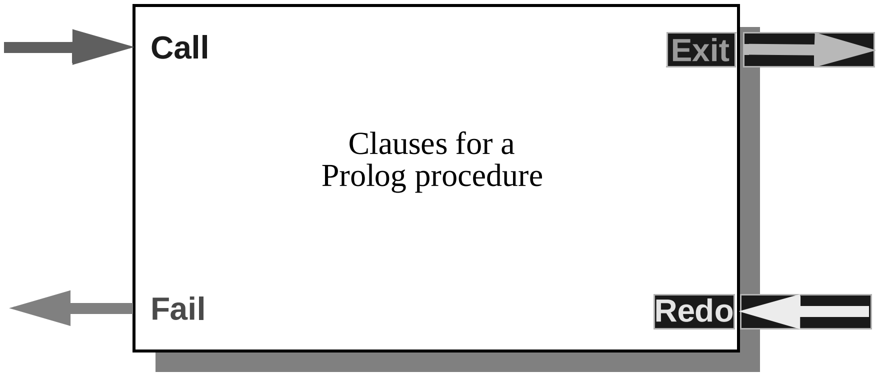


Figure 16. Generic Procedure Box.

The flow of program control can then be viewed as motion through one of the four ports. The ports are:

- `Call` is the entry point (in) to a procedure the first time it is called.
- `Exit` is the port (out) through which execution passes if the procedure succeeds.
- `Fail` is the port (out) through which execution passes if the procedure fails completely.
- `Redo (Retry)` is the port (in) through which execution passes when a later goal has failed and the procedure must try and find another solution, if possible.

Take, for example, the program

```
likes(john,Who) :-
  female(Who),
  likes(Who,wine).
likes(mary,wine).

female(susan).
female(mary).
```

Figure 17 shows model of the procedure `female/1`.

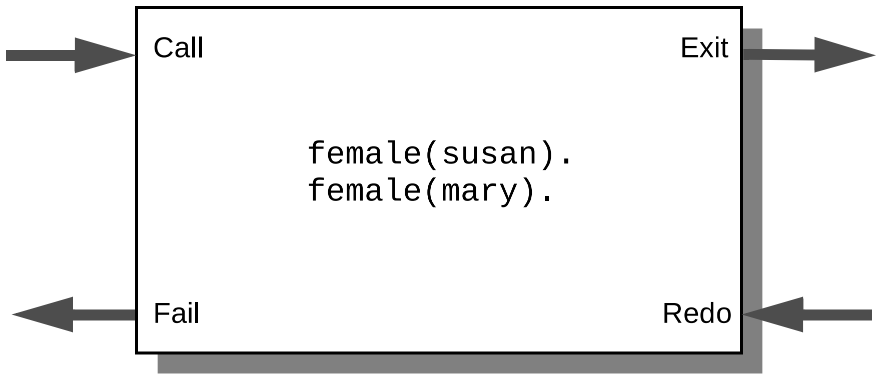


Figure 17. Procedure Box for `female/1.`

Suppose you make the query:

```
   ?- likes(john,Who).
```

The clause for `likes/2` is activated, and the debugger is ready to make the call to `female/1`. It enters the `female/1` procedure through the call port (see Figure 18 (a)) and picks up the first solution, binding `Who` to `susan`. Because the procedure succeeds, execution continues through the exit port of the procedure (as shown in Figure 18 (b)) and continues with the call `likes(susan,wine).`

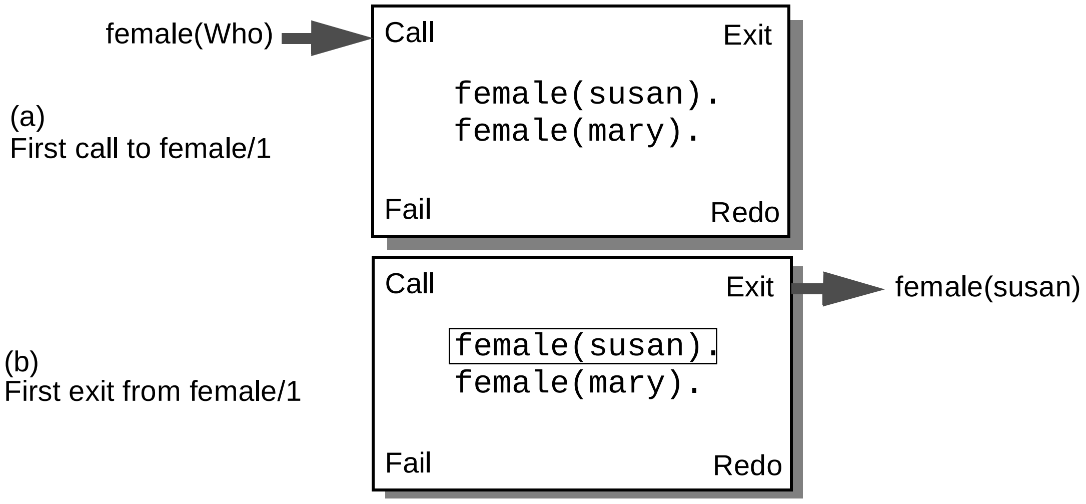


Figure 18. First call and exit tracing female/1.

The call `likes(susan,wine)` fails, because neither clause for `likes/2` matches with `likes(susan,wine)` in the first argument. Because of this failure, another solution to `female/1` is sought. The program re-enters the `female/1` procedure, this time through the redo port (Figure 19 (c)).

Entering a procedure through a redo port means that a solution to the procedure was not accepted in later parts of the program and another solution for the call is required. In the example here, after re-entering the procedure through the redo port, execution will first unbind `Who`, and then bind `Who` to `mary`, leaving the procedure by passing through the exit port, as shown in Figure 19 (d).

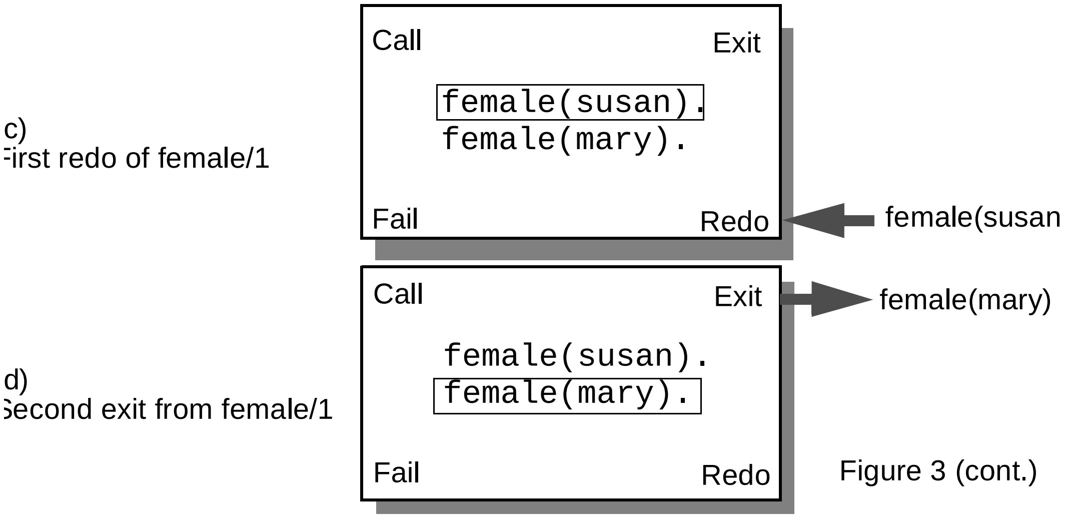


Figure 19. Redo and exit tracing female/1.

The call `likes(mary,wine)` succeeds, so the original goal succeeds:

```
?- likes(john,Who).
Who = mary
```

If you want Prolog to look for another answer, press '`;`' (semi-colon) followed by `Return`. This will cause failure to occur, forcing the search for another solution. In this example, execution re-enters the procedure box for `female/1` through the redo port (See Figure Figure 20 (e)). However, there are no more solutions for `fe-male/1`, so the procedure must fail. Execution then leaves the `female/1` box through the fail port, as shown in Figure 20 (f) . The failure of `female/1` causes the second clause of `likes/2` to be tried. Because the goal does not match the second clause of `likes/2`, the original goal, `likes(john,Who)`, now fails.

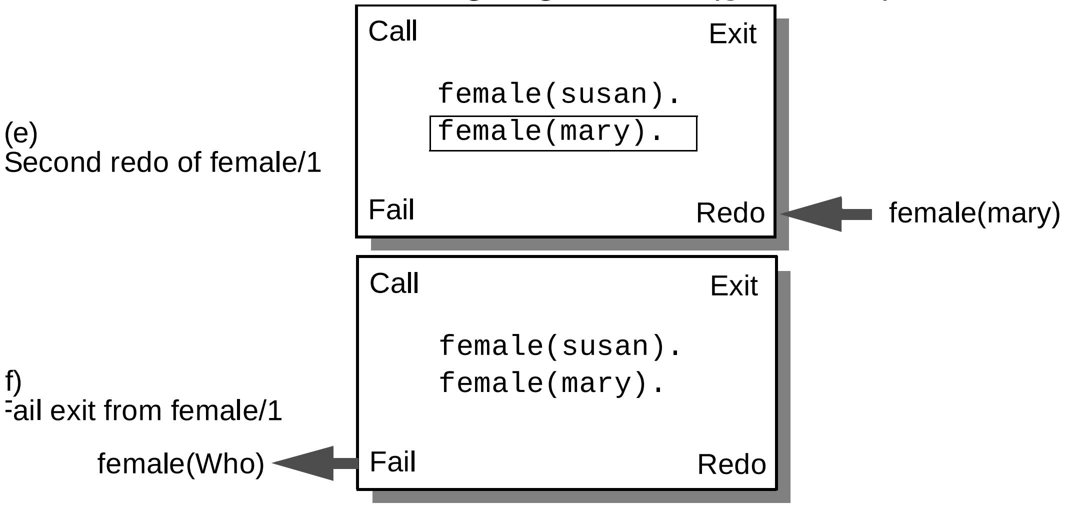


Figure 20. Redo and fail tracing female/1.

20.2 Creeping Along With the Debugger

The debugger helps you to find errors in your program by letting you look at the control flow of the program as well as showing you the variable bindings as the program goes through each of the ports. You can control how much information is printed by the command you give to the debugger when it stops at a port.

As an example, trace the execution of the goal `likes(john,Who)`. You can do this by using the debugger builtin trace/1:

```
   ?- trace likes(john,Who).
```

The debugger will then answer with

```
   (1) 1 call: likes(john,_93) ?
```

This means that the debugger is waiting at the entrance to the call port of the procedure `likes/2`. The current goal is printed for the call, as well as all the arguments to the call. The program text calls the `likes/2` procedure with the arguments `john` and `Who`. The debugger is only able to print out the internal names for variables, rather than the names found in the source code for the procedures in the program. In this case, the variable `Who` appears as `_93`. The number `93` is not important, since it is merely a place holder. The actual number assigned will vary depending on the prior state of the Prolog system.

The integer in parentheses is the number of the procedure box the debugger is currently examining. The next number (following the number in parentheses) is the level of the call. This number tells you the depth of the computation. In this example, the original goal `likes(john,Who)` runs at level 1, and all the subgoals in the clause run at level 2. If the call to female had any subgoals, those subgoals would take place at level 3.

You have a choice of how the debugger is going to continue examining the program. When you want to move slowly through the program, looking at everything there is to see, you use the *creep* command. To creep, you should respond with '`c`' followed by `return` at the `?` prompt of the debugger. `Return` alone will also make the debugger creep. However, for the sake of readability, the '`c`' will appear explicitly in all the examples.

```
   (1) 1 call: likes(john,_93) ? c
   (2) 2 call: female(_93) ?
```

The debugger is now at the call port for the procedure `female/1`. You can see by the last line that the program is calling `female/1` with one unbound variable and that this call is taking place at level 2 of the computation. To continue the computation, you can creep ahead:

```
   (2) 2 call: female(_93) ? c
   (2) 2 exit: female(susan) ?
```

After entering `female/1`, the program picks up the first solution and binds the variable `_93` to `susan`. After this, the program leaves the exit port for `female/1` and returns to the interior of the first clause for `likes/2`.

```
   (2) 2 exit: female(susan) ? c
   (3) 2 call: likes(susan,wine) ?
```

The debugger now enters `likes/2` through the call port. The number in parentheses has changed from `2` to `3` to show that this is a new procedure call. However, the call depth is still `2`.

```
(3) 2 call: likes(susan,wine) ? c
(3) 2 fail: likes(susan,wine) ?
```

Because there are no clauses in `likes/2` that match `likes(susan,wine)` the call to `likes/2` fails, and the debugger exits `likes/2` through the fail port.

```
(3) 2 fail: likes(susan,wine) ? c
(2) 2 redo: female(_93) ?
```

The debugger now re-enters `female/1` through the redo port, because the call to `likes/2` has failed, causing the search for another solution to `female/1`. Note that the number in parentheses becomes `2` again because procedure box `2` (for `female/1`) is being re-entered.

```
(2) 2 redo: female(_93) ? c
(2) 2 exit: female(mary) ?
```

Another solution to `female/1` is found, so the debugger exits through the exit port, and then enters `likes/2`. Since the call to `likes/2` is a new call, the number in parentheses becomes `4`.

```
(2) 2 exit: female(mary) ? c
(4) 2 call: likes(mary,wine) ? c
(4) 2 exit: likes(mary,wine) ? c
(1) 1 exit: likes(john,mary) ? c
Who = mary
```

Creeping the rest of the way through the program, you end up with a solution to the query:

```
?- likes(john,Who).
Who = mary ;
```

If you ask to see another solution to the query (by typing a semicolon), the debugger will pick up where it left off:

```
(4) 2 fail: likes(mary,wine) ?
```

The call `likes(mary,wine)` fails, and the computation creeps along.

```
(4) 2 redo: likes(mary,wine) ? c
(4) 2 fail: likes(mary,wine) ?
```

The debugger re-enters `female/1` through the redo port, but because no more solutions can be found, it leaves through the fail port. The rest of the trace looks like this:

```
(4) 2 fail: likes(mary,wine) ? c
(1) 1 redo: likes(john,_93) ? c
(1) 1 fail: likes(john,_93) ? c
no.
```

20.3 Additional Debugger Commands

If your program is large and/or complicated, looking at every port call in the program's execution is often tiresome and unnecessary. Once a procedure is debugged, it is no longer necessary to trace its execution in detail.

However, other procedures may still contain errors. In this case, you want to examine the execution of the questionable procedures without looking at the execution of the correct portions of the program. This can be done by limiting the amount of information printed by the debugger..

20.3.1 Skipping Portions of Code

The first method of limiting information is the *skip* command. This causes the debugger to run the current goal, while suppressing the port information for all subgoals in the interior of the call. However, if the traced goal fails because of the failure of a goal submitted after the traced goal, the debugger will print out all subgoals of the traced goal at their fail port. The following example demonstrates this behavior:

```
?- trace likes(john,Who).
(1) 1 call: likes(john,_93) ? s
(1) 1 exit: likes(john,mary) ? c
Who = mary;
(4) 2 fail: likes(mary,wine) ? c
(2) 2 fail: female(_93) ?
(1) 1 redo: likes(john,_93) ?
```

In this trace, the debugger skips the execution `likes(john,Who)`, and doesn't stop at any of the ports inside the call to `likes/2`. However, when the call fails because of the **;\hveleven** return command in the Prolog shell's answer showing mode, the fail ports from the interior of that call are printed.

20.3.2 Ignoring Even More Execution

The *big skip* command is similar to the skip command above, except that the internal failure ports are not printed when a call fails. You tell the debugger to do a big skip by typing **S** (uppercase 'S') followed by \ReturnKey . A big skip is also *much* more efficient that a normal skip.

```
?- trace likes(john,Who).
(1) 1 call: likes(john,_93) ? S
(1) 1 exit: likes(john,mary) ? c
Who = mary ;
(1) 1 fail: likes(john,_93) ?
```

In this case, only the original call to `likes/2` prints out a failure report. All the other failures are suppressed by the big skip in call number 1.

20.3.3 Getting Back Ignored Execution

Sometimes you might skip over a call only to find that the call failed for some unknown reason. In other cases, the variable instantiations produced by a call are not what you expected. The *retry* command gives you another chance to trace the same call again, presumably in more detail. In the following example, the debugger is waiting at the exit port of call number 1. You can see exactly why `likes(john,mary)`succeeded by retrying the call and creeping through its execution:

```
(1) 1 exit: likes(john,mary) ? r
(1) 1 call: likes(john,_93) ? c
(2) 2 call: female(_93) ? c
(2) 2 exit: female(susan) ?
```

After a retry command, the state of the program is reset to the way it was just before the retried goal ran, except for side effects. Side effects not undone by a retry include modifications to the database via `assert/1` or `retract/1`.

20.4 Changing the Leashing

After watching all of the ports during a trace, you might find that you want don't want to stop at every port that passes by. For example, it might not be useful to see the fail and exit ports in the execution of your program. By changing the *leashing* of the debugger via leash/1, you can control which ports are actually printed. The following goal disables the fail and exit ports, and enables the call and redo ports.

```
?- leash([call,redo]).
```

If you only want to set leashing on one port, you can omit the square brackets, as in

```
leash(call).
```

`leash(all)` enables the printing of every port.

20.5 Spying on Code

The spy/1 builtin allows you to set *spy points* in your program. A spy point will interrupt the normal execution of your program and begin tracing at every call to a particular procedure. This is useful when most of your program is working correctly, but a few isolated procedures still need attention. The following example uses a program that takes derivatives of a function and simplifies the result:

```
diff :-
  write('type in: Var,Fn'), nl,
  read((X,F)),
  diff(X,F,Answer),
  write(Answer), nl,
  simplify(Answer,Simple),
  write(Simple), nl.

simplify(A+B,Sum) :-
  number(A),
  number(B), !,
  Sum is A+B.
simplify(Exp,Exp).
```

Suppose that you are confident that `diff/3` itself works correctly, but suspect that there are bugs inside `simplify/2`. Rather than tracing the entire program, you can place a spy point on `simplify/2`:

```
?- spy simplify/2.
```

When your program attempts to call `simplify/2`, the debugger will take control and let you begin tracing.

```
?- diff.
type in Var,Fn
x,x+x.
1+1
(1) 1 call: simplify(1+1,_255) ? c
(2) 2 call: integer(1) ? c
(2) 2 exit: integer(1) ?
```

The debugger only stops at the ports for `simplify/2` and its subgoals. When `simplify/2` succeeds or fails, normal program execution resumes until the next spy point. In this case, there are no more spy points, so the program simply prints out its answer.

```
(1) 1 exit: simplify(1+1,2) ? c
2
```

If for any reason `simplify/2` tries to find another solution, the debugger will wake up again at the redo port and allow you to continue tracing.

20.6 Leaping Ahead

The debugger also lets you to *leap* from the trace of a call to the next spy point. Leaping suppresses the normal action of the debugger, allowing the program to continue uninhibited until it runs into the next spy point.

In the following example, spy points are placed on `diff/0` and `simplify/2`. As soon as the program starts, the spy point at `diff/0` activates the debugger. Then a leap command suppresses the debugger until the call to `simplify/2`, where the debugger picks up again:

```
?- spy simplify/2, spy diff/0.
yes.
```

```
?- diff.
(1) 1 call: diff ? l
type in: Var,Fn
x,x+x.
(7) 2 call: simplify(1+1,_255) ? s
(7) 2 exit: simplify(1+1,2) ? c
(8) 11 call: write(2) ?
```

20.7 Turning Off Spy Points

The nospy/0 builtin removes all spy points from your program, while `nospy/1` removes a specific spy point:

```
?- nospy a/1.
Spy point removed for user:a/1.
yes.
```

20.8 Getting Help

Typing ‘h’ at the `?` prompt of the debugger gives a summary of the debugger commands.

20.9 Exiting the Debugger

There are two ways to leave the debugger. The *abort* command (`a`) abandons the current computation, and returns control to the Prolog shell. The *exit* command (`e`) leaves the debugger, causing ALS Prolog to exit.

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