micro-PROLOG 3.1
Programmer's Reference Manual

CP/M and MSDOS Versions *

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This manual describes the micro-PROLOG system from the programmer's point of view. It describes the syntax of micro-PROLOG, the various built-in features, and how to interact with the system. Also included is a chapter which describes the machine code level interface, and how to augment the system with built-in predicates. In so far as it is specific to any particular micro-PROLOG implementation, this manual describes the CP/M80, CP/M86 and MSDOS/PCDOS versions.

The specification of micro-PROLOG is subject to change without notice.

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1. Introduction

This manual describes the micro-PROLOG logic programming system. PROLOG is a computer language based on predicate logic, in particular the clausal form of logic and resolution inference [Robinson 1965,1979]. micro-PROLOG is an interpreted version of PROLOG tailored for interactive use on micro-computers. It is the end product of four years of continuous development in the field of PROLOG systems on micros. It is a mature system, which while it runs on a micro computer, does not sacrifice any significant features of the PROLOG systems on large main-frame computers. Indeed, it contains many more features than some of the main-frame systems.

The first PROLOG (which stands for PROgramming in LOGic) was implemented in 1972 in Marseilles by Colmerauer and Roussell [Colmerauer 1973] as an interpreter in the medium level programming language ALGOL-W. A more efficient and improved interpreter was then built in 1973 [Roussell 1975], this time in FORTRAN. This implementation reached a wide audience in countries as far afield as Poland, Hungary, U.S.A., Canada, Sweden, Portugal, Belgium and the U.K. Building on and extending the implementation techniques of the Marseilles PROLOG, there have been several other implementations, the principal ones being the Edinburgh DEC-10 PROLOG [Warren et al. 1978], Waterloo PROLOG [Roberts 1977], the Hungarian M-PROLOG [Szeredi 1982] and a new implementation from Marseilles [Kanoui & Van Caneghem 1980]. The Edinburgh implementation incorporates a compiler, the first to be written for the language. Recently, interest in PROLOG has been stimulated by the Japanese decision to use it as the core language for which they will design their fifth generation computers. The Japanese interest derived from the 'academic export' of the Marseilles and DEC-10 implementations to Japan.

1.1 micro-PROLOG

To allow a compact and efficient implementation, mostly written in assembler, the syntax of the directly interpreted programs, called the standard syntax, and the built-in supervisor of micro-PROLOG are quite rudimentary. The standard syntax is very close to the list syntax of LISP and the supervisor is a small micro-PROLOG program that provides only the necessary program development and query facilities. The most important feature of the supervisor is that it is extensible. By loading other micro-PROLOG programs, wrapped up as modules, one can considerably enhance the program development and query facilities of the built-in supervisor. Several such supervisor extension modules are provided with the micro-PROLOG system.

Modules are an important program structuring facility of micro-PROLOG which is one of a very few implementations of PROLOG to support modules. micro-PROLOG modules are named collections of relation definitions that communicate with other programs via import/export name lists. All other names used in the module are local to the module. This localised name feature enables modules developed at different times, or by different programmers, to be used together without fear of a name clash. Finally, exported names of relations defined in the module can be used in other

programs as though they were primitive relations of micro-PROLOG. Hence the role of modules in extending the facilities of the supervisor.

One collection of supervisor extension modules, in the file SIMPLE.LOG, accepts program and queries expressed in the sugared, easy to read sentence syntax described in the book "micro-PROLOG: Programming in Logic". It compiles these into the standard syntax. It also incorporates an interactive program text editor which first decompiles program clauses so that they can be displayed and edited in the sentence syntax. The facilites of SIMPLE and the sentence syntax of SIMPLE programs are fully described in Chapter 5.

Another suite of program modules, in the file MICRO.LOG, provides all of the program development and query modes of SIMPLE but for programs and queries written in the standard syntax augmented with functional expressions. The facilities provided by the MICRO modules are described in Chapter 6.

In the file DEC.LOG is a program development system which allows the use of the syntax and most of the primitives of the DEC-10 version of PROLOG as described in [Clocksin & Mellish], as well as the facilities of the built-in supervisor. Because this front end is a large program, occupying some 33 kilobytes of program space, it is distributed only with micro-PROLOG systems for machines with more than 64kb memories. The DEC-10 development system is described in chapter 7.

Other utility modules are provided in the files :

EDITOR.LOG {a structure editor},
TRACE.LOG {a full trace package},
SPYTRACE.LOG {allows spy-tracing of individual programs},
MODULES.LOG {allows construction and editing of modules},
EXREL.LOG {a package that allows disc files to be used as virtual memory for programs},
SIMTRACE.LOG {a trace package for use with SIMPLE},
DEFTRAP.LOG {a simple error handler},
ERRTRAP.LOG {an error handling and recovery utility}.

The EDITOR, TRACE, SPYTRACE, MODULES and EXREL programs are described in Chapter 4. SIMTRACE and DEFTRAP are described in Chapter 5 along with SIMPLE, and ERRTRAP is described in Chapter 6 along with MICRO.

All of these utility modules can be optionally loaded as extensions to the built-in supervisor and deleted when they are no longer needed. Beginning micro-PROLOG programmers usually start by using the SIMPLE extension, in the manner described in the book "micro-PROLOG: Programming in Logic", and then when they are completely conversant with all its facilities, they move over to using MICRO or their own micro-PROLOG implemented aid to program development. Experienced micro-PROLOG programmers, like LISP programmers, have no problem using the micro-PROLOG standard syntax.

1.2 Extensibilty

A design objective of micro-PROLOG was to build a kernel system that could easily be extended by the user and tailored to his requirements. Program modules allow extension above, they allow new supervisor commands to be implemented in micro-PROLOG

and then protected and used as though they were primitive features of the system. On CP/M80 and MS-DOS systems, micro-PROLOG can also be extended below. New primitive relations can be added using a special system provided interface to machine code programs. This interface is described in Appendix F. The primitive relations already built-in to the interpreter are fully described in Chapter 8.

A further form of extension is the user defined error handler written as a micro-PROLOG program. The built-in error handler of the interpreter simple reports the error usually by just an error number. However, if there is a micro-PROLOG program for the relation name "?ERROR?" this program will be invoked to handle the error. Details of all the error conditions are given in Appendix C, and the way that they can be handled by such an error handler is described in Chapter 3. The program development systems SIMPLE and MICRO already contain error handlers.

The system can be further extended by the user defining his own supervisor. By implementing his own 'shell' a programmer can completely hide micro-PROLOG from the user, giving his own command language and error reporting. This "<USER>" supervisor is fully described in Chapter 3, and is used by the DEC-10 front end.

1.3 Version 3.1

This reference manual is for version 3.1 of micro-PROLOG for CP/M 2.x Z80 and 8086 MSDOS and CP/M86 computers. This is the sixth released version of micro-PROLOG. (The previous ones were 2.02, 2.11, 2.12, 3.0 and 3.05). In version 3.0 a large number of changes and improvements were made to the system compared with 2.12. Extra facilities included: floating point arithmetic, error trapping and user defined error recovery, record oriented input/output and the treatment of physical devices such as the console as special serial files. The supporting micro-PROLOG software was also extensively rewritten and improved for version 3.0.

Version 3.1 adds a further number of enhancements to version 3.0 but mainly differs with respect to the support software. These enhancements include a user-definable supervisor, automatic query execution on load, enlarged type-ahead and edit buffers, and several useful input/output programs.

The SIMPLE extension to the supervisor has also been changed. This now accepts sentences in a slightly different syntax. However all programs developed using the SIMPLE of version 3.0 can be used with the SIMPLE of version 3.1. The old compiled programs will be de-compiled by the new SIMPLE and displayed in the new syntax. The MICRO supervisor extension for 3.1 is also slightly extended and improved, as is the EDITOR.

The DEC-10 front end is also new for version 3.1 on 8086/8 machines. It is a good example of how it is possible in micro-PROLOG to build a system that completely hides the underlying micro-PROLOG system.

1.4 User preparation

To be able to exploit the full power of micro-PROLOG 3.1 we recommend that you study the book "micro-PROLOG: programming in logic" [Clark & McCabe 1984] in conjuction with Chapter 5 of this Manual, doing all the exercises given in the book using the system. (Sample solutions are given in an appendix of the book.) Then read the whole of the Manual. This effort to become fully conversant with all the facilities of micro-PROLOG will be well rewarded.

1.5 Notation conventions

The manual includes many examples of small micro-PROLOG programs to illustrate the use of some facility. All example programs are given in heavy type. Heavy type is also used when giving the name of a relation or module in the text.

In specifying the syntax of some micro-PROLOG construct the notation

<type>

is used to indicate that a field or sub-expression can be any instance of the indicated type. For example,

LOAD <file name>

is used to indicate that any allowed file name can be used in the LOAD command. <type1> and <type2> will be used when two uses of the same type can be different. The use of the different subscripts does not imply that they must be different.

One syntactic category, that of <term>, is used so often that the abbreviations t, t1, t2 etc. are used for <term>, <term1>, <term2>. The form

t1 ... tk

is used to indicate a sequence of k terms. Unless the condition k>0 is explicitly given, this form includes the case when there are no terms in the sequence. Again, the use of the different subscripts does not imply that the terms must be different, it implies only that they may be different.

To indicate the hitting of the RETURN or ENTER key <return> is used.

Finally, some example programs will be given with associated comments between "{", "}" brackets. They are not part of the program and should not be typed if you enter the program. micro-PROLOG does not accept comments in this form.

WARNING

This manual is not an introduction to micro-PROLOG programming. It is intended to be used as a reference manual by the programmer who already has some knowledge of PROLOG programming to the extent covered by the companion micro-PROLOG book. For an introductory text on the general ideas of logic programming we recommend the book "Logic for Problem Solving" [Kowalski 1979].

The reader should also have some knowledge of the host operating system, or be able to access a manual for that system.

2. Standard syntax of micro-PROLOG

Most mainframe PROLOG systems nowadays have a complex grammar based on operator precedences built into them. In micro-PROLOG a much simpler syntax is used, which is economical but very expressive. It is also ideally suited to the memory constraints of small micro computers.

The underlying syntax of micro-PROLOG programs, called the standard syntax, is modelled on LISP syntax [McCarthy 1962]. If a richer syntax is desired it has to be supported by a front end micro-PROLOG program that compiles into the standard syntax. In this chapter we describe the standard syntax.

In Chapter 5 a more user friendly syntax that is compiled into the standard syntax by the SIMPLE extension for the supervisor is described. The SIMPLE supported syntax is just one option for a more elaborate syntax.

There are only four different kinds of syntactic objects that micro-PROLOG knows about: Numbers, Constants, Variables and Lists. They are all different kinds of Term.

The only data constructor in micro-PROLOG is the list constructor |. Lists constructed using | can be written in a specially condensed syntax as in DEC-10 PROLOG and LISP. Other PROLOG systems do allow other kinds of data constructors; these can be easily simulated (with no great loss of efficiency) using lists.

2.1 Character set

micro-PROLOG uses an 8 bit ASCII character set, including any special graphics characters provided above 128 by any particular machine. The characters are represented internally by 8 bit numbers in the range 0..255.

2.2 Numbers

Numbers are either integers or floating-point numbers. An integer is any number with no fractional part.

A Positive integer is written as a contiguous sequences of digit characters, with no leading sign character. A negative integer is a sign character (-) contiguously followed by a positive integer. A sign character not directly followed by a positive integer is not regarded as the sign of a number. Integer precision is maintained for numbers between -99999999 and 99999999 inclusive. The following are integers:

```
9821        211327        -32768        0
```

Floating point numbers can also be used. They are written in fairly conventional notation, as illustrated below:

```
2.34        10.3e99        12.003E-100        -0.81
```

One and only one period must be present in a floating point

number. As with an integer, it must start with a digit or a minus sign and a digit. The e exponent is optional, but if used it must be contiguous to the number and must be contiguously followed by an integer. The following are not floating point numbers:

```
.9          {starts with .}
3e-22       {no .}
34 e3       {space before e}
-.7e45      {no digit after -}
56e4.8      {exponent not an integer}
```

Floating point numbers may be written in fixed point notation (eg 123.45) or scientific notation (eg 1.2345E2), but all numbers are printed by the system according to the following rules:

> If a number can be represented by 8 digits, a sign (if necessary) and a decimal point (again if necessary), without any loss of precision, then it is displayed as a standard decimal number (eg 123.45) or integer.
>
> All other numbers are displayed in scientific notation:
>
> 9.9999999E99
>
> but with only the significant digits displayed - trailing 0's after the . are suppressed.

This means in practice that all numbers with magnitudes between 1 and 99,999,999 inclusive are displayed without exponent, and any numbers with magnitude between 0.0000001 and 0.9999999 are displayed without exponent, provided that there are no digits afer the 7th decimal place.

```
     Thus      12345.678      displays as 12345.678
and            12345678       displays as 12345678
but            123456789      displays as 1.2345678E8

     also      1.234567E-1    displays as 0.1234567
but            1.2345678E-1   displays as 1.2345678E-1.
```

On CP/M80 and MSDOS systems numbers have up to 8 digits of precision, and have a exponent in the range -127 to 127.

As with integers, only negative floating point numbers have a sign character in front of them, positive floating point numbers do not have a sign character. If you enter +6.86 micro-PROLOG will interpret this as a sequence of two terms, the constant + and the positive number 6.86.

Note that an integer is a number with no digits to the right of the decimal point, and therefore micro-PROLOG allows free mixing of integers and floating point numbers in a generally unrestricted manner.

2.3 Constants

Constants are the simple unstructured objects of micro-PROLOG. They are used to name individuals such as fred, A1. They are also used to name relations such as member-of, father-of.

A constant is normally written as a alphabetical character (a letter), followed by a sequence of letters and digits (though see definition of variable below). This is similar to the way identifiers are written in conventional programming languages. The - character also counts as an alphabetic character in a sequence of letters and digits. This can be used to split up long names with several English words.

Constants can also be written using the non-alphanumeric characters such as . ! , etc. This kind of constant is written as any sequence of symbolic characters (or graphic characters supported by the machine) other than:

( ) |

which have a special syntactic role, and

{ } [ ] < >

which are always interpreted as single character constants.

The symbols that can be used to form a symbolic constant include:

! # $ % & ' = - ^ ~ \ @ ` ; : , . / + * ?

Thus,

** ! ?? — :=

are all symbolic constants.

Finally, a constant can also be written as a quoted sequence of characters, in which case there are no restrictions on the characters that can be used in the constant. A quoted constant consists of a sequence of characters surrounded by the double quote character: ". Examples of quoted constants are:

"1" "The man" "?ERROR?" "$100" "<SUP>"

A quoted constant can include a space, as in "The man", it can also include a new line or a tab. Outside a quoted string, these act as separators. Thus,

The man

is a sequence of <u>two</u> constants.

ASCII control characters can also be included in a quoted constant. This is useful for testing character input, or for positioning the cursor on a terminal which has cursor control. When printed using the micro-PROLOG P relation, a cursor control character in a quoted constant will move the cursor.

To put a control character in a quoted constant enter ~<letter> where ~ is the tilde character (ASCII 126), and

<letter> is the letter of the key you would press in the control-key combination for the control character. Thus, to insert control-A enter ~A. micro-PROLOG will convert this ~A in the quoted constant into ASCII control code for control-A. When you list the program the occurrence of control-A in the constant will be displayed as ~A.

In a quoted constant ~ acts as an escape character causing micro-PROLOG to interpret the next character in a special way. To enter ~ in a string you must use ~~. Thus, "~A~~" is the constant comprising two characters: control-A followed by ~.

An ~ character followed by the quote character means a quote character in the string.

```
"A quoted ~" string"
```

has the text:

```
A quoted " string
```

Note that the use of tilde (~) as the escape character in version 3.1 is a change from the convention used in earlier versions of micro-PROLOG. In versions 3.0 and 3.05, the @ character was used as the escape. This change has been necessitated by the enhancement of micro-PROLOG's character set to include all 256 ASCII characters. Under the old convention, ASCII 0 would have been written as "@@", which would be ambiguous since it also means the @ character itself. There is no control-tilde character, hence the new convention.

Although constants can be of any length, only the first 60 characters of a constant are significant, and only these 60 characters are stored. This applies to quoted constants as well as other kinds of constant.

2.4 Variables

Variables are represented by alphanumeric names which consist of a single letter optionally followed by a contiguous positive integer which has the role of a subscript. The first character must be one of the variable prefix characters, which in standard micro-PROLOG are: X, Y, Z, x, y & z.

So, for example, x, X1 and Y30 are variable names since they consist of a variable prefix character contiguously followed (if at all) only by digits, whereas yes, x12c are not variable names. The integer which follows the variable prefix character should be in the range 1..127, otherwise two apparently distinct names will be mapped to the same variable.

(WARNING: x and x0 are the same variable because x is implicitly subscripted with 0. Similarly, x3 and x03 are the same variable because 3 and 03 are the same integer subscript. The subscript is not the digit sequence but the positive integer that the sequence denotes.)

When a term is read in, and a variable is recognised in the term, the variable is converted into a special internal form and the actual variable name used is discarded. All occurrences of the same variable name in the term are converted into the same internal form. However, when the term is printed the original

name of the variables are not available. Instead, the variables in the term are displayed with names taken from the sequence X, Y, Z, x, y, z, X1, .., z1, ... The first variable in the term is given the name X, the second is given the name Y, and so on.

2.4.1 A note on separators

Variables, constants and numbers are generally separated by one or more of the separator characters: space, carriage-return/new-line, tab. The actual number of separators is not important.

See Section 2.10 for a fuller description of micro-PROLOG's lexical syntax. A separator character is not always necessary in order for micro-PROLOG to determine the end of one syntactic object and the beginning of another. On the other hand, insertion of a separator never does any harm.

2.5 Lists

Lists are the structured objects of micro-PROLOG. The simplest list is the empty list

```
()
```

which is written as a left (round) bracket followed by a right (round) bracket (separated by any number of spaces, including none). If there are terms inside the brackets we have a non-empty list. Thus

```
(2 3 5)
```

is a list of the three integers 2, 3, 5. The spaces between the integers are important. The list

```
(235)
```

is the list of one integer 235.

The objects in a list can be any term, including another list. For example,

```
((2 3) apple x (-2.3 &&))
```

is a list of four objects:

a sublist (2 3) of the two integers 2, 3
the constant apple
the variable x
a sublist of two objects: the floating point number -2.3 and the graphic constant &&.

As in LISP, sublists can be nested to arbitrary depth, e.g.

```
((a (b c)) ((d)) ((e) f) h))
```

is a list of three sublists.

2.5.1 The list constructor |

Internally, non-empty lists are represented as structures built up from the empty list by a sequence of |-constructions. | is the micro-PROLOG list constructor analogous to the LISP dot. For example,

```
(a b c)
```

is represented internally as

```
(a|(b|(c|()))).
```

The inner-most expression (c|()) represents the list constructed from the empty list by adding c as a front element. That is, (c|()) is the internal representation of the single element list (c). So (b|(c|())) is the list (c) with b added as a front element. In other words, it is the internal representation of the list (b c). Finally,

```
(a|(b|(c|())))
```

is the list (b c) with a added as a front element, which is the list (a b c).

The notation (t1 t2.....tn) for a list of n terms is just an accepted abbreviation for the explicitly constructed list

```
(t1|(t2|....(tn|())....))
```

More generally,

```
(t1 t2....tn|t)
```

is an accepted abbreviation for the explicit construction

```
(t1|(t2|....|(tn|t)....))
```

when t, as well as each of t1 .. tn, is any term - i.e. a number, constant, variable or list. The | should be read as: followed by. The above term is the list of the k elements t1, t2,..,tk followed by t.

examples

```
(a b c|x)
```

is the list comprising the sequence a, b, c followed by x. A list term of the form

```
(t1|t2)
```

is the list comprising the term t1 followed by t2. t1 is called the head of the list and t2 is called the tail.

Not all keyboards can generate the vertical bar character (|), and so micro-PROLOG contains an alternative list constructor which is two full-stops ".." . This is a special reserved graphics token (see 2.10 for more information about tokens). Examples of its use are:

```
(john mary .. X)    is equivalent to:   (john mary|X)
(nice going ..)     is a syntax error:  (nice going|)
```

(nice going "..") is a list of three constants.

Note that micro-PROLOG does not store the original text of your program, and when you list a program and dot-dot list constructors will be replaced with bars (or whatever character is displayed for ASCII code 124).

2.5.2 List patterns

Any list term with variables is a list pattern. The above

```
(a b c|x)
```

is a list pattern representing any list that begins with the constants a, b, c in that order. Since x may be the empty list, the list (a b c) is covered by this pattern. List patterns have a crucial role in micro-PROLOG. Relations over lists are defined using list patterns. Further examples of list patterns are:

(i) `(x|y)`

represents any list comprising at least one element x. Again, since y can be the empty list, this includes the single element list (x). Note that (x) is also a list pattern, representing any list of exactly one element.

(ii) `((x|y)|z)`

represents any list that starts with a non-empty list (the pattern (x|y). Since z and y can both be the empty list, the list pattern ((x)), denoting a singleton list with a singleton list as its only element, is a special case of the pattern ((x|y)|z).

(iii) `(x1 x2 (x3 x4))`

is a list of three elements, whose third element is a list of two elements.

(iv) `(x1 x2|y)`

is a list of at least two elements x1 x2, in that order. It covers the case of a list of exactly two elements since y may be ().

In each of the above patterns the variables represent any term, including lists. There are no types in micro-PROLOG over and above types of list structures represented by list patterns. Variables always represent any term.

Although the bar is the only data constructor in micro-PROLOG, which is a major difference between it and other PROLOGs, other constructors can easily be simulated by using list notation. In most PROLOGs, any constant f can be introduced as a data constructor with f-structures denoted as terms of the form

```
f(t1,...,tn)
```

In micro-PROLOG, you can represent this, as in LISP, as the list

```
(f T1 ... Tn)
```

where Ti is the list representing the term ti and the terms are

separated by spaces not commas.

All micro-PROLOG constructs are expressed in terms of the four types of term discussed so far: Numbers, Constants, Variables and Lists. The higher level syntactic constructs such as atoms and clauses make use of these basic objects, and they are generally list structures.

2.6 Atoms

Atomic formulae, or atoms, are the primitive sentence forms out of which program statements and queries are constructed. In the usual syntax of predicate logic an atomic formula is an expression of the form

Rel(t1,..,tn)

where Rel is a relation name (more formally, predicate symbol) and t1,..,tn are its argument terms. In micro-PROLOG, the atomic formula is written as the list

(Rel t1 .. tn)

comprising the relation name followed by the sequence of arguments. There are no separating commas. Spaces are used if needed (see section 2.10).

Example

(father-of tom bill)

is the atom which expresses the relation of father-of between tom and bill.

The relation name of an atom, that is the head of the atom list, must be a constant. (But see section 2.9).

2.7 Clauses

All PROLOG program statements correspond to a restricted form of sentence of predicate logic called Horn implications, or definite clauses. These are sentences of the general form

<atom> if <atom1> and <atom2> and...and <atomk>, k≥ 0

in which each variable appearing in the sentence represents any term. In the micro-PROLOG standard syntax the logical connectives if and and are dropped, and the clause becomes the list of atoms

(<atom> <atom1>...<atomk>)

Since each atom is itself a list, a clause is a list of sublists in which each sublist is a list that begins with a constant which is a relation name. (But see section 2.9 for exceptions.) The first atom is the head of the clause, the remaining atoms comprise the body of the clause.

Examples

(i) ((father-of tom bill))

is the unconditional statement that the atom

(father-of tom bill)

represents a true fact.

(ii) ((App () x x))

is the unconditional statement that for all x

(App () x x)

is an instance of the Append relation.

(iii) ((App (x|y) z (x|y1)) (App y z y1))

is the conditional statement that for all x, y, z and y1

(App (x|y) z (x|y1))

is an instance of the App relation if

(App x y y1)

is an instance of the App relation. These are both true statements when (App x y z) is understood to mean that z is the result of appending (concatenating) a list x to the front of a list y. Note the role of the patterns (x|y) and (x|y1) in the second clause. They tell us that the clause deals with the case of a non-empty front list and the repeated x in the two patterns tells us that the first element of the front list becomes the first element of the concatenation.

2.8 Comments

Since micro-PROLOG is first and foremost an interactive system, comments in the form of text in a source file that is ignored on loading is not directly supported. However, comments can be inserted as conditions in a clause, or as queries in a file.

2.8.1 Comment conditions

The built-in relation /* is a multi-argument relation that is always true. Thus an atom with /* as relation name, followed by any term or sequence of terms, is always skipped over by the micro-PROLOG interpreter.

Example

```
((App () x x)
    (/* App is the concatenation relation for lists))
```

is a commented assertion about the App relation. It will be slightly slower in use than the uncommented assertion.

2.8.2 Comment queries

The comment relation /* described above can be incorporated into queries in source files (using a text editor). micro-PROLOG's LOAD command executes queries in a file (see description of LOAD elsewhere), and this facility provides one method of commenting source files, as the following example shows:

```
?((/* App the concatenation relation for lists))
```

The ? query is evaluated during the loading of the file, but does nothing since its only condition is for the comment predicate. It gives the same information about the App relation as was used in the earlier example. The main difference is that it is not embedded in the App program and so is not automatically shown in a listing of App program. This comment will not be stored in any way by micro-PROLOG.

2.9 Meta-variable

The reader may skip this section on a first reading of the manual.

As an extension to the clausal syntax described above variables can appear in certain positions in a clause to name 'meta-level' components of the clause.

A variable can be used in place of the predicate symbol of an atom in the body, it can name a whole atom in the body, or it can be used to name the 'rest' of the body. These various uses of variables in the bodies of clauses are called the 'meta-variable' facility. This is to indicate that at run-time the variables concerned will be given values terms which become the relevant components of the clause.

The meta-variable is very important to the usability of micro-PROLOG, it enables many of the second order programs found in LISP (say) to be expressed succinctly in micro-PROLOG.

When the micro-PROLOG interpreter makes use of a clause containing a meta-variable the variable must have been given a value by the time that the meta-variable condition is reached. Moreover the term which is the value of the variable must be a valid syntactic item for the position of the meta-variable in the clause.

So, if the meta variable replaces a relation name, it must have been given a value which is a constant; if it replaces an atom it must have been given a value which is a list that is an atom; if it replaces the remainder of the body, it must have been given the value of a list of atoms. If this is not the case, an error is signalled.

2.9.1 Meta-variable as Predicate Symbol

A variable can be used as the predicate symbol of an atom in the body of a clause. (The head atom of a clause must always have a constant as the predicate symbol. This names the relation that the clause is about.) A predicate symbol meta-variable must be bound to a constant before the atom is evaluated. The constant is taken as the predicate symbol of the atom for this call.

This form of the meta-variable can be used to implement the

equivalent of the MAP functions in LISP. It is also similar to the facilities to pass procedures as parameters commonly found in more conventional programming languages like Pascal, ALGOL etc.

In the example program below Apply applies a test to each of the elements of its list argument. A call to Apply takes the form: (Apply OK <list>) and it succeeds if (OK y) is true of each element y of <list>. The x argument, the relation to apply to each element of the list, must be given in any call to Apply.

```
((Apply x ()))
((Apply x (y|Y))
     (x y)
     (Apply  x Y))
```

2.9.2 Meta-variable as an atom

A variable can also be used instead of an atom in the body of a clause. In this case the variable must be bound to a term which names an atom when the variable is 'called'.

This variant of the meta-variable is used to implement some of the meta-level extensions to the language. For example, the following program 'evaluates' a list as though it were a list of atoms:

```
((Eval ()))
((Eval (x|X))
     x
     (Eval X))
```

2.9.3 Meta-variable as the tail of the body of a clause

The final variant of the meta-variable is its use as the tail of the body of a clause or as the entire body of a clause. A variable in this case represents a list of procedure calls, rather than just a single call. For example, the following program encodes the disjunctive operator OR (available as a built-in program):

```
((OR x y) | x)
((OR x y) | y)
```

The use of the bar in these two clauses implies that the variables x & y name lists of atoms, and during execution they must be bound to lists of the correct format. Each list is interpreted as the body of the clause.

2.10 Lexical syntax

In this section we describe in more detail the lexical syntax that micro-PROLOG uses; the section can be omitted on a first reading of the manual.

The lexical syntax determines how the sequence of characters input to micro-PROLOG (either from the console or from a disk file) are grouped together into tokens.

In some sense the notion of token is a generalisation of word; in that tokens form the smallest groups of characters that can have a meaning associated with them; for example numbers, names and special symbols like (, | and) are all tokens. The

lexical rules themselves however, do not attach meaning to tokens, they merely define what tokens are. In micro-PROLOG there are five different types of token: special tokens, numeric tokens, alpha-numeric tokens, graphic tokens, and quoted tokens.

2.10.1 Token boundaries

The boundaries between tokens are determined by separator characters and by certain changes in token type. For example, a number token can be immediately followed by a graphic token since they are of different type, however two successive number tokens must be separated by at least one separator character. All control characters, as well as <del> (ASCII 127) are separators. Apart from their role as token separators, separator characters are ignored on input (but see quoted tokens below).

2.10.2 Special tokens

Special tokens consist of single characters, called special characters. Three special tokens form part of the list syntax of micro-PROLOG:

```
( ) ¦
```

while the others are always regarded as single character constants by micro-PROLOG (even though they are also bracket characters):

```
[ ] < > { }
```

The use of one of these special characters always marks a token boundary. They do not need to be preceded or followed by any separator.

2.10.3 Alpha-numeric tokens

Alpha-numeric tokens are defined in a similar way to identifiers in normal programming languages. They consist of a letter (lower or upper case letter) followed by a sequence of letters, digits. The sign character can also be used in alpha-numeric tokens to aid readability. Some example alpha-numeric tokens are:

```
A  A1  x  A1b3fred  father-of A-1
```

An alpha-numeric token must be separated from a preceding alpha-numeric token and from a following number token by at least one separator.

2.10.4 Number tokens

Numeric tokens are tokens which denote integers or floating point numbers. They are described in section 2.2.

A numeric token must be separated from a preceding number or alpha-numeric token and from a following number token.

2.10.5 Graphic tokens

Graphic tokens are names which are built up from the non alpha-numeric (and non special) characters. The sign character can also appear in graphic tokens. This includes such characters as : = % etc. Some example graphic tokens are:

```
- = : :: ?? /+ `-% &
```

Graphic tokens need only be separated from preceding or following graphic tokens.

All characters above 127 in the character table are treated both as graphic and as alpha characters. These characters can therefore be used either in graphic or alpha-numeric tokens, permitting programs to be written in greek or katakana (depending on machine)!

Note that one graphic token has a special reserved use. Dot-dot (..) is used as a synonym for the list constructor bar (|), since some keyboards cannot generate the latter. Where .. is to be included as a constant, it must be quoted.

2.10.6 Quoted tokens

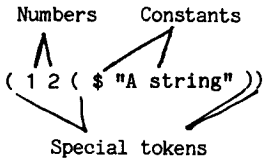
The final kind of token is the quoted token. This is used when the lexical roles of characters need to be ignored; it allows arbitrary characters to be grouped together as a single token. A quoted token is as a quote character " followed by an arbitrary sequence of characters (excepting the quote character itself) and terminated by another quote character. The quote character can be inserted in the token by prefixing it with the escape character tilde (~). (See section 2.3.)

Quoted tokens do not need to be preceded or followed by a separator.

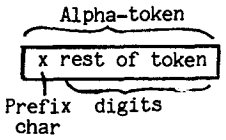
2.10.7 The lexical rules

The parser in micro-PROLOG has the fairly simple task of recognising tokens, converting tokens into variables, numbers and constants and constructing lists out of the token sequences that begin with (and end with).

There is a fairly close correspondence between the lexical token types and the distinctions the parser needs to make: numbers are made from numeric tokens, graphic tokens and quoted tokens form constants.



The remaining kind of token: the alpha-numeric token is recognised either as a variable or as a constant by the parser. micro-PROLOG recognises variables be examining the first character of alpha-numeric tokens (called the prefix character). If this character is a variable prefix character and the rest of the token is made up of digits then the token is read as a variable, otherwise it is taken to be a constant:



In standard micro-PROLOG the variable prefix characters are X, Y, Z, x, y & z.

3. The micro-PROLOG supervisor

micro-PROLOG is an interactive system. The top level interaction with the user is controlled through a special built-in micro-PROLOG program called the supervisor.

The micro-PROLOG supervisor provides a simple operating environment for the user. It allows programs to be entered, executed, edited, saved and loaded on disk files using various micro-PROLOG primitive relations as commands. In this chapter we describe the user interface to the supervisor and we illustrate the use of several primitives of micro-PROLOG that serve as useful supervisor commands.

The supervisor is an integral part of the micro-PROLOG interpreter, and is called as soon as you enter micro-PROLOG. It is a non-terminating program which controls all your interactions with micro-PROLOG.

3.1 Entering clauses and issuing commands

At this stage we suggest that the reader refers to Appendix A for details of how to enter micro-PROLOG. He can then follow the examples of this chapter using a computer.

As mentioned in Appendix A the

&.

prompt that you get when you enter micro-PROLOG comprises a "&" printed out by the supervisor to tell you that it is ready to accept a clause or a command. The "." is then the read prompt displayed by the keyboard read primitive of micro-PROLOG. It is displayed because the supervisor, which is a micro-PROLOG program, immediately tries to read user input from the keyboard.

The supervisor accepts two kinds of user input. It accepts clauses or single argument commands. A command comprises the name of some single argument relation (a unary relation) followed by its single argument. The single argument relation can either be one of the primitive single argument relations of micro-PROLOG, all of which are fully described in Chapter 8, or it can be user defined single argument relation. The supervisor does not distinguish between the two kinds of relations. The effect of this is to allow the user to define new supervisor 'commands'.

micro-PROLOG supports keyboard type-ahead (limited to 16 characters on CP/M80 systems), however, it is generally best to wait for the "&." prompt before entering commands or clauses.

3.1.1 Entering clauses

To enter a clause you simply type the clause in response to the "&." prompt and then press the <return> (or <enter>) key. The clause is added to the program at the end of the sequence of clauses currently defining the relation of the head of the clause. For example:

```
&.((Parent Mary John))<return>
&.((Parent Peter John))<return>
&.((App()x x))<return>
&.((App(x|X)Y(x|Z))<return>
1.(App X Y Z))<return>
&.
```

There is no supervisor command to enter a clause at a position other than at the end of the current sequence of clauses for its relation. To do this, you have to use the primitive ADDCL relation in a query command (see section 3.2 below), or the clause EDITOR (described in Chapter 4), or the MICRO extension to the supervisor (Chapter 6).

Notice that the last clause is entered over two lines and that at the beginning of the second line the prompt is "1." instead of "&.". The "1." prompt is issued by the keyboard read primitive because it knows that the term that is the clause for App is not yet finished even though the <return> key has been pressed. It knows this because the brackets of the first line do not balance. There is one right bracket to come. The "1" of the prompt tells you it is waiting for this one extra right bracket.

For more information on the entering of clauses, or any list term, over several lines, we refer the reader to Appendix B. This Appendix also describes the micro-PROLOG line editor which can be used for editing the text of an input line before the <return> is pressed.

3.1.2 Command format

The general format of a supervisor command is:

&.<Command name><Command argument>

where the command name is a constant, and the command argument is a term whose exact form is dependent on the actual command. The command argument is what would be the single argument if the command name were used as a unary relation in a program. The supervisor knows when you have entered a command because the first thing it reads is a constant which is the command name. If the first thing you enter in response to the "&." prompt is a list, it assumes that this is a clause and tries to add it to your program using the ADDCL primitive. If the list term does not satisfy the syntactic constraints of a clause you will get the ADDCL error message and the entered list will be ignored. If the first thing that you enter is a number the supervisor will display a "?" response and ignore the number. "?" is the supervisor response that you will also get whenever a command fails.

3.2 The query command ?

micro-PROLOG programs can be queried using the primitive query relation ?. This takes as its single argument a list of atoms which represents a conjunction of conditions to be solved. The way in which micro-PROLOG tries to find a solution to the conjunction of conditions is fully decribed in [Clark and McCabe, 1984].

If a solution to the ? query is found then the supervisor displays its normal prompt:

```
&.?((Parent  x1  x))
&.
```

The query to show that someone x1 is the parent of someone x succeeds.

If a solution cannot be found, i.e. the query fails, then a ? is displayed before the next prompt:

```
&.?((Parent x1 x2)(Parent x2 x1))
?
&.
```

The query to show that someone x1 is the parent of someone x2 and that the found x2 is also the parent of the found x1 has failed.

micro-PROLOG does not automatically print any response if the evaluation of the ? query succeeds. If you want to see the values for variables for the found solution you must add an extra PP condition/call to the list. For example, to find the name of a Parent of John use the query:

```
&.?((Parent x John)(PP The parent of John is x))
The parent of John is Mary
&.
```

PP is a built-in multi-argument relation that always succeeds with the side-effect of displaying its sequence of arguments at the screen.

In Chapters 5 and 6 other forms of query are described that automatically display the solutions.

3.2.1 Interrupts and errors

To interrupt the execution of any command two interrupt keys are provided. If the Control-S key is pressed, then execution is suspended as soon as any screen output is attempted by the system. Execution continues as soon as any other key except for Control-C (see below) is pressed. This is particularly useful when listing a large program with the LIST command.

To break into an execution the Control-C key is used. When a break is detected the "Break!" error is signalled and the execution is interrupted. Below we decribe how interrupts and errors can be trapped by user micro-PROLOG programs.

3.2.2 Other uses of the query command

The primitive relation ADDCL can be used in a query command to add a clause at a specified position in the current sequence of clauses for its relation.

Thus,

```
?((ADDCL ((Parent John James)) 1))
```

will add the clause

```
((Parent John James))
```

after the current first clause for the Parent relation. Since we

already have

```
((Parent Mary John))
((Parent Peter John))
```

the new clause will be inserted between these two clauses.

Individual clauses can be deleted using DELCL. This has a unary form and a binary form. In the unary form the single argument is the clause to be deleted. In this form it can be used as a command, e.g.

```
DELCL ((Parent Peter John))
```

In the binary form its arguments are a relation name and the position of the clause to be deleted. In this form it must be used inside a query command, e.g.

```
?((DELCL Parent 2))
```

deletes the current second clause for the Parent relation. See Chapter 8 for a complete description of the ADDCL and DELCL relations. See also Chapter 4 for an explanation of how to add and delete and reposition clauses using the EDITOR.

3.3 User defined relations as commands

As we remarked earlier, any unary relation can be used as a command including relations defined by our own micro-PROLOG programs. This allows us to define new 'commands' to the system. For example, suppose that we have added the clause:

```
((Show x) (? x)(PP x))
```

which uses the supervisor query command ? as an ordinary unary relation. By using Show as a command relation with a command of the form:

```
&.Show (<atom1> <atom2> .. <atomk>))
```

the Show program is invoked as though it was called with query:

```
?((Show (<atom1>  <atom2>  ..  <atomk>)))
```

It evaluates the list of atoms and then prints the list in its solved form, i.e. with variables replaced by their answer bindings.

The ? command that we saw above is itself defined as a unary relation by the clause:

```
((? X)!X)
```

This clause uses the meta-variable feature described in Section 2.9 in which the body of the clause is replaced by the value of the variable X. Many other supervisor commands, such as LIST, are themselves just built-in micro-PROLOG programs for unary relations.

3.4 Multi-argument commands

Sometimes it is convenient to enter a command which has several arguments. One way to do this is to define it as a unary relation that takes a list of its parameters as its single argument. ? is rather like this. Its single argument is a list of any number of conditions to solve. Alternatively, one can define the command as a program for a unary relation that immediately reads in its extra arguments.

As an example,

```
((addcl X)
  (R Y)
  (ADDCL Y X))
```

is a program for a relation that can be used as though it were a two argument command. An example use is:

```
&.addcl 1 ((Parent John James))
```

When executed, the first argument, the 1, is read in by the supervisor and becomes the single argument to the addcl call. This invokes the single clause for the relation which immediately reads in the next term (the clause to be added) using the primitive R relation. Then the two argument ADDCL is called with the position X and the clause Y. Compare this with the direct use of ADDCL using ? that we gave earlier.

3.5 Basic supervisor commands

3.5.1 The LIST command

The micro-PROLOG clauses that you have entered can be listed at the console with the LIST command. When a program is listed it is displayed in an indented format to aid readability of the program.

```
LIST ALL
```

lists the entire program.

```
LIST <relation name>
```

lists all the clauses (in the current program) for the named relation. Finally,

```
LIST (<relation name1> ... <relation namek>)
```

lists the programs for each of a list of named relations.

```
&.LIST ALL
((App () X X))
((App (X|Y) Z (X|x))
  (App Y Z x))
((Parent Mary John))
((Parent Peter John))
&.LIST Parent
((Parent Mary John))
((Parent Peter John))
&.
```

The variables that appear in a listed clause will usually be different from the ones you used when you entered the clause. This is because, as we noted in Section 2.4, variables are converted into a special internal form when a term such as a clause is read in. The name of the variable is lost, only its positions within the term are remembered.

When the term is listed, each variable is given a print name from the sequence of names X, Y, Z, x, y, z, X1, ..etc. The first variable in the term is displayed as X, the next as Y and so on. That is why the second App clause is listed as above.

3.5.1.1 Copying to the printer

If you type control-P all screen output will be copied to the printer, until you type control-P again. So if you wish for a copy of your program to appear on the printer then you can use this before you LIST the program.

3.5.2 LOAD and SAVE commands

A user program can be saved onto a disk file, and subsequently loaded back into the workspace. The two supervisor commands SAVE and LOAD respectively save and load the user's programs.

The formats of the load and save commands are:

LOAD <file name>
SAVE <file name>

The <file name> must be different from that of any program relation and different from the name of any currently loaded module. If it is not you will get a signalled error on trying to obey the command. If you get an error during a LOAD you should CLOSE the file with a

CLOSE <file name>

command because the file which was automatically opened for the LOAD will have been left open.

The LOAD command reads a program from the file specified and, if the program is not a module, it adds the program into the user's workspace as if it were typed in. Any program already in the system is not disturbed in any way by the load: each new clause is added to the end of the current sequence of clauses for its relation. In this way the programmer can have a library of programs, on a number of different files, which are loaded in as required when building up a new program.

The SAVE command saves the program currently in the workspace into the named file. The entire workspace is saved, i.e. all the clauses that are listed in response to a LIST ALL command. If the program is saved onto an already existing file, then the old file is renamed with file extension **.BAK.** This automatically ensures that at least one back-up copy of a file is maintained. A subsequent LOAD of the file containing the saved program will add the program to the workspace.

To save the programs for named relations only you need to use the two argument form of SAVE in a query command.

```
?((SAVE FAMILY (Parent Male Female)))
```

will save all the clauses for the relations Parent, Male and Female in the file FAMILY.LOG of the currently logged in drive. The second argument to SAVE is a list of the relations to be saved.

SAVE does not delete any program from the workspace. To do that you need to use DELCL or the KILL command described below.

There is an additional feature built in to the LOAD command, enabling queries to be run automatically. Query commands encountered in a file are treated exactly as if they had been typed in at the keyboard, enabling "batch" jobs or "turnkey" systems to be run, and also the screen prompting during the loading of a file.

For example, suppose the file AUTO.LOG contains the following:

```
?((PP Loading AUTO)
  (/* append is the concatenation relation for lists))
((append () X X))
((append (X|Y) Z (X|x))
  (append Y Z x))
?((PP Loading of append complete)(LIST ALL))
```

The command LOAD AUTO will cause the message "Loading AUTO" to be printed. Then the append program will be loaded, followed by the message "Loading of append complete". Finally all programs in the user workspace will be LISTed. Note the use of a comment condition in the first query. This has no affect on the loading program, but allows direct commenting of the source text file.

Files need not contain any programs at all, and may be treated purely as a list of instructions. The following file RUNIT.LOG, for example, could be used to load a large system consisting of modules M1.LOG ... M4.LOG, and then run a top level query, say (consult system)

```
?((P Loading ... Module 1 ...)(LOAD M1))
?((PModule 2 ...)(LOAD M2))
?((P Module 3 ...)(LOAD M3))
?((P Module 4 ...)(LOAD M4))
?((PP All loaded)(consult system))
```

The command LOAD RUNIT would cause the four modules to be loaded, each being labelled on the screen. When all were loaded, the message "All loaded" would be printed, and the system would begin to run from the query (consult system). Note, however, that the file RUNIT.LOG would remain open for reading until explicitly closed, or until the user program terminated.

Any of the files M1 ... M4 could in turn load further files, the only limit being that micro-PROLOG can only support 4 open files at any one time.

Queries cannot be saved by the built-in SAVE command, but must be edited into a file using a text editor. The reason for this is that the order in which micro-PROLOG saves programs in a file is dependent on the dictionary, which does not matter for declarative programs. Queries, on the other hand, are somewhat procedural in nature, and so need to be placed at strategic

points in the file if they are to be of any use: hence this restriction in SAVE, and the suggested use of a text editor.

3.5.3 File names

A file name is a constant which describes a file in the CP/M and MS-DOS style. The general format of a CP/M or MS-DOS file descriptor is:

<Drive Letter>:<File name>.<File type>

The drive letter and file type are optional, in which case the colon and dot (respectively) are omitted. micro-PROLOG uses the file type LOG as the default file type if one is not given, and it uses the current 'logged-in' disk drive if a drive is not specifically specified. Since the colon and the dot are not alphabetic characters a file name using them must be written inside string quotes. Some example constants describing files are:

```
"A:TRACE.LOG"
TRACE
"TRACE.LOG"
ERRTRAP
"OTHER.ASM"
"B:OTHER"
```

The quotes are needed for any file name that includes a ":" or "." to make it into one constant. File names can be given using lower case letters. The name as given is passed on to the operating system which treats all letters as though they were uppercase. But beware the problem mentioned above. Your file name as given in the micro-PROLOG LOAD or SAVE command must be different from that of any relation or module name. Using only uppercase letters in a file name helps to avoid that problem.

You can change the currently logged in drive or change a disk in a drive, using the command

LOGIN <letter>

where <letter> identifies the drive (i.e. it is A or B or C etc.). Before you execute the command, put any new disk in the selected drive. Thus, to change the disk in B, put in a new disk and then enter

LOGIN B

Other built in relations for file handling are:

ERA for erasing files
REN for renaming files
DIR for inspecting the directory files

They are described in Chapter 8. As an example of the use of DIR,

?((DIR * X)(PP X))

will give you a list of all the names of the **.LOG** files of the currently logged in disk.

3.5.4 The KILL command

The KILL command can be used to delete all the clauses for a particular relation or list of relations.

```
KILL Parent
```

deletes all clauses for Parent and

```
KILL (Parent App)
```

deletes all clauses for Parent and App.

```
KILL ALL
```

will delete all clauses in the current workspace. It should be used with care, and usually only after the use of **SAVE**. (However it will **not** delete any LOADed modules.) A final form of use of KILL is

```
KILL <module name>
```

This does get rid of a loaded module.

3.5.5 Exiting the system

To exit micro-PROLOG and return to the host operating system use the command:

```
QT.
A>
```

The . following the QT is needed to give an (ignored) argument to QT. (Remember all commands must have one argument.) It can be any argument:

```
QT goodbye
```

will work as well but is not as brief. Notice that in this case the separating space is needed.

3.6 The dictionary relations

All constants that are used in a user program are stored in a dictionary and uses of the constant in the program become pointers into the dictionary. So do not worry about using long relation names. You can see this dictionary by executing

```
LIST DICT
```

What you will see is something of the form

```
((DICT & () (...) App Parent John .....)
```

which is a clause for the relation DICT which is a multi-argument relation. The first three arguments are:

(1) the constant & which is part of top-level &. prompt and is the name of the workspace area,
(2) the empty list,
(3) a list that will be empty unless you have loaded any modules, if you have, the second list will be all the names exported by currently loaded modules.

The remaining arguments are all the constants used in the workspace program.

The workspace name & is there because this is also the form in which you will see the dictionary of a module once the module has been opened (see 8.11). & is the name of the special root module which is the workspace area. The first argument of DICT is always the name of the current module. For any module other than the root module the second argument will not be the empty list. It will be the list of all the exported names of that module.

The garbage collector clears constants from the workspace dictionary once there is no longer a reference to them in the program.

3.6.1 The SDICT relation

About 80 constants never appear in the DICT relation: these are the system constants which comprise the names of micro-PROLOG's built-in programs, supervisor commands and special files. As with user constants, the system constants are maintained in a dictionary.

The SDICT relation contains the full list of these constants, which can be seen by executing:

```
LIST SDICT
```

... which will result in:

```
((SDICT NUM DEF VAR ... ISALL FORALL))
```

The 80 or so arguments of SDICT are the system constants. System constants are all those and only those constants of which the relation SYS is true.

3.7 Trapping error conditions by micro-PROLOG programs

micro-PROLOG has relatively few error conditions, and most of them can be trapped by a micro-PROLOG program. The errors are divided into two groups - the numbered errors and the message errors. All the numbered errors can be trapped. (See Appendix C for a complete description of the numbered and message errors.)

When a numbered error occurs, if there are clauses for the relation "?ERROR?", the program for the relation is called with a call of the form:

```
("?ERROR?" <error number> <error call>)
```

This call replaces the erroneous call which is passed as the second argument, this is the call that was being evaluated when the error occured. Thus, if the call to the "?ERROR?" program succeeds, possibly binding variables in its error call second argument, the error call is assumed to have succeeded and the evaluation continues with the next call. If the call to the "?ERROR?" program fails, the error call is assumed to have failed. The call to the error handler may also result in an ABORT to the supervisor.

If there are no clauses for the "?ERROR?" relation, the

message

```
Error: n
```

where n is the error number, is displayed. The current evaluation is then aborted and you are returned to the supervisor. In addition, for MSDOS and CP/M86 systems a short description of the error is also displayed.

The following program is an example of a simple error handler which just reports the error with a short message and then aborts to the top-level supervisor:

```
(("?ERROR?" X Y)
  (P-code X Z)
  (P Z)(PP Y)
  ABORT)
((P-code 0 "Arithmetic Overflow"))
((P-code 1 "Arithmetic Underflow"))
((P-code 2 "Predicate Not Defined"))
((P-code 3 "Control Error"))
((P-code 4 "Predicate Protected"))
((P-code 5 "File Handling Error"))
((P-code 6 "Too Many Files Open"))
((P-code 7 "Disk Login Error"))
((P-code 8 "Disk Read Error"))
((P-code 9 "Disk Write Error"))
((P-code 10 "Disk Or Directory Full"))
((P-code 11 "Break!"))
((P-code 12 "Module Handling Error"))
((P-code X (Unknown Error X)))
```

The messages in the above example are those given by the 8086 version of micro-PROLOG when no ?ERROR? relation has been defined.

A simple alteration will allow the error 2 (which occurs when attempting to execute a program for which there is no definition) to be treated as a failure. All that is needed is to add the following clause to the ?ERROR? program:

```
(("?ERROR?" 2 x)
   /
   FAIL)
```

This must must be placed before the main ?ERROR? clause. The the / followed by the FAIL causes the error call given as the x argument to fail.

A further refinement of this is to treat error 2 as a failure only if the clause ((data-rel <rel>)) in the user's program declares that it should be so treated. The extra clause for ?ERROR? is then

```
(("?ERROR?" 2 (X|Y))
  (DEF data-rel)
  (data-rel X)/
  FAIL)
```

The error handlers which are defined in the SIMPLE and MICRO front end programs (errmess-mod, deftrap-mod and errtrap-mod) all treat error 2 in this way. The use ofCL prevents another error 2 arising should there be no data-rel clauses. See the description

of CL in Chapter 8 of this Manual.

It is generally a good idea to have some definition for ?ERROR? present. The ERRTRAP.LOG file contains a module that exports a definition for this relation. It provides a sophisticated error trap and recovery utility. Its facilities are described in the MICRO chapter, Chapter 6. However, you can load and use it separately from the MICRO system.

3.8 The user defined supervisor

A significant feature of the supervisor is the ability of the user to redefine the supervisor program which runs for the duration of a micro-PROLOG session. In enables the user to have complete control of the system, even after Space Error, Dictionary Full, or where the ABORT primitive has been invoked.

3.8.1 The <SUP> relation

To explain the use of this facility, a few words need to be said about the actual default supervisor. This is a program, written in micro-PROLOG, which performs a very simple loop indefinitely. Called <SUP>, its definition is shown below:

```
(("<SUP>")
  (DEF "<USER>")
  ("<USER>")
  FAIL)

(("<SUP>")
  (CMOD Y)
  (P Y)
  ("<R>" X)
  ("<>" X)
 /("<SUP>"))
```

The second clause is this loop, and forms the only clause in micro-PROLOG 3.0 and earlier. CMOD is used to find the name of the current module (initially &), and this is printed by P. <R> is a special form of the R predicate which is fail-proof, and merely reads a term into X. The <> predicate processes this term as follows:

```
(("<>" X)
  (CON X)
  (R Y)
  (X Y))

(("<>" (X|Y))
  (ADDCL (X|Y)))

(("<>" X)
  (PP ?))
```

If the term read by <R> is a constant, the first clause of <> reads a second term and uses the meta-variable facility of micro-PROLOG to run the terms as a query or command. If <R>'s term was a list (X|Y), the second clause attempts to add it as a program clause. If either of the first two clauses fail for any reason, or if the term returned by <R> was a number or a variable, then the third clause of <> succeeds by printing the fail message ?.

3.8.2 The <USER> relation

The first clause of <SUP> (see above) is what provides the user supervisor facility. On each loop of the <SUP> program, this first clauses tests to see whether a program called <USER> is defined. If not, it fails and the default loop described above takes over. As soon as <USER> is defined, however, it is called and takes over from the default supervisor.

As with <SUP>, any program called <USER> should be a tail-recursive loop. If <USER> does fail or succeed, no harm is done, but the first clause of <SUP> fails, and the default second clause is entered for at least one iteration. This provides enough time to edit the bad <USER> program, kill it, or to exit from micro-PROLOG with QT.

A simple example of the use of <USER> is given below:

```
(("<USER>")          {there are no arguments}
  (TIME X Y Z)
  (SPACE x)
  (P Time is X:Y:Z - x kb Free:)
  ("<R>" y)
  ("<>" y)
 /("<USER>"))
```

This performs a loop analogous to the default supervisor, except that it displays the time of day and amount of free space left as its prompt, rather than the current module name.

Warning

The <USER> program is always entered in place of the default supervisor, even after any error short of System Abort. If the definition of <USER> contains a micro-PROLOG error, or if <USER> loops without allowing user interaction, then the user no longer has any control of the system.

For example, the following bad definition:

```
(("<USER>")
  (SUM X Y Z))       {a Control Error}
```

will cause micro-PROLOG to generate error messages forever, since after each error message aborts the execution, <USER> is again enterred and the error occurs a second time.

Again, the definition:

```
(("<USER>")
  ("<USER>"))
```

will loop forever, and no error conditions, including Control-C 'Break!' can abort the loop.

3.8.3 Turnkey systems and security

Two main reasons exist for including a user supervisor option. The first relates to the ability to write turnkey systems. If a program is loaded from disk, and it includes a definition of <USER> such as:

```
(("<USER>")
   (run rest of system)  {or any other start command}
   (PP Goodbye)          {print log-out message}
   QT)                   {return to MS-DOS or PC-DOS}
```

then the program will run automatically, and any ABORT error conditions will result in the system being run again from the start. When the run is complete, the user will be returned automatically to the operating system.

Related to the above is the ability to provide secure systems where the user cannot break in and look at the clauses created by the system while it was running. If the start-up command for the system is of the form:

```
((start up)
   (ADDCL (("<USER>")
           (PP Private Program - Aborted)
           QT))
   (carry on))
```

then once the program is underway, any error, including Space and Dictionary Full errors, and Control-C 'Break!'s, will leave the user with the bland message, and back in the operating system. Data structures or clauses created by the system while running can therefore remain private.

4. Utility modules

4.1 Tracing Execution

A trace program is provided with the system as a module with the name trace-mod in the file TRACE.LOG. The trace module allows, interactively, selective tracing of the execution of a query.

To use the trace program execute a LOAD TRACE command. This will load the module that is in the file. To get rid of the program when you have finished tracing do a KILL trace-mod. Note the asymetry. To bring in a module you do a LOAD using the name of the file that contains it. To delete it you do a KILL using the name of the module. Nearly all the modules provided on the distribution disk have a name of the form: <name>-mod where <NAME>.LOG is the name of the file that contains them.

The module exports the relation name ??. This is used in exactly the same way as the supervisor ? query command, e.g.

&.??(<atom1>..<atomk>

The difference is that you are lead through the evaluation of the query step-by-step, a call at a time.

When entering a call for the first time a message of the form

<call id>(R <seq. of args of call>)

is displayed at the console. The term printed represents the call/condition just before any attempt at evaluation, with all of the known values of variables substituted in place. The <call id> is a list of numbers identifying the ancestry of the call back to the original query. The length of the list corresponds to the depth of the evaluation. As an example, the list

(1 3 2)

identifies the call as the first condition of the body of a clause invoked to solve the 3rd condition of the body of a clause invoked to solve the 2nd condition of the original query.

If the relation name R of the call refers is one of the micro-PROLOG primitives (all described in Chapter 7) then the call is immediately executed. (The logical primitives IF, OR, NOT, ISALL and FORALL are an exception. These can be traced - see below.) If the call is for a user defined relation then the message trace? is also printed. One of the allowed trace responses must then be entered.

The trace responses allow selective tracing of the program. For example, low level (or already debugged) programs can be skipped by responding:n i.e. no tracing. The allowed trace responses are:

n(for no), y(for yes)
s(for succeed), f(for fail),
q(for quit), /(followed by any command)

1. **n**

If n is entered the call is executed without tracing. In this case one of two things normally happens: either the call is solved or the attempt to solve it fails. If it fails then the message

<call id> failing (R <seq. of arguments of call>)

is displayed at the console, and the system backtracks. This failure may cause backtracking on calls that were previously solved if there are no untried ways of solving these calls. Each time there is backtracking on a call, the call is displayed with the **failing** message.

If the evaluation of a call succeeds then the message

<call id> solved (R <seq of instantiated arguments of call>)

is displayed. In this case the call is printed with the answer bindings substituted, so that you can see the result of the evaluation just completed. If the call was the last in the body of a clause then the immediate ancestor of the call is also solved, in which case a **solved** message is displayed for it too.

After solving a call remaining unsolved calls are entered and traced in turn. This continues until the last call of the original query is solved or until its first call is failed.

2. **y**

The y response allows the tracing of the evaluation of the call. The trace program looks for a clause to match the call. If no clause matches the call, the **failing** message described above is displayed. If there is a clause that matches (i.e. a clause whose head atom unifies with the call) the message

<call id> matches clause n

is displayed. The n is the position of the clause in the sequence of clauses for relation of the call.

If the clause that matches the call is an assertion, then since there are no atoms to trace inside the body of the clause, the call has been solved and a **solved** message displayed. Otherwise each of the atoms in the body of the clause are entered and traced in turn. On entering the body of any clause that matches the call the <call id> is extended by a first number that identifies the position of the call in the body of the clause. The clause being used is also identified by a message of the form

3. **s**

Entering s allows one to arbitrarily solve a call. The immediate response is a printing of the call with the **solved** message. The trace program does not try to use any clauses for the call, nor does it instantiate any variables in the call.

4. f

Entering f allows the user to arbitrarily fail the call, and to cause the evaluation to backtrack. The failing message for the call is displayed.

5. q

Entering q quits the trace evaluation. It is used to obtain a quick exit. You are returned to the supervisor.

6. /

When you get the trace prompt "trace?" you can enter any command providing it is preceded by the escape symbol /. You can use this facility to LIST the clauses for the relation of the condition about to be traced e.g.

```
(1 2) (parent ...) trace?/LIST parent
.
. <clauses for parent>
.
(1 2) (parent ...) trace?
```

or to EDIT the program using the EDITOR described later in this Chapter.

The trace program insists that a legal trace response is entered. If an erroneous response is input the program displays the message:

```
ENTER y n s(for succeed) f(for fail) q(for quit) or
   / followed by a command
```

and prompts the user again. When you are asked whether you want tracing inside one of the logical primitives IF, OR, NOT, ISALL or FORALL the allowed responses are only y or n. But this restriction is indicated by the prompt trace?(y/n) that you will get in this case. To this prompt any response but y is taken as n.

Warning

The use of the trace program greatly increases space demands on the heap and stack, thus programs which run without tracing may well run out of space when traced.

As we mentioned earlier, the trace program, being a module, will not be loaded into the user program workspace. So when you do a LIST ALL you will not see any of the trace program. (However, if you do a LIST ?? you will be able to see the clauses for ?? since this is an exported relation of the module.) Loading the trace module does however reduce the amount of space available for user programs. It should therefore be deleted when you have finished using it with the KILL trace-mod command. You can always re-load it when required.

4.2 Spypoint tracing

Sometimes, all that you want to trace is the entry/exit behaviour of some of your programs. A utility module called spytrace-mod enables you to spypoint trace a program in this way. To use the module do a LOAD SPYTRACE. To get rid of it when you have finished, do a KILL spytrace-mod.

When you load the file you will find that an extra clause

```
((spypoints on))
```

has been added to your workspace program. This is a message that causes entry/exit information to be given for all the spy specified relations . The module exports three relations: spy, unspy, spying. The first two are unary relations that are used as commands. The spying relation has two uses, as a command to turn the tracing on and off, and as a two argument relation to give entry/exit information for a particular call.

4.2.1 The spy command

If you want to have entry/exit information for all calls for a user defined relation <rel>, do a

```
spy <rel>
```

command. If you now LIST <rel> you will find an extra clause has been added to the front of its program. The spy command has added the clause.

```
((<rel>|X)
  (spypoints on) {check that spy relations should be traced}
  (/)            {execute / to prevent other clauses being
                  used to solve this call}
  (spying <rel> X)) {evaluate (<rel>|X) call using the other
                     clauses giving some trace information}
```

(The "{","}" bracketed comments will not appear.) If the ((spypoints on)) clause is not in the workspace, the user provided clauses for <rel> will be used to solve the call in the normal way. If it is present, the call (<rel>|X) is evaluated by the call (spying <rel> X) to the spying relation.

You cannot spy a micro-PROLOG primitive relation or any relation exported by a module. The attempt to do so will result in the "Cannot add clauses for" error being signalled as the spy command tries to add the extra clause.

4.2.2 The spying relation

This takes two arguments, the name of the relation <rel> of the call to be entry/exit traced and the list X of the arguments of the call.

The evaluation of

```
(spying <rel> X)
```

is equivalent to the evaluation of

```
(<rel>|X)
```

except that some trace information is given as the call is evaluated.

On entry, a message of the form:

<call id> : <rel> <list X of arguments of call>

is displayed. The <call id> is an integer. The <call id> is increased on each call of spying and decreased if the call fails. During the evaluation the call to <rel> it is identified in subsequent trace messages by the <call id>.

As each user supplied clause that matches the call is tried the message

<call id> matches clause <clause number>

is displayed. The <clause number> is the position of the clause in the listing of all the clauses for <rel> including the clause added by the spy command. So the first user clause for <rel> has clause number 2.

If the call is solved using this clause the message

<call id> solved <rel> <list X of instantiated arguments>

is displayed giving any solution bindings for the call.

Finally, if the call fails, the message

<call id> backtracking on <rel> <list of original arguments X>

is displayed. After this message, the <call id> will be re-used to identify a different spying call.

The spying relation can be used directly in user supplied clauses and queries. For example, the query

?((spying father-of (tom X))(spying male (X)))

will give you trace information on the evaluation of the two calls even if father-of and male are not spy specified relations.

4.2.3 The spying command

The command

spying off

will remove the

((spypoints on))

clause from the workspace and replace it by

((spypoints off))

It switches off the spying of all the spy specified relations.

The command

spying on

has the reverse effect.

4.2.4 The unspy command

The command

unspy <rel>

will remove the extra clause added for <rel> by the spy command. It stops all the automatic spying of calls to <rel>.

4.3 The micro-PROLOG Structure Editor

The micro-PROLOG structure editor allows the PROLOG programmer to edit programs within the micro-PROLOG environment. It is an editor which takes into account the list structure of micro-PROLOG clauses and terms. Since the editor is itself written in micro-PROLOG it is easy to extend and modify, should the need arise.

At any moment the editor is focused on a current term which has an immediate context, which is the list that the current term is in. To act as an 'aide-memoire' the editor uses the current term to form its prompt when the editor is ready to accept a command. At the top-most level of editing a program (where the current term is one of the clauses of the program and the context is the list of clauses for a relation) the editor prefixes the prompt with a number; this number indicating the position, within the list of clauses, of the current clause.

If at any time the current term 'pointer' is not a term or clause in the program then the editor displays **No term** or **No clause** as its prompt. The commands allow changing the current term, changing the context, moving or deleting or modifying the current term, and inserting new terms.

4.3.1 Edit Commands

Before using the editor it is necessary to LOAD the editor module (called editor-mod) using the command:

LOAD EDITOR

To delete it when you have finished use:

KILL editor-mod

The editor is invoked using the command:

EDIT <relation name>,

for example to edit the likes program enter:

EDIT likes

The editor uses the first clause in the program (if the program is non-empty) as the initial current term. In the case of the likes program this could be:

[1]((likes John Mary)).

If there are no clauses for likes you will get

```
[0] No clause.
```

in which case the first thing you should do is add a clause using the a command. The editor offers a handy tool for building new programs as well as for modifying existing ones.

When the editor displays its prompt it is ready to accept an edit command, which at the top level can be any of the i(insert), a(append), k(kill), f(fix), v (vars), n(next), b(back), m(move), c(copy), t(text), e(enter) and o(out) commands. The edit commands are divided into two groups: those which move the current term pointer in the structure of the terms being edited, and those which change the terms in some way.

4.3.2 Cursor Movement Commands

There are four commands which can be used to walk over the program; these are n, b, e and o.

1. The n (next) command changes the current term to the next term to the right in the immediate context. At the top level this means move to the next clause. As an example, if the current term is (A B), and the immediate context is (C (A B)(D)) then the n command moves the current term to (D):

```
(A B).n
(D).
```

whereas at the top-level we get the next clause:

```
[1] ((likes John Mary)).n
[2] ((likes X Y) (knows X Y) (likes Y X))
```

If the current term was already at the last term in the immediate context, or if it was the last clause in the program, the pointer is stepped on, but the current term becomes **No term**, (or **No clause** at the top level) indicating that it is not actually pointing to a term or clause. It is impossible to step beyond this point.

2. The b (back) command is the inverse of the n command, it is used to step back to the term to the left of the current term in the immediate context, or to step to the previous clause. To undo the effect of the previous n command above:

```
(D).b
(A B).

[2] ((likes X Y) (knows X Y) (likes Y X)).b
[1] ((likes John Mary)).
```

If the current term were already the first term, then the b command steps back to in front of it, again causing the prompt to become **No term** (**No clause**). e.g.

```
(A B).b
C.b
No term.

[1] ((likes John Mary)).b
[0] No clause.
```

It is not possible to move before this point.

3. The e (enter) command steps 'into' a term or clause so as to edit its components. The term being stepped into must be a list structure. (You cannot get 'inside' a number, constant or variable using these structure move commands. To change these you must use the t (text) or the s (substitute) command.) The immediate context becomes the list term just entered, and the current term is the first element (if any) of that list. So in our example, if we enter the list (A B) we change our immediate context and point to A:

```
(A B).e
A.
```

or

```
[2] ((likes X Y) (knows X Y) (likes Y X )).e
(likes X Y).n
(knows X Y).n
(likes X Y).
```

Note what has happened as we stepped along the entered clause. As we reach each atom it is printed with the variables in the atom assigned print names from the list X, Y, Z, x, ...This means that sometimes it will appear that the editor has changed the variable names.

As we moved to the (knows X Y) atom of the clause we actually got the same names displayed by accident. When we moved to the (likes Y X) atom of the clause this is displayed as (likes X Y). Within this atom, the Y that we saw when the whole clause is displayed is the first variable, so its print name is X. The variable we now see as X is the variable that we saw as Y at the whole clause level.

This change of names as we enter and then step along a clause can be a little disconcerting. It does not matter unless you want to change a variable in a clause. To do this you should use the t text edit command at the whole clause level or at least at a term level in the clause that covers all the occurrences of the variable you want to change. Alternatively, you should use the f and v commands described below to temporarily fix the variables of a clause as constants. Changing or adding a new variable is then achieved by changing or adding new vars constants.

4. The o (out) command is the inverse of the e (enter) command. The current immediate context becomes the current term, and the 'old' immediate context (prior to the corresponding e command) is re-established as the immediate context. The o command is also used to exit the editor, when at the top level:

```
(likes X Y).o
[2 ](likes X Y ) (knows X Y) (likes Y X)).o
Edit of likes finished
&.
```

The o command may fail if the entered term has been incorrectly changed. This will happen if on returning to the outer level the predicate symbol of the head of the clause has been changed to a variable or the name of a primitive relation. When an edit command fails the editor responds with a ? and re-prompts at the appropriate level. If you change the relation that a clause is about to another allowed program relation name

you will be asked if you want the clause added to the program for the new relation; if you respond yes, you will be asked for the position for the clause. This should be a positive integer. The clause will be inserted after the current clause at that position.

With these four cursor control commands any sub-term of a program can be reached. In the next section we look at those edit commands that directly change the current term.

4.3.3 Edit change Commands

There are nine commands which directly affect the current term; these are i(insert) a new term, a(append) a new term, k(kill) the current term, s(substitute) another term, m(move) the term, c(copy) a clause, t(text) edit the term, f fix the variables as vars constants in a clause and v introduce variables for the vars constants of a clause. The c, f and v commands can only be used at the top clause level and the s command is only available below the clause level.

1. The i (insert) command inserts a term before the current term. The i is followed by the term to insert as in:

```
(A B).i (F)
(F).
```

The new term just inserted becomes the new current term, the old one can be regained by stepping on to it with the n command.

At the top level the i command inserts a new clause into the program. In this case the form of the clause is checked to ensure that at least the clause is for the relation currently being edited. If it is not, or the clause is incorrectly formed, the insert fails and the old term is re-displayed as the prompt.

```
[1] ((likes John Mary)).i((likes bill mary))
[1] ((likes Bill Mary)).n
[2] ((likes John Mary)).
```

2. The a (append) command appends a new term (or clause) after the current term. Otherwise it is like the i command.

3. The k (kill) command deletes the current term from the immediate context. The term (or clause) to the left of the deleted term in the immediate context becomes the new current term, if there is not a previous term (or clause) then the current term becomes **No term** (**No clause**). We can delete a particular element of a list by using a sequence of cursor movement commands to move to the required term and then using the k command.

For example, to delete the third element of (A B C D):

```
(A B C D).e
A.n
B.n
C.k
B.o
(A B D).
```

4. The s (substitute) command replaces the current term with a new term. The argument to s is a pair:

(t1 t2)

The term t1, is unified with the current term, and then the current term is replaced by t2. The use of unification allows quite powerful pattern matching, but more importantly the specification of the replacement can make use of variables bound in this match. For example, to reverse the first two elements of a list:

```
(A B C D). s((x y|z)(y x|z))
(B A C D).
```

Note. The s command is not available at the top level.

5. The t (text) command allows the current term to be changed using the line editor described in Appendix B. It displays the term on one or more lines of the console and positions the cursor at the beginning of the line. You are in the edit mode of the line editer in a state equivalent to just having executed the l command. The edit mode commands described in Appendix B are available to modify the text of the term. Upon hitting the RETURN key the system reads the text back in and replaces the current term by it.

If you use t to modify a term which is a component of a clause be careful not to change the displayed names of any variables that also occur outside the term. If you leave the names unchanged then the link between these 'global' variables with their occurrences outside the term will be restored on exit from the text edit. This is possible because the primitive RFILL relation (see Chapter 8) used by the t command remembers the print name it assigns to each variable (which has a unique internal name) before it puts the text of the term into the keyboard buffer. When it reads in the text it replaces the occurrences of these remembered print names with the original internal names of the variables. This re-establishes the link with the variable occurrences in the rest of the clause when the reconstructed term is inserted in the clause. Alternatively, you can fix all the variables of the clause as constants using the f edit command.

6. The c (copy) command allows the copying of a clause. It can only be used at the clause level. It is very useful when building up a program in which two or more clauses differ only slightly. You insert one, then copy it using c. c places the copy after the copied clause and makes it the current clause. You then edit the copy to give the variant of the first clause.

7. The m (move) command allows you to move a term within the current context. At the top level it repositions a clause within the sequence of clauses for its relation. m takes one argument, an integer which gives the displacement to the right or left within the current context. A positive integer n moves the term to the right (forwards) n positions, a negative integer -n moves it to the left (backwards) n positions. You cannot move the term outside the current context. If you give too large a right move the term is simply placed at the right end, too large a left move puts it at the left end. The moved term remains the current term after the move.

```
[1] ((likes Bill Mary)).m 1
[2] ((likes Bill Mary)).b
[1] ((likes John Mary)).n
```

```
[2] ((likes Bill Mary)).m -4
[1] ((likes Bill mary)).
```

8. The f command allows you to temporarily fix all or some of the variables of a clause as constants. It can only be used at the top clause level and it can only be used once. (A second f applied to the same clause before the effect of the first has been undone with the v command described below will fail.) Its form of use is

```
f (constant1 constant2 ... constantk)
```

The result is that the first k variables of the clause will be replaced by the k constants given in the list following the f and when the clause is displayed an extra atom

```
(vars constant1 constant2 ... constant3)
```

will be appear as a new last condition of the clause to remind you which constants in the clause are really variables. To change a variable you now change the constant that has replaced the variable. To add a new variable, use a new constant and then record that it is a constant standing for a variable by editing the vars atom so that it includes the new constant.

Example

```
[2] ((likes X Y) (knows X Y) (likes Y X)).f (person1 person2)
[2] ((likes person1 person2) (knows person1 person2) (likes
person2 person1) (vars person1 person2))
```

9. The v (vars) command reverses the f command. Again it can only be used at the clause level. It replaces all the contants given in the vars last condition of the current clause by new variables thoughout the rest of the clause. Each occurence of the same vars constant gets replaced by the same new variable. After the substitution, the vars atom is removed from the displayed clause.

Example

We can continue the above example use of f in order to add a new condition which requires person2 to be female.

```
[2] ((likes person1 person2) (knows person1 person2) (likes
person2 person1) (vars person1 person2)).e
(likes person1 person2).a (female person2)
(female person2).o
[2] ((likes person1 person2) (female person2) (knows person1
person2) (likes person2 person1) (vars person1 person2)).v
[2] ((likes X Y) (female Y) (knows X Y) (likes Y X))
```

To add this extra condition without using f and v we would have to use the t command at the clause level to text edit in the new condition (female Y).

Exiting the edit without doing a v

If you exit the edit of the definition of a relation in which you have used f but you have not undone its effect with a v command you will still be able to use the clause in the normal way. If you LIST the program you will see that all the vars constants have actually been replaced by new variables as when

you do a v but there will be an extra /* comment condition as the first condition of the clause. This will be of the form

```
(/* vars (X1 | constant1) .. (Xk | constantk))
```

where constant1 .. constantk are the vars constants of the clause that were given in the vars atom just before you exited the edit and X1 ... Xk are the variables that now appear in place of these constants.

Example

Suppose that in the above example we exit the edit before doing the v. If we list likes the second clause will be displyed as

```
((likes X Y)
  (/* vars (X person1) (Y person2))
  (female Y)
  (knows X Y)
  (likes Y X))
```

In fact, it was saved in this form even during the edit. The editor automatically converts clauses that have a first condition which is a comment associating constants with variables into the special form in which the variables are replaced by the associated constants when you are about to edit the clause. It also maps the /* comment into the vars last atom of the clause. The f command adds such a condition to the clause, relying on the editor to display it in the right form, and the v command simple deletes the comment. This means that if we now start to re-edit likes we will see the clause in the form in which it was last displayed by the editor.

```
EDIT likes
[1] ((likes John Mary)).n
[2] ((likes person1 person2) (knows person1 person2) (likes
person2 person1) (vars person1 person2))
```

Finally, if we use the editor to develop programs we can even enter clauses which use constants instead of variables. All we need do is make sure that this special use of constants is signalled to the editor by the appropriate vars condition at the end of the clause.

Example

```
EDIT append
[0] No clause.a
((append () list list)
  (vars list))
[1] ((append () list list) (vars list)).a
((append (h|t) list (h|t1))
  (append t list t1)
  (vars h t list t1))
[2] ((append (h|t) list (h|t1)) (append t list t1) (vars h t
t1 list)).o
Edit of append finished
&.LIST append
((append () X X)
  (/* vars (X list)))
((append (X|Y) Z (X|x))
  (/* vars (X h) (Y t) (Z list) (x t1))
```

```
    (append Y Z x))
&.
```

4.4 Editing modules

We refer the reader to Section 8.11 for a description of modules and the problem of editing a user program that has been wrapped up as a module. Only workspace programs can be easily edited using the above structure editor. So what is needed is a utility that allows modules to be unwrapped into workspace programs, and then, after editing, allows them to be wrapped up again as modules.

The file MODULES.LOG of the distribution disk contains such a utility program as the module **modules-mod**. To use it do a LOAD MODULES. To get rid of it, do a KILL modules-mod.

The module exports two unary relations wrap and unwrap that are used as commands. Both commands use the currently logged in disk for writing files. So this disk should have enough space for a file of all the clauses in the module and it should not be write protected. (The LOGIN primitive can be used to change the logged in disk and disk drive. See Chapter 8 or Chapter 3.)

The wrap and unwrap commands of this module are quite different from the w and u editor commands described above.

4.4.1 The unwrap command

To transfer the clauses of a module named M into the workspace for editing first SAVE any existing workspace program, then do a KILL ALL to clear the workspace, then do an

```
unwrap M
```

command. All the clauses owned by the module will enter the workspace along with an extra clause

```
((Module M <export list> <import list>))
```

which gives the name M of the unwrapped module and its export and import name lists. You can now edit or add to the clauses in the workspace using the structure editor described above. You can also edit the extra Module clause to change the name of the module or to change its export/import lists. But do not delete it. It is used by the wrap command to reconstruct the module.

The unwrap command uses the current logged in disk to store a temporary file which it deletes when all the clauses are in the workspace.

4.4.2 The wrap command

When you have finished editing the unwrapped module do a

```
wrap <file name>
```

command. This command uses the information in the Module clause in the workspace to create a module containing all the other clauses in the workspace. It also saves the new module on the named file.

By explicity adding a Module clause to a workspace program you can use wrap as a quick way of creating new modules.

4.4.3 The save-mods command

This is a command that allows you to save several modules in a single file. When the file is LOADed all the modules it contains will be loaded. Its form of use is

save-mods <file name> <list of module names>

e.g.

save-mods suite (first-mod second-mod third-mod)

will save the three currently loaded modules

first-mod second-mod third-mod

in the single file

SUITE.LOG

of the currently logged in disk.

4.5 Using external relations - the EXREL utility

On occasions, especially when the definition of some of your relations comprises a lot of single atom clauses, there is very little space left when the entire program is loaded.

When space is at a premium, you can trade time for space and have some of your relation definitions reside in a specially created disk file. The file is created using the external command of the utility module exrel-mod which is in the program file EXREL.LOG of the distribution disk.

The external command saves all the current clauses for one or more relations in a disk file. It then deletes them from the workspace and adds a single new clause for each relation. This new clause 'gives' the segment of the disk file in which the defining clauses for the relation are to be found. During a query evaluation these defining clauses are automatically accessed from the file as and when required.

We now describe the commands and facilities of exrel-mod in more detail. It can be used to set up disk file data bases of micro-PROLOG relation definitions which interface with the query evaluation system in a transparent way.

To load the module do a LOAD EXREL command. To delete it do a KILL exrel-mod command. The module **must** be present whenever you want to query external relations. This is because it exports the definition of the interface program RPRED.

4.5.1 The external command

This has two forms of use:

external <file name> <relation name>

sets up a file containing the defining clauses for a single relation.

external <file name> (<relation name1> .. <relation namek>)

sets up a file containing the current defining clauses for each of the list of relations. The disadvantage of packing several relations onto one file comes when we want to edit one of the relations - more on this later. The advantage is that it reduces the number of external files. Since micro-PROLOG only allows four files to be open at any one time, only four external files can be accessed during a single query evaluation.

The command deletes all the saved clauses from the workspace program. For each externally stored relation a single new defining clause is added. This links the relation with the segment of the file where the defining clauses were saved.

Example

Suppose that the workspace program contains a sequence of clauses of the form

((worker-ID <name list> <identifying number>))

e.g.

```
((worker-ID (Tom Jones) 2334))
((worker-ID (Bill J Bell) 2867))
.
.
((worker-ID (Jane Roberts) 900))
```

and a sequence of clauses of the form

((salary <identifying number> <dept> <annual salary>))

e.g.

```
((salary 2334 invoicing 12000))
.
.
((salary 3456 design  14500))
```

and a conditional clause

((salary x y 8000) (LESS x 1000))

expressing the company 'rule' that all trainee clerks have an ID number less than 1000 and a fixed salary of 8000. (This is not meant to be realistic. The general rule is there to emphasise that any form of clause can be used in the definition of a relation that is made external. You are not restricted to relations defined only by single atom clauses.)

We can make the definitions for both relations external with

external EXFILE1 (salary worker-ID)

A file named EXFILE1.LOG will be created on the currently logged in disk drive and all the current clauses for the two relations will be saved on the file. They are deleted from the workspace and replaced by clauses such as:

((salary!x) (RPRED EXFILE1 (0!0) (3!72) (salary!x)))

((worker-ID x) (RPRED EXFILE1 (3|72) (7|1) (worker-ID|x)))

These are the clauses for salary and worker-ID that you will see if you now try to LIST these relations. To see the old defining clauses you have to use the LISTEX command described below.

If you now want to pose queries that will access these two relations do an open EXFILE1 command. This is more fully described below. Basically, it opens the external file for access by RPRED (using the micro-PROLOG primitive OPEN) and records the fact that the file is open by adding an opened clause for the relation to the workspace.

4.5.2 The RPRED relation

RPRED is a relation which converts a query condition for an external relation into a search through the clauses saved on a file segment. The segment is identified by its first three arguments - the file name, the start position and the stop position. As the segment is searched, each clause found is matched against the atom given as the fourth and last argument. The RPRED definition of salary given above can be read:

To solve any atom of the form (salary|x) (the x represents any list of arguments)

find a clause in the opened file EXREL1.LOG in the segment between character position (0|0) and character position (3|72) that matches the atom (salary|x) and solve the conditions of the clause

In general there will be several clauses in the segment that match (salary|x) for the given x, so there will be several solutions to the query.

The character positions are |-pairs of numbers because this is what is used by the file I/O primitives of micro-PROLOG (see Chapter 8). A single integer identifying the character position is not used because this would limit files to 64K characters. Chapter 8 also includes a description of the definition of a simplified version of RPRED in terms of the file primitives of micro-PROLOG.

4.5.3 The open command and the opened relation

The use is

open <file name>

It is equivalent to the primitive OPEN command of micro-PROLOG with the added feature that it 'remembers' the opened files by adding an opened assertion to the workspace. You can therefore find out which are the currently opened files by LISTing the opened relation. You should always use open before posing a query that will access an external relation. Use it instead of the OPEN primitive because the opened assertion it generates provides useful information for the various listing commands described below.

If you do not open the external relation file before querying any of its relations you will get an error. If you are

using the errtrap-mod error handler decribed in Chapter 6 you will be able to recover from the error by opening the file and continuing. Otherwise, the query will be aborted. You must open the file and repose the query.

micro-PROLOG only allows four files to be open at any one time. This limits the number of different external relations you can access during a single query. You increase the number by putting more external relations on each file. When you have finisned accessing all the external relations on a file you should close the file.

4.5.4 The close command

The use is

close <file name>

It is the opposite of open. It closes the file (using the primitive CLOSE) and deletes the opened assertion for the file from the workspace.

4.5.5 The internal command

This is almost the opposite of external. The difference is that it handles one relation at a time and leaves other external relations on the same file unchanged.

The use is

internal <relation name>

Notice that the file name is not given - it is not needed. The command picks up the clause defining the named relation in terms of RPRED, deletes this clause, and loads all the clauses on the file segment identified in the RPRED condition of the deleted clause.

The RPRED definitions for any other relations on that file are left unchanged, they can still access the appropriate segments of the file. However, there is now an unaccessible segment - a hole in the file - from which the definition of the internalised relation has been read. All its defining clauses are now in the workspace and can be added to or edited before the relation is again made external on another file. Well, it must be another file if there are still accessible relations on the old file on which it was kept. This is the disadvantage of packing more than one relation onto a file.

4.5.6 The LISTEX, LISTFILE commands

If you LIST a relation that has been made external you see its RPRED definition. To see its actual defining clauses you need to use LISTEX. Its use is

LISTEX <relation name> where the named relation is external (i.e. is defined by an RPRED clause in the workspace program)

e.g.

LISTEX salary

will produce listing of all the old clauses for the salary relation. This command automatically opens the file on which the clauses are kept and will close it again unless there is an opened assertion for the file.

Hence the importance of using open rather than the primitive OPEN to open external files for querying. If you use open, listing the clauses for the external relation will not result in the file being automatically closed after the listing. It will be left open for the queries.

To see all the saved clauses on a file use LISTFILE.

LISTFILE <file name>

will list all the clauses on the file. This can be used for any file on which a micro-PROLOG program has been saved, not just the files holding the external relations. So you can use it to list a normally SAVEd program. Again, the command automatically opens and closes the file unless there is an opened assertion for the file left by the open command.

4.5.7 The listex and listfile commands

These are alternatives to the LISTEX and LISTFILE commands which can only be used when the query-mod module of the SIMPLE front end system described in the next Chapter has been loaded. They require query-mod to be present because they use one of its exported relations, Parse-of-SS, to map the clauses on the file back into SIMPLE sentence form. Otherwise, they have exactly the same effect as LISTEX and LISTFILE. listfile should only be used to list a file of clauses that have been entered and saved using SIMPLE, similarly listex should only be used to list the clauses for external relations entered as SIMPLE sentences.

4.5.8 Changing the definitions of external relations

If you need to edit or delete some clause about a relation that is external then you must use the internal command described above to bring all the defining clauses back into the main memory. When you have made the changes, make the relation external again. You must use a different file if there are still external relations on the old one.

If the change to the definition is just the adding of some new clauses, you can just enter these in the normal way, leaving the old clauses on the file. If you ADDCL them before the RPRED definition for the relation, the new clauses will be used before the file clauses for the relation.

You can add them so that they are positioned after the RPRED clause, or in such a way that the RPRED definition is sandwiched between new clauses. Wherever the RPRED definition is positioned it will be used by micro-PROLOG as though it were replaced by all the clauses that it points to on the disk file.

When you eventually do an internal command for the relation, the RPRED definition is deleted, no matter where it is, and all the external clauses are added at the end of the remaining clauses. A new external command will now save all the defining clauses onto the specified file.

5. SIMPLE PROLOG

SIMPLE provides a quite elaborate extension to the facilities of the built-in supervisor. It provides commands to add, delete and text edit programs and supports several high level forms of query. The most important feature is that it allows clauses to be entered and queries to be posed using a much more user friendly syntax than the basic syntax described in Chapter 2. The SIMPLE syntax for clauses is much closer to the syntax of English. SIMPLE is therefore a very suitable system to use for beginning micro-PROLOG programmers. It is the system described in the book "micro-PROLOG: Programming in Logic" [Clark and McCabe, 1984].

The form of clause accepted by SIMPLE is called a sentence because its syntax is so different. The program development commands of SIMPLE compile sentences into clauses and map the clauses back into sentences when they are displayed. For most uses, the programmer does not need to know anything about the syntax of clauses, only the syntax of SIMPLE sentences. However, you can always see the sentences in their compiled clause form by using the LIST supervisor command. In contrast, the list command of SIMPLE maps the clauses back into sentence form before displaying them.

To use SIMPLE you execute a LOAD SIMPLE command. (Note the warning at the beginning of the next chapter on MICRO. None of the MICRO modules should be present when you load in SIMPLE.) The easiest way to enter the SIMPLE system is to invoke micro-PROLOG with a LOAD SIMPLE in the operating system command line as in:

```
A>PROLOG LOAD SIMPLE
```

The file SIMPLE.LOG which will be loaded contains three modules called:

```
query-mod
program-mod  {also in the file PROGRAM.LOG}
errmess-mod
```

query-mod is the module which defines and exports all the relations that compile and de-compile SIMPLE sentences and it also includes the definitions of the query commands and other pre-defined relations supported by SIMPLE. program-mod is the module that defines all the program development commands, for example, the commands to add, delete and list SIMPLE sentences. It can be optionally killed, with a

```
KILL program-mod
```

command, when a program has been developed in order to free space for the evaluation of queries. When the program needs to be edited or added to this module can then be loaded from the file PROGRAM.LOG which only contains the module with a

```
LOAD PROGRAM
```

command. Finally, errmess-mod is a very simple error handling

module. It exports the definition of a relation called "?ERROR?". When this relation is defined the micro-PROLOG interpreter calls its program on encountering a runtime error. The "?ERROR?" program in errmess-mod displays the condition currently being evaluated together with a more meaningful error message than the default error messages. For more information on error handling consult Appendix C. The messages given by errmess-mod are very similar to those of the example error handler given in that appendix. The module can be killed and replaced by the errtrap-mod error handler described in 6.3 of the MICRO chapter, or by one called deftrap-mod which is described below.

Two other modules in the files EXPTRAN.LOG and and TOLD.LOG can be optionally loaded and used with SIMPLE. The first file contains the module exptran-mod. When this is present expressions can be used in sentences and these are compiled into a sequence of conditions that evaluate the expression. The second file contains the module told-mod which defines and exports the relation is-told. This can be used in a straightforward way to write interactive programs, programs that ask for information by posing queries to the user. The is-told program can also be invoked from the error handlers deftrap-mod and errtrap-mod.

5.1 Syntax of sentences accepted by SIMPLE

A **sentence** is either

(i) a simple sentence

or (ii) a conditional sentence.

simple sentences have four forms: infix, postfix, prefix and single condition.

infix simple sentences have the form:

<term> Rel <term>

where Rel is a constant which is the name of a two argument (binary) relation. The terms on either side of Rel are the two arguments of the binary relation.

e.g. John likes Mary
x LESS 45

postfix simple sentences have the form:

<term> Rel

where Rel is a constant which is the name of a single argument (unary) relation.

e.g. Tom male {male is the unary relation}
x a-father {a-father is the unary relation}

prefix simple sentences have the form

Rel(<term1> <term2> .. <termk>)

where Rel is a constant which is the name of a k argument

relation. The list of terms following Rel are the k arguments of the relation and are separated only by spaces.

e.g. SUM(X 5 34)
APPEND((2 3) (4 5) X)

Sentences about binary relations and unary relations can be entered in this prefix form but will always be displayed by SIMPLE in the infix or postfix form.

e.g. Bill likes x can be entered as likes(Bill x)
x male can be entered as male(x)

Single condition simple sentences have the form

C

where C is a constant that names a 0-argument relation or condition.

e.g. FAIL
/
Bill-likes-Mary {the hyphens make it one constant}

conditional sentences have the form:

<simple sentence> if <conjunctive condition>

where a **conjunctive condition** is

(i) a condition
or (ii) a conjunction of the form:

<condition> and <conjunctive condition>

& is an accepted abbreviation for and.

A **condition** is

(i) a simple sentence

or (ii) a complex condition.

A **complex condition** is

(a) a **negated condition** of the form:

not <condition>
or
not (<conjunctive condition>)

e.g. not x male
not (x male and x likes Mary)

or (B) an **isall condition** of the form:

<term> isall (<term> : <conjunctive condition>)

e.g. x isall (y : Bill father-of y and y male)

or (C) a **forall condition** of the form:

(forall <conjunctive condition> then <conjunctive condition>)

e.g. (forall Tom father-of y then y male and y married)

The outer brackets are essential.

or (D) an **or condition** of the form:

(either <conjunctive condition> or <conjunctive condition>)

e.g. (either x likes Peter or Peter likes x & Sally likes x)

Again the outer brackets are essential.

or (E) an **equality condition** of the form

<expression> = <expression>

or (F) an **expression condition** of the form:

Rel # (<expression> <expression> ... <expression>)

Expressions are terms of a special form. The syntax of expressions is given in 5.3 below. Expressions can only be used if the optional EXPTRAN has been loaded.

The syntax of terms is as described in Chapter 2. There is one difference. The control characters that are allowed in quoted constants in clauses should not be used in sentences. If they are, they will not be displayed in the correct form by the SIMPLE list command and may well upset the way the sentence is displayed.

Example conditional sentences

PRED(x y z) if PQ(x y z) and y LESS z

x likes y if y female and not y likes Peter

x GE y if not y LESS x

PRED(x y z1) if x LESS y and not(PR(y z x) & QUALIFY(x))
and z1=(x*y+z)

x all-the-sons-of y if x isall (z : y parent-of z & z male)

only-has-sons(x) if (forall x parent-of y then y male)

x parent-of y if (either x father-of y or x mother-of y)

Constants as variables

Constants can be used in place of variables in conditional sentences providing their use in this special role is declared by a vars comment condition at the end of the rule.

e.g.

person1 likes person2 if person2 likes person1 and (person1 person2) vars (A)

This sentence is equivalent to

X likes Y if /*(vars (X ¦ person1) (Y ¦ person2)) and Y likes X (B)

in which the constants given as variables are associated with real variables in a /* comment condition. (A) will be compiled into the clause form of (B).

The form of the vars condition, which must be the last condition of the sentence, is

(constant1 ... constantk) vars

where constant1 ... constantk are all the constants used in place of variables in the sentence. Sentences entered using this special vars comment facility will always be diplayed in this form by the list and edit commands of SIMPLE. To see the sentence with variables in place of the vars constants you need to use the supervisor LIST command which will diplay it in the fully compiled clause form.

5.2 The relations and commands defined by program-mod

We briefly describe the program development commands defined in and exported from program-mod. For a more tutorial introduction to the use of SIMPLE we refer the reader to [Clark and McCabe, 1984].

5.2.1 add

The add command allows you to add a sentence to the current workspace program. The sentence to be added must be enclosed in brackets. (Thus the argument to add is a list of terms that conforms to the syntax of a sentence.) One form of the command is:

add (<sentence>)

e.g.

```
&. add (Peter likes x if not x likes John)
&.
```

The sentence will be compiled into a clause and added to the end of the current list of clauses for the relation that the sentence is about. In this case, the sentence is about the relation likes.

To add into the middle of a program the form

add n (<sentence>)

is used, where the number n refers to the position that the new sentence should occupy in the listing of the sentences for its relation. For example, to add to the beginning of the likes relation use

```
&. add 1 (Peter likes John)
&.
```

Whenever you add a sentence about a new relation the relation name will be recorded in a dict assertion which is automatically added to your workspace program by the add command. So to see all these relation names you list the dict relation.

5.2.2 list

The list command displays the program on the console. To display the whole of your program type

```
&. list all
Peter likes John
Peter likes X if
     not X likes John
&.
```

Note that the clauses are displayed in sentence form. The list command de-compiles the clauses back into sentences before displaying them. You will see all the sentences for the relations recorded in the dict relation.

To display just a single relation, the likes relation say, use

```
&. list likes
```

This uses the alternative form of the command:

```
list <relation name>
```

You can only list relations recorded by a dict assertion.

To print a program on the printer use the ^P (control-P) toggle before listing the program. This will automatically print the program on the printer as it is displayed on the screen.

```
&.^Plist all
.
.    {listing of the program copied on to the printer}
.
&.^P
```

The final ^P turns off the copying of the screen display onto the printer.

To see all the currently defined relation names use:

```
&.list dict
```

You will see all the relation names about which you have added a sentence, providing you have not killed the relation.

5.2.3 delete

This deletes a single clause from the program. It has two forms of use:

```
(i)   delete (<sentence>)
(ii) delete <relation name> n
where  n is the position of the sentence to be deleted.
```

e.g.
```
&. delete likes 3
&. delete (tom likes mary)
```

5.2.4 kill

kill will delete an entire relation using the form:

```
kill <relation name>
```

e.g. to delete all the clauses for the likes relation type

```
&. kill likes
```

To get rid of the entire workspace program (you should normally only do this after a save) use

```
&.kill all
```

You will be asked if you really want to do this with the question

```
Entire program ?(yes/no)
```

The "yes" response causes all relations recorded by a dict assertion to be killed.

cp4
Finally, to get rid of a module use the form : kill <module-name>

```
&.kill exptran-mod
```

will get rid of the expression parser after you have used it to compile expressions in some added sentences.

All the uses of kill report the successful deletion of the program or module. When a program for a relation is killed its entry in the dict relation is also deleted. After a kill all the dict relation will be empty.

5.2.5 accept

The accept command can be used as an aid in adding a lot of simple sentences for a relation. It enables a sequence of simple sentences to be added without the need to repeatedly use the add command. An example use is:

```
&. accept likes
likes.(John Mary)
likes.(John Peter)
likes.end
&.
```

The Accept command prompts for a simple sentence (in prefix form) with the name of the relation involved. The list of arguments of the sentence are then entered. You can continue entering sentences in this way until you enter end. The above example is equivalent to:

```
&.add(likes(John Mary))
&.add(likes(John Peter))
```

5.2.6 edit

The line editor can be used to edit an individual sentence by using this edit command. (See Appendix B for details of the line editor) The edit command is invoked as follows:

```
&.edit likes 1  {the relation followed by the sentence number}
  1 (Peter likes John)
```

The sentence (surrounded by brackets) will be displayed preceded by the number which is its position and both the sentence and its position can then be edited using the line edited commands. Like **list**, **edit** maps clauses back into sentence form before displaying them. It then re-compiles them into clauses on exit from the edit when the **ENTER** or **RETURN** is pressed.

You can change the position number of the sentence in order to re-position the sentence whether or not you have edited the sentence. In the above example, changing the position number 1 to 2 will move the sentence to the second position in the listing of likes. The old second sentence will therefore become the new first sentence. You should never delete the position for the sentence from the beginning of the edit line since this is used when you exit the edit to determine where the edited sentence should be added. The old sentence is deleted just before the edited version is added to the program. If you change the name of the relation that the sentence is about you will be told that this has been done with the message

relation changed to ....

on exit from the edit.

You can only edit relations with names recorded in the **dict** relation, and the displayed sentence must not exceed the length of the keyboard buffer. This is only 256 characters on Z80 systems, but 1840 characters (23 * 80 chararacter lines) on 8086 systems.

5.2.7 cedit

Exactly the same form of use as **edit**. The difference is that the old version of the sentence is not deleted. The command is very useful for building programs in which two are more sentences differ only slightly.

example

```
&.add (y greater-of (y z) if not y LESS z)
&.cedit greater-of 1
1 (X greater-of (X Y) if not X LESS Y)
```

This line can now be edited to

```
2 (Y greater-of (X Y) if not Y LESS X)
```

as an alternative to explicitly adding it as a second sentence.

5.2.8 function

This is the command that is used to declare that a relation is to be used as a function in expressions. Its use is fully described in Section 5.4.

5.2.9 "?REV-P?"

This is the relation that is used to map each clause for a relation into a list which when displayed using the P primitive of micro-PROLOG will be the sentence form of the clause formatted with each condition of the sentence on a new line. It does this by inserting control character constants in the sentence list that it generates from the clause. It is used by the list command. The Parse-of-S relation described in the next section is more general in that it can be used to generate clauses from sentences as well as sentences from clauses. When "Parse-of-S" generates a sentence from a clause no control character constants are inserted so that if the sentence is then diplayed using P or PP it will not be formatted.

The form of use of "?REV-P?" is

X "?REV-P?" Y

where X is a clause and Y is a variable.

example

```
&.?(("?REV-P?" ((likes X Y)(likes Y X)(female Y)) x) (P | x))
X likes Y if
     Y likes X and
     Y female
&.
```

This query uses the primitive ? described in Chapter 3. The condition (P | x) is used rather than (P x) so that terms of the sentence list x will be treated as a sequence of different arguments and so displayed without the outer brakets. If (P x) had been used the display would be

```
(X likes Y if
     Y likes X and
     Y female)
```

5.3 The relations and commands exported by query-mod

5.3.1 is

The is command makes a YES/NO query of the program. It has the form:

is (<conjunctive condition>)

with the single argument a bracketed conjunctive condition. If the conjunctive condition can be solved, the response is YES otherwise it is NO.

For example,

```
&. is (John likes Mary)
YES
&. is (SUM(2 3 x) & x LESS 5)
NO
```

5.3.2 which (all an accepted synonym)

The which query finds all answers to some condition of a specified form. The syntax of the command is

which (<sequence of terms> : <conjunctive condition>)

where <sequence of terms> denotes the form of the answer required, and the <conjunctive condition> is the query to be evaluated. For example, to find all the people that like John use:

```
&. which(x : x Likes John)
Peter
Mary
No (more) answers
&.
```

To find the pairs of people who like each other:

```
&. all(x y like each other : x likes y and y likes x)
Peter Mary like each other
No (more) answers
```

Notice the use of the constants in the sequence of answer terms to make up an answer message. The sequence of answer terms can be of any length and can contain any form of term. The answers are displayed by the micro-PROLOG primitive PP.

To compute the sum of 3 and 5

```
&.which(x : SUM(3 5 x))
8
No (more) answers
```

5.3.3 one

The one query is similar to which except that it prompts after each solution has been found with

more(y/n)?

a "y" response gives the next answer if there is one, a "n" response terminates the query evaluation.

```
&.one(x : x likes John)
Peter
more(y/n)?.y
Mary
more(y/n).y
No (more) answers
&.
```

5.3.4 save

The entire workspace program can be saved for later use with this command. It is saved in clause form, not in sentence form. The use of the save command is:

&. save <file name>

where <file name> is a file name in the normal micro-PROLOG form. (See section 3.5.3) save is just a lower case synonym for the

supervisor SAVE.

The <file name> must be different from any relation name in the program. The saved program can subsequently be reloaded using load.

5.3.5 load

The load command is used to re-load a previously saved program. Its use is

&. load <file name>

Like save it is just a lower case synonym for the supervisor LOAD.

5.3.6 APPEND, ON, true-of

query-mod includes and exports definitions of two useful list processing programs for the relation names APPEND and ON. In sentence form, their definitions are:

```
APPEND(() X X)
APPEND((X|Y) Z (X|x))
   if APPEND(Y Z x)

X ON (X|Y)
X ON (Y|Z)
  if X ON Z
```

The APPEND relation has many uses. It can be used in exactly the same way as the append relation of [Clark and McCabe, 1984]. The relation ON can be used to find members of a list or test for membership in the same way as the belongs-to relation of [Clark and McCabe, 1984].

true-of can be used when the relation name of a prefix form condition or its argument list is to be given as the value of a variable. Its form of use is:

<variable or relation name> true-of <list pattern>

The <variable> must be a relation name Rel by the time that the condition is evaluated. The <list pattern> represents the list of arguments for the relation. true-of gives the power of the predicate symbol and argument list meta-variables of the standard syntax (see Chapter 2) to programs entered in sentence form.

For the clause form definition of true-of see the next chapter. The definition that is exported from query-mod cannot be given in sentence form.

Example use

```
x true-of-all Y if (forall y ON Y then x true-of (y))
```

defines a relation true-of-all that can used to test if all elements of a list Y have some property given as argument x. Notice that since x names a property - a unary relation - the second argument of true-of is a unit list (y) comprising the element to be tested.

```
is( male true-of-all (Peter John Sam))
```

checks that Peter, John and Joan are all recorded as males.

```
which(x : x dict & x true-of (tom|y))
```

will find all the names of the relations recorded in dict such that tom 'satisfies' the relation. That is, if the relation is a property, then tom can be shown to have the property, and if it is a relation with more than one argument, then tom can be shown to be related to some other things by that relation.

The y in the list pattern (tom|y) represents the remaining arbitrary number of arguments of the relation x. When the true-of condition is solved y will be bound to a list of these extra arguments. When x is a property, y=().

The <list pattern> of a true-of condition can be a variable representing a list of any number of arguments. The use of variable in this way is not restricted to true-of conditions. Any simple sentence, written in prefix form, can have its list of arguments represented by a variable. As an example,

```
which(X : father-of X)
```

can be used to find all the pairs in the father-of relation. It is a shorthand for

```
which((x y) : father-of(x y))
```

The use of a single variable as the argument following a relation is always a shorthand for a list of different variables, one for each argument of the relation. This, and true-of, are the only 'meta syntax' forms allowed in SIMPLE programs.

5.3.7 CONS, @, #, =

CONS and @ are used in expressions which are dealt with in the next section. The # and = relations are only used together with expressions and are also described in the next section. query-mod does not actually contain a definition of =, but it cannot be defined in a user program because it has a special role in the syntax of sentences.

5.3.8 *, %, +, -

The query-mod module exports definitions for the auxiliary arithmetic relations *, %, +, -. The auxiliary relations *,%,+,- are recognised as arithmetic operators in expressions. The query-mod definitions of the operators are:

```
+(X Y Z) if SUM(X Y Z)
-(X Y Z) if SUM(Y Z X)
*(X Y Z) if TIMES(X Y Z)
%(X Y Z) if TIMES(Y Z X)
```

5.3.9 defined, reserved

defined can be used to check if a relation name has any defining sentences. It can only be used in this checking mode.

```
&.is(likes defined)
```

```
YES

&.is(animal defined)
NO
```

reserved can be used to find all the SIMPLE reserved words. More precisely, it returns a list of all the names exported by the currently loaded modules with the names dict, func and data-rel appended to the front. All though these last three are not exported by any of the SIMPLE modules they have a special role in SIMPLE programs and should not be used as normal relation names. We have already encountered dict. The role of func will be explained in the next section and the role of data-rel in section 5.5 on errmess-mod.

5.3.10 Parse-of-S, Parse-of-ConjC, Parse-of-SS, Parse-of-Cond, Parse-of-CC

This are the relations used by query-mod to compile and de-compile sentences into clauses.

Parse-of-S

```
X Parse-of-S Y
```

holds when X is the clause version of the sentence list Y.

e.g.
((likes X Y)(likes Y X)) Parse-of-S (X likes Y if Y likes X)

It can be used to parse a sentence list into a clause with a condition of the form

```
X Parse-of-S <sentence list>
```

or to de-compile a clause into a sentence list with

```
<clause> Parse-of-S Y
```

Parse-of-ConjC

```
X Parse-of-ConjC Y
```

holds when X is the atom list form of the conjunctive condition list Y.

e.g.
((likes Tom Y)(NOT male Y)) Parse-of-Conj (Tom likes Y & Y male)

It can be used for parsing conjunctive conditions with a condition of the form

```
X Parse-of-ConjC (<conjunctive condition list)
```

or for de-compiling lists of atoms into conjunctive conditions

```
<atom list> Parse-of-ConjC Y
```

Parse-of-SS

```
Parse-of-SS(X Y Z)
```

holds when X is the atom form of the simple sentence which is

formed from the sequence of terms on the list Y upto the list Z. That is, X is the atom form of the difference between the lists Y and Z.

e.g.
Parse-of-SS((likes X Y) (X likes Y if Y likes X) (if Y likes X))

It can be used for finding and parsing the front simple sentence of a list with a conditon of the form

Parse-of-SS(X <sentence list> Y)

X will become the atom and Z the remainder of the sentence list. To map an atom into a simple sentence use the condition of the form

Parse-of-SS(<atom> Y ())

where the remainder is given as the empty list. A condition

Parse-of-SS(<atom> Y Z)

will give Y the list pattern value (<simple sentence form of atom> |Z).

e.g. Parse-of-SS((likes x y) Y Z)

gives Y the value (x likes y |Z).

Parse-of-CC

Parse-of-CC(X Y Z)

holds when X is the atom form of the complex condition represented by the difference between the lists Y and Z. It has the same uses as Parse-of-SS.

Parse-of-Cond

Parse-of-Cond(X Y Z)

holds when X is the atom form of the condition which is the difference between lists Y and Z. It has the same uses as Parse-of-SS. Reflecting the syntax definition of a condition that we gave at the beginning of this Chapter Parse-of-Cond is defined by the two rules

Parse-of-Cond(X Y Z) if Parse-of-SS(X Y Z)
Parse-of-Cond(X Y Z) if Parse-of-CC(X Y Z)

5.3.11 "FIND:", "?VARTRANS?"

Both these relations are used internally by the parse programs and are of little use in user programs. They are exported from query-mod only because they are used by other modules.

5.4 Using expressions in sentences - the module exptran-mod

Expressions can be used in equality conditions and expression conditions in sentences and queries when the optional module exptran-mod has been loaded with a

```
load EXPTRAN
```

command. The expressions are actually compiled into a relational form by the single relation Epression-Parse exported by exptran-mod.

5.4.1 Expression conditions

Expression conditions have the form

```
Rel # (E1 E2 .. Ek)
```

where Rel is the name of a relation and E1 ... Ek are expressions. Expressions are just terms of a certain form. The # is the signal that E1 ... Ek are not normal arguments but that some or all of them contain arithmetic operators and function calls. The syntax of expressions is formally defined below. For now we shall just look at examples.

Example

```
LESS # ((2*x) (5+y))
```

is a LESS condition with arguments the values of the expressions (2*x), (5+y). When it is evaluated, the variables x and y should have been given values.

The relational form into which the condition is compiled is:

```
(X LESS Y) # (* (2 x X) and + (5 y Y))
```

The # in this form should be read as **where.** So this condition is read as

```
X LESS Y where X is 2 * x and Y is 5 + y
```

This is the sentence syntax form of what is produced by Expression-Parse. It is what will be displayed if you kill exptran-mod after the expression condition has been entered or if you add rel-form to your program and list the sentence in which it is used (see 5.3.5 below).

The relational form of an expression condition

```
Rel # (E1 E2 .. Ek)
```

is

```
(Rel(t1 t2 .. tk)) # (<conjunctive condition>)
```

The evaluation of the conjunctive condition will produce values for the variables in the terms t1, t2, .. tk so that they become the values of the original expressions E1, E2, .. Ek. In our LESS example, the terms are the variables X, Y and the evaluation of the conjunctive condition

```
* (2 x X) and + (5 y Y)
```

will result in X having the value of (2*x) and Y the value of (5+y).

When a compiled # condition is evaluated, the conjunctive

condition that produces the values of the expression arguments is evaluated first, then the Rel condition. On backtracking, only the Rel condition will be retried for alternative solutions, since there will be no alternative solutions for the evaluation of the expression values.

Example The condition

```
salary # (x (12*157))
```

is compiled into the relational form:

```
(x salary X) # (* (12 157 X))
```

The * condition computes the value of (12*157) and the evaluation of the # condition will reduce to the evaluation of

```
x salary 1884
```

in order to find an x with recorded salary of 1884. Backtracking will result in different values for x being sought but will not cause the re-computation of the value 1884.

For details of the standard syntax form of a compiled expression condition and for the definition of # that is exported from query-mod, and which is used to evaluate # conditions, see the next chapter. The MICRO definition of # relation is exactly the same as the query-mod definition.

5.4.2 Equality conditions

An equality condition has the form

```
E1 = E2
```

where E1 and E2 are expressions. It is a shorthand notation for the expression condition

```
EQ # (E1 E2)
```

Thus, the two expression arguments E1, E2 of an equality condition are evaluated and then their values are checked for identity using the primitive EQ relation. EQ is itself defined by the sentence

```
EQ(X X)
```

So, if one of the expressions is a variable, this will result in the variable being given the value of the other expression.

Examples

```
x=(y * 67 + z)
```

can be used to give x the value of the bracketed expression if y and z have values at the time that the condition is evaluated. If they do not, there is a "Too many variables" error message displaying either a call to SUM or a call to TIMES.

```
0=(2*x*x + 7*x - 23)
```

can be used to check that the value of x satisfies the equation:

$2x^2 + 7x = 23$

(It cannot be used to find the roots of the equation)

5.4.3 Syntax of expressions

An **expression** is

(i) an arithmetic expression
(ii) a function call
or (iii) some other term

An **arithmetic expression** is a list of the form

(<expression> <operator> <expression>)

where the operator is one of

*	for multiply
% or /	for divide
+	for addition
- or ~	for subtraction (the ~ is safer because of the other syntactic roles of -. If you use - you should always surround it with spaces.)

The outermost brackets of an arithmetic expression are essential - so an arithmetic expression is just a three element list whose second element is an operator. However, if the expression arguments of this operator are also arithmetic expressions the inner brackets around them may be dropped in accordance with the following precedence

* / %	equal - left associative
greater than	
+ ~ -	equal - left associative

Examples

```
(x * y + 3 / z)   equivalent to  ((x * y) + (3 / z))
(x + y / (5 + z)) equivalent to  (x + (y / (5 + z)))
(x * y / 5 + z)   equivalent to  ((x * y) / 5) + z))
```

query-mod exports definitions for the operators * % + -. Uses of / and ~ in expressions are mapped into conditions for % and - respectively. Any use of ~ or / in an expression will subsequently be displayed as a use of - or %.

A **function call** is a list of the form

```
(Rel E1 .. En-1)
```

where E1...En-1 are expressions and Rel is a n-ary relation name that has been declared a function with the command

```
function Rel
```

The expressions are the first n-1 arguments of what would otherwise be given as an expression condition of the form

```
Rel # (E1 ..  En-1 x)
```

The x found by the evaluation of this condition is the value denoted by the function call (Rel E1 .. En-1). Notice that this means that relations should be declared as functions only if the value of the last argument of the relation is uniquely determined by values for the preceding arguments.

Example

Suppose the relations div and mod are defined by the rules:

```
div(x y z) if TIMES(y z1 x) & INT(z1 z)
mod(x y z) if div(x y z1) & z=(z~y*z1)
```

(Note the essential use of ~. If - had been used the z-y would have been parsed as a constant resulting in the call to TIMES failing; this would cause the evaluation of mod to fail. However z~y is recognised by the lexical analyser as three terms z, ~ and y and hence as a use of the subtraction operator.

INT is a primitive of micro-PROLOG that can be used to test if a number is an integer or to find the integer part of a number, as here. So, div(x y z) can be used to find the integer divisor z of x and y and mod(x y z) can be used to find the remainder z of the integer division of x by y. For both div and mod the last argument is functionally determined by the first two arguments. So, we can declare these relations as functions

```
function div
function mod
```

and then use them in expressions:

```
x=((mod 85 23)*34)
LESS #((div 500 x) 23)
```

If you forget to declare that some relation Rel is a function before using it in an expression the expression parser of exptran-mod will assume that the function call is just a list that has as its first element a constant. However, it will tell you this by giving you the message

```
Rel assumed not to be a function
```

If the expression was in a query you will get the wrong answers. If the expression was used in an added sentence you can easily recover from the error. Declare Rel as a function and Edit the sentence. Just call the line editor and then immediately exit it with <return>. The editor de-compiles the clause for the original sentence, mapping compiled expressions back into source form. It re-compiles the expressions on exit. This time it will recognise the use of Rel as a function call because of the declaration.

A function Rel declaration causes a "Rel func" sentence to be added to the user workspace program. It is this that causes the expression parser to treat a list beginning with Rel as a function call when it appears in an expression. You can examine what functions have been declared with a

```
which(x : x func)
```

query. Alternatively, you can list the func relation. If you kill a relation that has been declared a function the func

sentence for the relation will be automatically deleted. (This only happens if you use the kill command of SIMPLE. If you use the supervisor KILL neither the func sentence nor the dict sentence for the relation will be deleted.)

5.4.4 Warning on the use of | in expressions

From the above discussion on the problem of undeclared function names it will be obvious that lists can be given as arguments to function calls in expressions. As an example

```
x = (APPEND (1 2) (APPEND (3 4) (5 6)))
```

can be used to append three lists. As we remarked earlier, the relation APPEND is defined in and exported from query-mod. It is also recognised by the expression parser as a function name so you do not need to declare it as a function in order to use it in expressions. However,

```
x=(3 | (APPEND y z)))
```

cannot be used to make x the list 3 followed by the concatenation of the lists y and z. This is because, as a micro-PROLOG term, the list

```
(3 | (APPEND y z))
```

is just another way of writing the list

```
(3 APPEND y z)
```

in which the function call sublist has disappeared. So the expression parser sees a list of four elements and leaves it unchanged. The moral is that the term following a | in an expression can never be a function call. When you do want to denote the rest of a list by a function call you must use an explicit CONS function call (as in LISP) to construct the list instead of the primitive |. The above = condition needs to be re-expressed as

```
x = (CONS 3 (APPEND y z))
```

Like APPEND, CONS is defined in and exported from query-mod and is recognised as a function in expressions. Its definition, in sentence form, is

```
CONS(X Y (X|Y))
```

Finally, there is one other predefined function. It is the apply function @. Its definition, which can only be given in clause form, is given in 6.1.16 of the next chapter. It applies its first argument, to the rest of its arguments. An example use is in the expression

```
x = (@ y 3 4)
```

If y is bound to * when this is evaluated x will be bound to 12.

The @ is needed. If you instead use

```
x = (y 3 4)
```

then (y 3 4) is not recognised as a function call. The equality

is compiled into

```
EQ(x (y 3 4)) # ()
```

with an empty condition for the argument evaluation. It will result in x being bound to the list (* 3 4) when evaluated. @ is the expression equivalent of the true-of sentence condition and the predicate meta-variable (see Chapter 2) for atoms.

5.4.5 The relation Expression-Parse

Expressions occurring in equality conditions and expression conditions are compiled into relational form using the relation Expression-Parse that is exported from the module exptran-mod. This same relation is used to de-compile the expressions when a clause is listed or edited.

```
Expression-Parse(X Y Z)
```

holds when Y is the term X with all the expression sublists replaced by new variables and Z is the list of atoms the evaluation of which will give these new variables the values of the expressions of X.

e.g. `Expression-Parse((x * y + (fact z)) X ((* x y x1)(fact z x2)(+ x1 x2 X)))`

It can be used to parse expressions with a condition of the form

```
Expression-Parse (<expression> X Y)
```

or to de-compile expressions with

```
Expression-Parse(X <term> <atom list>)
```

5.4.6 When the expression handler is not needed

If you kill the exptran-mod module after you have entered some sentences that used expressions the expressions will then be displayed in the compiled relational form even by the list and edit commands. This is because a check is made to see if the module is present before Expression-Parse is used to de-compile expressions.

If the exptran-mod module is present then the expressions are displayed in the normal expression form. This means that you can have the convenience of using expressions in sentences whilst you are developing a program. Then, when you want to start using the program, you can get rid of exptran-mod with a

```
kill exptran-mod
```

command to make available more space for the query evaluations. Of course, you will not be able to use expressions in the queries to the program.

If you do enter a sentence or query that uses expressions with the exptran-mod module not present you will get an error message of the form

```
No definition for relation
trying: Expression-Parse(<expression> <variable> <variable>)
```

If you are using one of the alternative error handlers deftrap-mod or errtrap-mod you can recover from this error and return to the interrupted compilation of the expression - more on this later. Otherwise you should load the exptran-mod module with a

```
load EXPTRAN
```

command and re-enter the sentence or query.

Incidentally, you can see the compiled relational form of any expression in a program, even when exptran-mod is present, by adding the sentence rel-form to your program with

```
&.add (rel-form)
```

Now, when you list or edit the program, compiled expressions will not be put back into expression form but will be displayed in relational form. (The relational form of an expression condition can be edited and it will be compiled back into clause form on exit from the edit.) The display of the relational forms will continue until you delete the rel-form sentence. It is useful if you want to check that you did not make a mistake in an expression and that what you intended is what has been recognised and compiled.

5.5 The error handler errmess-mod

On a runtime error the error handler errmess-mod that is loaded as part of SIMPLE just prints out a message identifying the error (the messages are similar to the ones given by the example error handler in Appendix C) along with the condition it was trying to evaluate when the error occurred. The current query or command is aborted and you are then returned immediately to the supervisor (you will get the &. prompt for a new query or command).

An alternative error handler, that allows you to recover from the very common error of not having a definition for a relation of the condition about to be evaluated (through forgetfulness or misspelling) is in the file DEFTRAP.LOG of the distribution disk. You can switch to this error handler by executing the following pair of commands, in the order given.

```
kill errmess-mod
load DEFTRAP
```

It is important that you do the kill first. This is because errmess-mod and the module deftrap-mod that is loaded from the file DEFTRAP.LOG both export definitions for the error trap relation ?ERROR? (see Appendix C). If you do the load first you will get the error: "Illegal use of modules".

The only difference between errmess-mod and deftrap-mod is that the error "No sentences for relation" is specially handled by deftrap-mod. The condition that was being evaluated, which contains the undefined relation, is displayed followed by the prompt:

```
error&(? for info).
```

error& is the prompt you will continue to get whilst in this error state with the evaluation in which the error occurred suspended. Entering ? produces the message

```
to quit enter: q
or enter: tell (see manual)
or enter: / <any command> (eg / add (sentence), / load file)
to continue enter: c
```

If you enter any other first response than q / or c you will again get the ? info.

The q causes an ABORT to the top level supervisor which is what normally happens with the errmess-mod handler.

tell adds the sentence

```
Rel x if (Rel x) is-told
```

where Rel is the offending relation, and continues the evaluation. The effect is to invoke is-told (see below) with an argument which is the error condition.

It enables the condition to be answered interactively during the current query evaluation. This is useful for 'top-down' development of programs. You can define the higher level relations in terms of lower level relations whose programs are yet to be constructed. Then, when you query the partly developed program and get the "No sentences for relation" message for a lower level relation you can supply the answer to the condition using tell.

The rule that tell adds to your program effectivley says that all conditions involving the relation Rel are to be solved by the user. When you are ready to give a proper definition of the relation you can kill this single rule program for Rel and add the defining sentences.

But note, your answers are not remembered. Alternatively you can respond to the error by immediately adding sentences defining the relation or to load a file that contains a definition of the relation. You then enter the c to continue the suspended query evaluation. You can add any number of sentences for the undefined relation before entering the c, in fact you can enter any number of commands providing each is preceded by the /. The / is the escape symbol that allows a command to be entered whilst in the error state.

Loading a file is the appropriate recovery response if you have killed a module such as exptran-mod and you get an error message such as

```
No sentences for relation
trying: Expression-Parse((X*Y) Z x)
error&(? for info).
```

This will happen if you forgetfully use a = or # condition in a query, or in a sentence that you are adding to the program, after you have got rid of the exptran-mod module. The recovery response is

```
/ load EXPTRAN
c
```

and the parsing will continue from the point that the error occurred.

A final example concerns the appropriate recovery action if you have misspelt a relation name, say you have used fatherof instead of father-of, you can recover by adding a sentence that defines fatherof as father-of. When the query evaluation is over you can edit the program to correct the spelling error and delete the definition of fatherof.

```
No sentences for relation
trying : fatherof (X bill)
error&(? for info). / add (x fatherof y if x father-of y)
error&. c
```

Notice that the error handler displays the condition in the prefix form.

For an even more sophisticated way of handling errors, kill errmess-mod and load the MICRO error handler described in the next chapter. This is in the file ERRTRAP.LOG.

data-rel relations

Sometimes, usually when a relation is being used to record facts, it is more convenient of micro-PROLOG interprets having no sentences for a relation has a failure to solve the condition rather than as an error. The errmess-mod, deftrap-mod and errtrap-mod error handlers can be informed that they are to treat a particular relation Rel in this way simply by adding the sentence

```
Rel data-rel
```

to your program. Before displaying the "No sentences for relation" error message each error handler checks to see if there is such a sentence about the relation. If there is, the message is not displayed and the evaluation continues as though there had been sentences but none had matched the condition being evaluated.

e.g.

```
&.add(jolly data-rel)
&.which(x : Tom father-of x & x jolly)
No (more) answers
```

even if we have no sentences for jolly.

5.6 Using the relation is-told

is-told is a multi-argument relation exported from the module told-mod in the file TOLD.LOG. To use it, type LOAD TOLD. When evaluated, an is-told condition displays its sequence of arguments followed by a ? and waits for a response. If there is just one argument, which is a list, this is displayed without the outer brackets. The responses and their effects are:

response	effect
yes	The is-told condition for the displayed argument is assumed to be true. Backtracking will not cause the question to be posed again.
no	The is-told condition is assumed false (i.e. it

fails).

ans .. The .. is a sequence of terms, one for each different variable in the displayed message. The is-told condition is solved for values of the variables given in the response. The i'th term in the response sequence becomes the value for the i'th variable in the displayed message in the left to right order of the text.

Example, if the is-told condition is

(X likes Y) is-told

the message and response

X likes Y ? ans tom bill

makes X=tom and Y=bill. Backtracking will result in the message being re-displayed when an alternative solution can be given. This repeated prompting for new solutions on backtracking continues until you enter no or just.

just .. The same as ans except that on backtracking you are not asked for another solution. It is assumed to be the last solution to the is-told condition.

5.6.1 Example use of is-told

(1) which(percent z : (mark x outof y) is-told & z=(x/y*100))

sets up an interaction that can be used to convert pairs of numbers to percentages. A example interaction is:

```
mark X outof Y ? ans 20 40
percent 50
mark X outof Y ? ans 15 60
percent 25
mark X outof Y ? just 40 120
percent 33.333333
No (more) answers
```

(2)
```
x is-male if x known-male

x is-male if not x known-male &
             (x a male) is-told & (x known-male) add
```

defines is-male in such a way that the user is queried whenever an is-male condition is encountered with argument given but not recorded as a known-male. A yes response to the question such as

```
keith a male ?
```

results in the keith is-male condition that provoked the question being solved and a keith known-male sentence being added to the program. A no response results in the condition failing.

5.6.2 Using is-told from the DEFTRAP error handler

The tell response of the DEFTRAP error handler will invoke is-told with argument the error condition for the undefined relation which you can then answer interactively. If you use the tell

response and you have not loaded TOLD you can still recover from the error by loading the file when you get the second error message. The interaction will be something like:

```
No sentences for relation
trying : father-of (tom X)
error&(? for info).tell
No sentences for relation
trying : is-told (father-of (tom X))
error&(? for info). / load TOLD
error&.c
father-of (tom X) ? .
```

and you can now continue by answering the father-of(tom X) question in the manner described above. You have recovered from an error encountered in an error recovery action! You are now out of the error state.

5.7 Using external relations - the EXREL utility

On occasions, especially when the definition of some of your relations comprises a lot of simple sentence facts, there is very little space left when the entire program is loaded. Incidentally, you can always find out the amount of free space left - for query evaluation or the loading of extra sentences - by querying the primitive SPACE relation.

```
which(x : x SPACE)
```

will give you the amount of free space as a number of K bytes.

When space is at a premium, you can trade time for space and have some of your relation definitions reside in a specially created disk file. The file is created using the external command of the utility module exrel-mod which is in the program file EXREL.LOG of the distribution disk. This can be loaded and used in conjunction with the SIMPLE system.

The use of this utility is described in Chapter 4. Note that there are two commands supported by EXREL - listex and listfile that can only be used when the query-mod module is present. They give a listing of an external relation and a program file in sentence form.

5.8 Tracing SIMPLE queries using SIMTRACE

The TRACE program described in Chapter 4 can be loaded and used to trace evaluations of programs developed using SIMPLE. The drawback of using this program, especially for beginning programmers, is that its ?? query form has the query expressed as a list of atoms and during the trace conditions are displayed as atoms. In fact, to use TRACE none of the SIMPLE modules need be present. They are best deleted to make available more space for the trace.

There is a version of the trace facility called SIMTRACE, that makes use of some of the exported relations of query-mod which allows the user to trace is and all queries posed using the SIMPLE syntax. It also gives more information during the evaluation - it gives information about the failed matches as well as the successful matches - and it displays the conditions being evaluated as SIMPLE syntax conditions. It is a useful

program for a beginner to use to sharpen his understanding of how micro-PROLOG evaluates queries using backtracking. But because at least the query-mod module must also be present, and because tracing takes up a lot of space, only relatively small programs can be traced using SIMTRACE.

The trace program is in the file SIMTRACE.LOG of the distribution disk. To use it do a load SIMTRACE. It contains one program module called **simtrace-mod.** So to get rid of the tracer when you have finished do a kill simtrace-mod.

The SPYTRACE program described in Chapter 4 can also be used to set up spypoints on programs developed and queried using SIMPLE. That there are spypoints on a program will not prevent the use of SIMTRACE. However, you will not be able to trace the evaluations of conditions for spypoint relations. You have to unspy the relation if you want to trace it using SIMTRACE.

Finally, to free space for the trace we suggest that you get rid of the program-mod module with a

```
kill program-mod
```

before loading SIMTRACE. After you have finished tracing and have killed simtrace-mod you can reload this module from the file PROGRAM.

5.8.1 The relations exported by simtrace-mod

simtrace-mod exports two relations: is-trace and all-trace. They are used in exactly the same way as the is and all queries of query-mod. To trace the query

```
all(x : Tom parent-of x & x male)
```

use

```
all-trace(x : Tom parent-of x & x male)
```

The trace will take you through the evaluation step by step. As each condition is reached, the condition is displayed in the form

```
<condition identifier> : <condition>
```

where the condition identifier is a list of integers that also gives the 'history' of the condition back to the original query. All the conditions of the original query have a single integer identification which is the position in the query. In the above query Tom parent-of x will have the identifier (1) and x male the identifier (2). Whenever a rule is applied, the identifier grows by one number. The identifier (2 1) tells you that the condition is the second condition in the rule currently being used to evaluate the first condition of the original query. The identifier (3 2 1) tells you that it is the third condition of the rule currently being used to solve the second condition of the rule being used to solve the first condition of the original query.

When the condition displayed is for a relation in your program (one recorded in the dict relation) you will also get the prompt

```
trace ?
```

and the tracing will be suspended until you respond. The responses are the same as those for the TRACE of Chapter 4 except that the /<command> response is not allowed. They are:

- y to trace the evaluation of the condition
- n not to trace it, only the solutions to the condition will be shown
- q to quit the trace entirely
- s to resume the trace with the condition, as displayed, assumed solved
- f to resume the trace with the condition, as displayed, assumed failed, i.e. assumed to have no solution

If you enter any other response you will be reminded of the allowed response s and prompted again.

The tracer will also prompt you when it reaches a complex condition such as an **isall**. This time the prompt will be

trace ?(y/n)

indicating that **y** and **n** are the only responses. In fact, any other response than **y** is taken as **n**. A **y** response enables you to trace inside the evaluation of the complex condition.

When a condition for one of your program relations is traced you will be told which sentence is being used to try to solve the condition with a message of the form

matching I : <condition> with head of N : <conclusion of sentence>

where I is the condition identifier and N is the number of the sentence being used. (It is the position in the listing of the sentences for the relation of the condition.) You will be told whether the sentence matches the condition. If it does the result of the match will be displayed. Then, if the matched sentence has preconditions, these will be displayed as

new query : <precondition(s) of the matched sentence>

and the trace will continue with the evaluation of each of the conditions of the new query. The identifier for each of these conditions will be the identifier for the condition just matched with an extra condition number at the front.

When a condition is solved you will get the message

<condition identifier> solved : <condition in solved form>

When backtracking results in an alternative solution for a condition being sought, you will get the message

retrying <condition identifier> ..

Finally, when a condition cannot be solved, or when all solutions have been tried and the evaluation is backtracking to find alternative solutions to preceding conditions, you will get the message

<condition identifier> failing: <condition>

6. The MICRO extension to the supervisor

The MICRO.LOG file of the distribution disk contains two modules called micro-mod and errtrap-mod and the modules exptran-mod and told-mod in the files EXPTRAN.LOG and TOLD.LOG can be optionally loaded as with SIMPLE. The errtrap-mod module is also supplied on the distribution disk in the file ERRTRAP.LOG.

micro-mod is the main module containing definitions for the program development commands and other useful relations. The commands are similar to those provided by the SIMPLE system of Chapter 5. The major difference is that the the facts and rules that can be entered using MICRO are are essentially standard syntax clauses. There are two elaborations. In the clause arguments of the MICRO add and delete commands, and in clauses entered using the two MICRO edit commands, constants can be used in place of variables and expressions can be used as arguments to = and # conditions. The use of constants as variables must be declared with an explicit vars condition at the end of the clause. This is similar to the allowed use of constants as variables in SIMPLE sentences. Expressions can be used only if the optional exptran-mod is present.

The errtrap-mod module is an error handler. The error handling allowed by errtrap-mod is quite sophisticated and is described below.

Any program developed under the SIMPLE system can be loaded and queried using MICRO.

WARNING If you want to switch from using SIMPLE to using MICRO, or vice versa, you must first kill all the modules of the SIMPLE system before you load MICRO. This is because the modules of the two systems export common relation names. The attempt to load a module that exports a name already exported by another module gives an error. The safest thing to do when switching between the two program development systems is to save your user program, exit micro-PROLOG using QT., and restart using the other system.

6.1 The relations exported by micro-mod

To use the facilites of MICRO do a LOAD MICRO command. To get rid of it you must kill each of its modules with

```
KILL errtrap-mod
KILL micro-mod
```

6.1.1 add

add has two uses:

(1) add <clause>

will add the clause to the end of the list of clauses for its relation. Except when the the clause contains expressions or uses vars constants, it is equivalent to directly entering the clause in the manner described in Chapter 2.

(2) add n <clause> n a positive integer

This adds a clause at the position indicated by the positive integer. It is equivalent to

?((ADDCL <clause> m)) where m is n-1

if the clause contains no expressions or vars constants. This means that if there are already at least n-1 clauses for the relation the added clause becomes the new n'th clause. It is inserted before the old n'th clause if there is one. If there are not already n-1 clauses for the relation it is added as a new last clause.

A clause entered using add that uses constants C1 ... Ck as variables must have a last condition which is the atom

(vars C1 ... Ck)

The add command will replace all the uses of these constants in the rest of the clause by new variables X1 ... Xk and will replace the vars condition at the end of the clause by a /* comment condition of the form

(/* vars (X1 | C1) ... (Xk | Ck))

at the beginning of the clause. This comment links the vars constants that you used with the variables that now replace them.

```
e.g.    &.add ((likes person1 person2)
               (likes person2 person1)
               (vars person1 person2))
```

The added clause will be converted into the clause

```
((likes X Y)
  (/* vars (X person1) (Y person2))
  (likes Y X))
```

by the add command and this is the clause that is added to the likes program. It is also the clause that you will see when you LIST the program using the supervisor command or if you list it using the alternative MICRO command. However, when you edit the clause, using either the edit or cedit commands described below, or the EDIT command of the structure editor described in Chapter 4, the clause will be displayed as entered with the constants replacing the variables and with a vars condition at the end of the clause.

6.1.2 delete

This also has two usages:

(1) delete <clause>

Again, except when the clause contains expressions or vars constants, it is equivalent to

DELCL <clause>

with the added feature that if there is no such clause you will get the message "No such clause".

(2) delete <relation name> n n a positive integer

will delete the current n'th clause for <relation-name>. It is equivalent to

?((DELCL <relation name> n))

with the added feature that if there is no current n'th clause, it displays the message "No such clause".

6.1.3 edit

The edit command can be used to text edit a clause and/or reposition a clause. Its use is:

edit <relation name> n n a positive integer

The result is that the n'th clause for the named relation together with the number n will be displayed as

n <clause>

and both can be edited using the line editor described in Chapter 2. If n is changed, it is taken as the new position for the edited clause, i.e. the position that would be used in an add command. If the relation that the clause is about (i.e. the relation of the head atom) is changed then the new n is taken to be the position for adding the changed clause to the sequence of clauses for the new relation. The old clause is always deleted immediately before the edited version is added.

The main difference between edit and the t command of the structure editor is that any compiled expressions in the clause are de-compiled back to expressions before the clause is displayed. This de-compiling only takes place if exptran-mod is present. If it it is not present then the clause will be displayed with all expresssions in their compiled form.

If the clause has a first condition which is a /* comment of the form

(/* vars (X1 | C1) ... (Xk | Ck))

linking constants with certain variables of the clause, the clause will be displayed with the constants substituted for the variables and with a

(vars C1 ... Ck)

condition at the end of the clause instead of the /* comment. Thus, clauses entered using the vars comment facility, or entered using the f command of the structure editor, will be diplayed as entered with constants used as variables.

6.1.4 cedit

Same form of use as edit. The difference is that the old clause is not deleted. Useful, for building up a definition of a relation where the clauses have common components. (c.f. the c command of the structure editor). As with edit, compiled expressions are de-compiled and displayed as expressions if exptran-mod is present. They are then re-compiled on exit from

the edit. Clauses are also displayed in the vars comment form.

6.1.5 kill

Same uses as the primitive KILL command of the supervisor. Only difference is that the use to delete entire workspace program is

kill all (note the lower case all)

and you are asked to confirm that the entire program is to be deleted. The memory space that is available when the workspace is cleared is also displayed. This space is the value given by the built-in micro-PROLOG SPACE relation. The other uses of kill are:

kill <relation name>
kill <module name>
kill <list of relation names>

They each report the successful deletion of the corresponding programs.

6.1.6 list

Again, same uses as supervisor command LIST with the exception that a request to list the entire workspace program is

list all (with lower case all)

Compiled expressions are displayed in their compiled form and vars comment clauses are displayed in their stored form with the /* comment.

6.1.7 load load <file name>

Same effect as supervisor LOAD <file name> command. The only difference is that after a load the memory space that is left is given.

6.1.8 save save <file name>

Exactly, the same meaning as the supervisor SAVE <file name> command. It saves the entire workspace program on the named file.

6.1.9 reserved

A call (reserved x), x a variable, will result in x being bound to a list of all the names exported by the currently loaded modules. Useful for reminding you of the names of these exported relations which are names you cannot use for your own program relations.

The attempt to add a clause for a primitive relation or a relation exported by a loaded module results in the "Cannot add clauses for ..." error message. Nor can you avoid this error by adding clauses for the exported relation before you load the module. This will result in the "Illegal use of modules" error message. The programs inside modules are protected. To change them you should use the module utility described in Chapter 4.

6.1.10 space

The command

space. (the . or some other argument term is needed)

will give the current space left as a number of K bytes. It is equivalent to the query:

?((SPACE x)(PP x K free))

which uses the primitive SPACE relation.

6.1.11 is

Use is

is <list of atoms>

Except when the list of atoms contains expressions, which it compiles before evaluating the atom list, its effect is almost the same as the supervisor query command

? <list of atoms>

However, if the evaluation is successful, YES is displayed. If the evaluation fails, NO is displayed.

6.1.12 which, all

Use is

which (<term> <atom1> <atom2>...<atomk>)

Again, any expressions are compiled before the command is executed. The effect is the display of <term> for each different solution of the query

?(<atom1> <atom2>...<atomk>)

Example

which((x y) (APPEND x y (1 2 3))

produces the answer

```
(() (1 2 3))
(1) (2 3)
(1) (2 3)
(1 2) (1)
(1 2 3) ( )
No (more) answers
```

APPEND is a relation defined in and exported from micro-mod. See below.

all is an accepted synonym for which

Example

all((y son of bill) (parent-of bill y) (male x))

produces an answer such as

```
(john son of bill)
(peter son of bill)
No (more) answers
```

6.1.13 one

Use is similar to which

one(<term> <atom1> <atom2>...<atomk>)

It will also display <term> for each solution of the sequence of atoms given in the query. The difference is that after each solution is displayed, it prompts with

more?(y/n)

If you enter y, it will give the next solution, if any. Any other response stops the evaluation. Again any expressions in the query condition are first compiled before the query is ansered.

6.1.14 accept

accept enables a sequence of single atom clauses to be entered for a relation to be entered quite quickly. Its use is :

accept <relation name>

You will then receive the relation name as a prompt and you need only enter the list of arguments for the single atom clause that you want to enter. You can continue in this way until you enter end.

example

```
&.accept male
male.(tom)        {(tom) is entered, male. is the prompt}
male.(bill)
male.(john)
male.end
```

will add the clauses

```
((male tom))
((male bill))
((male john))
```

to the end of the male program.

6.1.15 APPEND, ON, true-of

We have already mentioned that micro-mod defines and exports the list processing relation APPEND. Its definition is:

```
((APPEND () X X))
((APPEND (X|Y) Z (X|x))
  (APPEND Y Z x))
```

micro-mod also exports another useful list processing relation ON. It can be used to find members of a list or test for membership. Its definition in micro-mod is:

```
((ON X (X|Y)))
((ON X (Y|Z))
  (ON X Z))
```

true-of has the definition:

```
((true-of X Y)
  (X|Y))
```

You never need to use this relation in programs entered using MICRO. Any use of a call (true-of X Y) can be replaced by (X|Y). However, the relation may have been used in some sentence form of a clause entered using the SIMPLE extension of the supervisor described in the last chapter. It is included in micro-mod so that programs developed using SIMPLE can be loaded and queried when using MICRO. (See the remark at the beginning of the chapter.)

6.1.16 CONS, @, #, =, function

The definitions of the CONS and @ relations are:

```
((CONS X Y (X|Y)))

((@ X | Y)
  (X | Y))
```

They are used in expressions. The # and = relations are only used together with expressions and are described in the next section. micro-mod does not actually contain a definition of =, but it cannot be defined in a user program because it has a special role in the syntax of MICRO programs. function is the command that is used to declare a relation as a function before using it in expressions. (See the section 6.2.3 below.)

6.1.17 *, %, +, -

micro-mod exports the following definitions for the auxiliary arithmetic relations *, %, +, -. TIMES and SUM are primitive arithmetic relations of micro-PROLOG implemented in machine code. The auxiliary relations are recognised as arithmetic operators in expressions.

```
((+ X Y Z) (SUM X Y Z))
((- X Y Z) (SUM Y Z X))
((* X Y Z) (TIMES X Y Z))
((% X Y Z) (TIMES Y Z X))
```

The definitions are the same as those given in 5.2.14 which are exported from query-mod.

6.1.18 dir

dir is a command that will produce the list of all the files on the currently logged in disk whose names match some 'ambiguous' file name. Its use is

dir <ambiguous file name>

Examples are:

```
dir *      {will display a list of all the .LOG files}
dir *.*    {will display list of all files}
```

```
dir tudors {will check if TUDORS.LOG is on file and echo
        name if it is. If it is not, nothing is displayed}
```

Remember that you can change the logged in disk using the primitive LOGIN and you can erase and rename files using the primitives ERA and REN. These are all described in Chapter 7.

6.2 Expressions in MICRO clauses

You can use expressions as arguments to certain calls in the body of clauses that are entered using the add, edit or cedit commands described above. The expressions can be used as arguments to calls that use the two relation names = and #.

The three commands just mentioned scan each clause before adding it to the workspace. If any call has the relation name =, or the relation name # followed by a first argument which is a constant, the expression arguments of the call are compiled into a list of relation calls which becomes an argument of a compiled form of the original = or # call. You see this compiled form when you list or LIST the clause.

However, when you edit the clause using edit or cedit the compiled call is mapped back into its source form before it is displayed. The delete <clause> command also compiles = and # calls before it scans for the clause to delete.

Expression arguments to = and # calls are also allowed in is, which and all queries. Expressions are compiled and de-compiled using the relation Expression-Parse which is exported from the optional module exptran-mod. Before you use expressions you should load the module with a

```
LOAD EXPTRAN
```

6.2.1 The # relation

Source calls to #, i.e. calls that will be compiled, have the form:

```
(# Rel E1 E2..Ek)
```

where Rel is a relation name and E1,..,Ek are expressions. The expressions are the arguments of the relation call, which is really to the relation Rel. The # signals that these arguments to Rel are not just ordinary terms, but are expressions, terms that contain calls to functions and arithmetic operations. An # atom in a MICRO clause is the equivalent of an expression condition in a SIMPLE sentence. The atom (Rel # E1 ... Ek) would be the expression condition Rel#(E1 ... Ek)

Example

```
(# LESS (2 * 3) (5 + 7))
```

is a call to the relation LESS with arguments the values of the expressions (2 * 3) (5 + 7). This source call will be compiled into the target call

```
(# (LESS X Y) (( *  2 3 X) (+  5 7 Y)))
```

in which a list of atoms that will evaluate the expressions

(2 * 3) (5 + 7) appears as the second argument. The first argument is the call to the relation LESS with arguments the variables which have the values of (2 * 3) and (5 + 7) when this list of atoms is evaluated.

This # call is logically equivalent to the three ordinary calls:

```
(* 2 3 x) (+ 5 7 y) (LESS x y)
```

The definition of #, which is exported from micro-mod, is

```
((# X Y)
   (? Y)/
    X)
```

Thus # evaluates the atom list Y before it evaluates the call X. Note the use of the backtracking control primitive /. This prevents backtracking on the atom list evaluation, i.e. on the evaluation of the arguments to the call X. However, it does not prevent backtracking on the evaluation of X.

Example

```
(# salary x (2 * y))
```

will be compiled into

```
(# (salary x z) ((* 2 y z)))
```

If the value of y is known at the time the call is evaluated, the * call will compute z and the evaluation of the # call will reduce to the evaluation of

```
(salary x N), N some number
```

Backtracking will result in different values being sought for x, but not in the re-computation of N.

6.2.2 The = relation

Uses of = have the form

```
(= E1 E2)
```

where E1 and E2 are expressions. It is equivalent to

```
(# EQ E1 E2)
```

i.e. to a call of the primitive EQ relation with arguments the values of the expressions E1, E2. An = atom in a MICRO clause is the equivalent of an equality condition in a SIMPLE sentence.

Example

```
(= (2 * x) (3 + y))
```

is equivalent to

```
(# EQ (2 * x) (3 + y))
```

and will be compiled into

```
(# (EQ X Y) ((* 2 x X) (+ 3 y Y)))
```

The EQ relation is a primitive of micro-PROLOG and is defined by the single clause

```
((EQ X X))
```

So, a = call evaluates its arguments and then unifies them. When the values are numbers, as here, this amounts to checking that they are identical. When one of them is a variable, as in

```
(= x (234/23))
```

it will result in x being given the value of the expression (234/23) i.e. 1.0173913E1.

6.2.3 Syntax of expressions

We refer the reader to section 5.4.1 for the syntax of expressions as well as for information about how a relation Rel may be declared a function, using the

```
function Rel
```

command, and then used in expressions. This command adds a

```
((func Rel))
```

clause to the workspace program. The func clause is not automatically deleted when you kill the relation Rel. So you should delete it yourself if you do kill a relation that has been declared a function.

As with SIMPLE, you can recover from the error of not having declared a relation as a function before using it in an expression in a clause. You will get the warning message from exptran-mod

```
Rel assumed not to be a function
```

edit the clause and immediately exit from the editor. The expression is de-compiled before it is displayed and the re-compiled on exit. This time the use of R as a function name will be recognised.

6.2.4 Killing exptran-mod

The exptran-mod module occupies between 2 and 3K of program memory. After it has been used to compile expressions in the clauses of some entered program it can be killed. You will not of course be able to use expressions in any of the queries to the program. If you do, or you forgetfully add a clause containing expressions when exptran-mod is not present, you will get error of the form

```
No clauses for (Expression-Parse <expression> <var> <var>)
```

This is because the add command has found some use of an expression and has tried to call the Expression-Parse relation exported by exptran-mod. The error message has been displayed by the errtrap-mod error handler. You can recover from the error by loading the EXPTRAN.LOG file which contains just exptran-mod.

The details are in the next section.

You will not get this error message when you try to edit a clause with compiled expressions even though Expression-Parse is normally also called by the edit commands to de-compile expressions. This is because before Expression-Parse is called to de-compile expressions a check is made to see if the exptran-mod module is present.

If exptran-mod is not present, the expressions are displayed in their compiled form. This means that you can use exptran-mod whilst you are developing a program and want to use the convenient shorthand provided by expressions. Then, for serious use of the program where space might be at a premium, you can kill the module. You can re-load the module as required.

6.3 The error handler errtrap-mod

The module errtrap-mod exports the relation "?ERROR?". As described in Appendix C, if this relation is defined by some loaded module or workspace program, the micro-PROLOG interpreter will call the "?ERROR?" program when it encounters a runtime error. The program for "?ERROR?" given in errtrap-mod then displays a message of the form:

```
<short phrase describing the error> <atom of the call>
error&(? for info).
```

The short phrase for the error is similar to the one given by the example "?ERROR?" program given in Appendix C. The error& is the prompt that you will continue to get whilst in an error trap state. The query evaluation that caused the error is suspended. There are now various options that allow recovery action to be taken and the suspended evaluation to be resumed.

You can obtain a brief description of these options by entering ?. You will then get displayed:

```
to quit enter : q
to fail call enter : f
to succeed call enter : s
to line edit call and resume enter : e
or enter / <any command> (eg / add <clause> , / load file)
or enter : tell
to resume enter : c
error&.
```

q response This quits the suspended evaluation and returns you to the supervisor. After the q you will get the normal supervisor prompt &. and you can use any of the supervisor or MICRO supported commands in the normal way.

f response The suspended query evaluation is resumed but with the error invoking call assumed to have no solution, i.e. to have failed.

s response Same as for f except the call is assumed to have beeen solved with its current arguments.

e response The offending call will be re-displayed with the line editor of micro-PROLOG in edit mode. You can line edit the call in any way but if you want to leave variables in the

call you should use the variable names displayed in the call. On exit from the line editor, the evaluation will be resumed but with the offending call replaced by its edited form.

Note you have not edited the program. You have only changed the call for this one execution in order to avoid the error. Generally, you should also have edited the clause that lead to the error using the / <command> response, or you should edit the program when the current query evaluation finishes.

/ <command> response The / is the escape character that enables you to enter any supervisor command or MICRO command. This must be the command name followed by its arguments. (You cannot just enter a clause. You must use add or ADDCL to do this.) You can thus edit your program, list it, load files, or add new clauses. An example of a / load file recovery response is given below.

tell response This calls the is-told relation exported by the module told-mod with argument the offending call which can then be answered interactively in the manner described in Section 5.5 and in 6.4.2 below. (The clause

((<name> | x) (is-told (<name> x)))

will be added to your program.) It is a useful for top-down programming. You can use relations in your program before defining them. Then, when you get the the error "No clauses for" when the a call on the relation is reached you can provide the answer or answers to the condition in response to the is-told prompts without having to give the definition. But note that your answers are not saved. A subsequent use of the relation in the current query may force you to give the same answers. The only way to avoid this is to load a file with a program for the relation, or to add some clauses to define it. The use of tell is also in many cases an alternative to editing the call.

c response This should only be given after you have executed one or more commands that will ensure that the error will not occur when the evaluation is resumed. For example, you have added some clauses for a relation after getting the "No clauses for" error message and are now ready to continue with the suspended evaluation. The evaluation is resumed at the point where the offending call was tried, so the call is re-evaluated.

If you enter any other response you will get the ? message.

6.3.1 Example error recovery

(1) Suppose that you have killed exptran-mod or you have not loaded it and then you use an expression in a query or added clause. You will get an error message of the form:

```
No clauses for (Expression-Parse <expression> <var> <var>)
error&(? for info).
```

The . is the prompt for you to enter a response. If the file EXPTRAN.LOG is on the disk of the currently logged in drive (you can change the disk if need be using the LOGIN supervisor command

- see Chapter 7 which descibes all the primitive relations) then the following will recover from the error.

```
error&(? for info). / load EXPTRAN
error&.c
```

(2) Suppose that you have mispelled a relation name in some call of a program clause, using say parentof instead of parent-of. You will get an error message of the form:

```
No clauses for (parentof .. ..)
error&(? for info).
```

There are several ways to recover.

(a) You can use e to edit the call and change parentof to parent-of. But remember this change only applies to this call. If the clause with the mispelled relation is used again you will get the error again.

(b) You can add a clause defining parentof as parent-of and then resume with the responses:

```
/ add ((parentof X Y)(parent-of X Y))
c
```

This avoids the error on this and all subsequent uses of the incorrect clause. After the current query evaluation is over you can find the mispelling, edit it and then delete this added clause. This is perhaps the best recovery response.

(c) You can list the clauses in which you think the mispelling appears and then edit the offending clause. This removes the problem for subsequent uses of the clause but not for any currently active uses which includes the current error. To avoid a recurrence of the current error, either do (b), deleting the new clause when the current evaluation is finished, or edit the call, or enter tell to invoke is-told with argument the offending call.

6.4 Using the is-told relation

is-told is a multi-argument relation exported from the module told-mod in the file TOLD.LOG. When evaluated it displays its sequence of arguments followed by a ? and waits for a response. If there is just one argument, which is a list, this is displayed without the outer brackets. The responses and their effects are fully described in 5.6. To use is-told in MICRO programs you must load the module with a

```
LOAD TOLD
```

6.4.1 Example use of is-told

These are the same examples as given in 5.6 but using the query commands of MICRO and its clause syntax:

(1) all((percent z) (is-told mark x outof y) (= z (x/y*100)))

sets up an interaction that can be used to convert pairs of numbers to percentages. A possible interaction is:

```
mark X outof Y ? ans 20 40
(percent 50)
mark X outof Y ? ans 15 60
(percent 25)
mark X outof Y ? just 40 120
(percent 33.333333)
No (more) answers
```

(2) ((is-male x) (known-male x))

```
((is-male x) (NOT known-male x)
             (is-told (x a male)) (ADDCL ((known-male x))))
```

defines is-male in such a way that the user is queried whenever an is-male condition is encountered with argument given but not recorded as a known-male. A yes response to the question such as

```
keith a male ?
```

results in the (is-male keith) condition that invoked the query being solved and a ((known-male keith)) assertion being added to the program. A no response results in the condition failing.

6.4.2 Using is-told from the error handler

The tell response of the errortrap-mod error handler calls is-told with argument the error atom. You can then provide one or more answers to the condition using any of the is-told responses. If you use tell and the is-told has not been loaded you can still continue. The interaction will be something like:

```
No clauses for (father-of tom X)
error&(? for info).tell
No clauses for (is-told ((father-of tom X)))
error&(? for info). / load told
error&.c
(father-of tom X) ? .
```

and you can now continue by answering the (father-of tom X) question in the manner as described above. You have recovered from an error encountered in an error recovery action! You are now out of the error state.

6.5 External relations

The EXREL utility described in 4.5 can be loaded and used in conjunction with MICRO. The only constraint is that the listex and listfile commands must not be used as they require SIMPLE to be present. Their clause form equivalents LISTEX and LISTFILE can be used instead.

6.6 Tracing and Structure Editing

Both the TRACE and SPYTRACE utilities described in Chapter 4 can be loaded and used in conjunction with MICRO. If you use TRACE it might be useful to kill the optional modules exptran-mod and told-mod before tracing in order to gain space. You can re-load them after the trace. Alternatively, you can kill all four MICRO modules, and re-load all four with a LOAD MICRO after the trace.

The structure editor in EDITOR.LOG can also be loaded and used with MICRO. It is described in Chapter 4.

7. The DECsystem-10 PROLOG supervisor

Steve Gregory

The file DEC.LOG implements a subset of DEC-10 PROLOG, the original member of the Edinburgh family of PROLOG systems, on which is based the book "Programming in Prolog" by W.F.Clocksin and C.S.Mellish (Springer-Verlag 1981). Our implementation is based on version 3.47 of DEC-10 PROLOG, documented in the "DECsystem-10 Prolog User's Manual" by D.L.Bowen, L.Byrd, F.C.N.Pereira, L.M.Pereira and D.H.D.Warren (Department of Artificial Intelligence, University of Edinburgh, November 1982).

We have attempted to remain as close as possible to the DEC-10 PROLOG system, both in syntax and in the built-in procedures provided; any substantial differences are pointed out in these notes. However, several features of the DEC-10 system have been omitted, in particular: debugging facilities, compilation, "logging", initialization, nested executions, definite clause grammars, internal database and term comparison. Some other built-in procedures have also been omitted; these are listed in these notes. On the other hand, all the features of micro-PROLOG are available interactively to the DEC-10 PROLOG user.

These notes are intended to enable anyone who has read the Clocksin and Mellish book to use the system. No knowledge of micro-PROLOG is required. Section 7.1 explains how to get started, while 7.2 and 7.4 describe the syntax and built-in procedures respectively. Section 7.3 explains how programs are represented internally. For those who are familiar with the (real) DEC-10 PROLOG system, the differences have been underlined in 7.2 and 7.4.

The file DEC.LOG contains about 20 modules which together occupy about 33K. It is intended that all modules should be present; none should be **KILL**ed by the user.

The **error-mod** module provides the error handler. It deals with micro-PROLOG error codes 2 and 11 in a special way as described in sections 7.1.6 and 7.1.7. For other errors, the error code and the offending call are displayed and an **ABORT** occurs to the supervisor.

7.1 How to run the DEC-10 PROLOG supervisor

7.1.1 Getting started

To invoke the DEC-10 supervisor, type the command

A>prolog load dec

After displaying the usual micro-PROLOG banner and an ampersand **&** the following prompt will be displayed:

| ?-

This indicates that the DEC-10 PROLOG supervisor is running and

waiting for a directive. Note that it is not possible to escape to micro-PROLOG at this point except by using the built-in procedure **micro**, described below. If the directive occupies more than one line, the prompt on subsequent lines will be the usual micro-PROLOG prompt . .

7.1.2 Reading in programs

To input a program from one or more files, the files should be "consulted" by typing the filenames in a list (all directives must be terminated by a full stop .):

```
| ?- [file1,file2,'file3.pl'].
```

The filenames must conform with the conventions of the host operating system. The filenames must be atoms, so they must be enclosed in single quotes if necessary. Note that if no extension is specified, the default extension is **.LOG**, so that **file1** denotes the file **FILE1.LOG**.

If a filename in the list is preceded by a - the file will be "reconsulted". This means that clauses for a procedure that are read in will replace any existing clauses for that procedure, rather than being added to them.

7.1.3 Inserting clauses at the terminal

To enter clauses from the keyboard, the special file **user** should be consulted:

```
| ?- [user].
```

When the micro-PROLOG prompt . appears, the supervisor is waiting for clauses to be typed in. There are two possible ways to terminate the entry of clauses: type the term **end_of_file** (terminated by a .), or type ^C (control-C) to abort to the supervisor. If ^C is typed, it is important that the system is waiting for input (indicated by a . prompt), otherwise the program may be incomplete. Note that ^Z (control-Z) is not recognized as the end of file for **user**.

7.1.4 Directives: questions and commands

A directive is either a question or a command. A question is a list of goals preceded by **?-** . At the top level, a question may be entered as simply a list of goals in response to the | ?- prompt, e.g.

```
| ?- append(X,Y,[1,2]).
```

The question is evaluated and the values of any named variables (not anonymous variables) displayed in the form

```
X = [],
Y = [1,2] .
```

The final . is the micro-PROLOG prompt indicating that the system is waiting for a response, either a **<cr>** (carriage return) or ; followed by **<cr>**. If **<cr>** is typed, the reply is **yes**. If ; **<cr>** is typed, alternative solutions will be sought by backtracking and displayed in the same form. If there are no further solutions, the reply is **no**:

```
X = [],
Y = [1,2] ;

X = [1],
Y = [2] ;

X = [1,2],
Y = [] ;

no
```

A command is a list of goals preceded by :- , and can appear either at the top level or in a file that is consulted. At the top level, the :- is typed after the **| ?-** prompt:

```
| ?- :- append(X,Y,[1,2]),write((X,Y)).
```

After the first solution to a command is found, the values are not displayed and there is no backtracking. If the command fails, a **?** message is displayed.

7.1.5 Syntax errors

If a syntactically illegal term is read, the system displays the message

```
*** syntax error ***
```

Note that the offending term is not displayed.

7.1.6 Undefined predicates

If an undefined predicate is called, the call will fail.

7.1.7 Program interruption

To interrupt a program at any time, type a single **^C**. The system will respond with the message

```
function (h for help):
```

If you type **h**, the available commands will be displayed:

```
a abort
c continue
e exit
h help
```

Typing **c** will continue the original execution. **a** will abort to the top level, displaying the **| ?-** prompt. **e** will exit to the operating system.

7.1.8 Exiting

To exit from the DEC-10 PROLOG supervisor to the operating system, either call the built-in procedure **halt** or type **^C** followed by **e**, as described above. Note that it is not possible to restart except by starting up the system again. Note also that ^Z has no effect.

7.1.9 Saving and restoring states

The state of a program can be saved in a file and restored later using the built-in procedures **save** and **restore.** The state of the program consists of the program clauses and the operators. The command

```
| ?- save(prog).
```

will close all files and save the state in file **prog,** while the command

```
| ?- restore(prog).
```

will close all files, remove the current state and restore the state to that contained in **prog.**

The state saved in a file comprises a set of micro-PROLOG clauses, so the interested user can examine such a file to see how a program is represented in micro-PROLOG syntax. More importantly, **save** and **restore** work at the micro-PROLOG level and so are much faster than **listing** and **consult.**

7.2 Syntax of programs

The syntax of programs is almost identical to that of DEC-10 PROLOG. The details are summarized here, with any differences underlined for emphasis.

7.2.1 Terms

A term is either an integer, an atom, a variable or a compound term.

An integer is written as a sequence of digits, optionally preceded by a minus sign - , e.g.

```
0        123        -456
```

Note that, in a negative integer, the minus sign must be written immediately before the first digit. If a layout character intervenes, the minus sign will be interpreted as the atom - , for example "- 456" is the compound term -(456), not the integer -456. Also, integers may not be written in bases other than decimal, and must fall within the range supported by micro-PROLOG.

An atom is one of the following:

1. A sequence of alphanumeric characters, including _ , beginning with a lower case letter.

2. A sequence of symbol characters, i.e. characters taken from the list
   `+ - * / \ ^ < > = @ ~ : . ? # $ &`

3. An arbitrary sequence of characters enclosed in single quotes, e.g. **B:A.LOG.** The quote character must be duplicated if it appears in the atom.

4. One of the bracket pairs [] and {} or one of the characters ! and ; . (%(and %) can be written as substitutes for

the characters { and } respectively).

A variable is a sequence of alphanumeric characters, including _ , beginning with an upper case letter or the character _ .

A compound term is written as a name (which is an atom) followed by the arguments enclosed in parentheses. The number of arguments is the arity. There must be no space between the name and the left parenthesis.

There are alternative ways to write certain kinds of compound term, as follows.

1. The term **{}(T)** can be written **{T}**.

2. Lists are built using the constructor . and the empty list atom **[]**. A list term can be written in list notation, e.g.

[a,b,c]	is	**.(a,.(b,.(c,[])))**
[a,b|L]	is	**.(a,.(b,L))**
[a,b,..L]	is	**.(a,.(b,L))**

3. A list of integers can be written as a string, e.g.

"DEC"	is	**[68,69,67]**

The integers in the list are the ASCII codes of the characters in the string. If the double quote character appears in a string it must be duplicated.

4. Binary terms can be written in infix form, while unary terms can be written in prefix or postfix form. The functor must be declared as an operator, see below.

7.2.2 Operators

Functors may be declared as operators, using the types **fx, fy, xf, yf, xfx, xfy, yfx** and priorities between 1 and 1200. **fx** and **fy** are used for prefix operators, **xf** and **yf** for postfix, **xfx, xfy** and **yfx** for infix operators. Note that there must be a space between a prefix operator and its argument if this begins with a left parenthesis (, e.g. **":- (a,b)"** is the term with unary functor **:-** and one argument **(a,b)**, while **":-(a,b)"** (with no space) is a term with binary functor **:-** and two arguments **a** and **b**.

The following operators are predeclared, as in DEC-10 PROLOG. Like any operator declarations these can be changed or deleted using the **op** procedure.

```
op(1200,xfx,[:-,-->]).
op(1200, fx,[:-,?-]).
op(1150, fx,[mode,public]).
op(1100,xfy,[;]).
op(1050,xfy,[->]).
op(1000,xfy,[(,)]).
op( 900, fy,[\+,spy,nospy]).
op( 700,xfx,[=,is,=..,==,\==,@<,@>,@=<,@>=,
                          =:=,=\=,<,>,=<,>=]).
op( 500,yfx,[+,-,/\,\/]).
op( 500, fx,[+,-]).
op( 400,yfx,[*,/,<<,>>]).
op( 300,xfx,[mod]).
op( 200,xfy,[^]).
```

7.2.3 Comments

Comments may appear anywhere between a % character and the end of the line, or between the symbol /* and the next */ symbol.

7.3 Internal form of programs

This section describes how terms of DEC-10 PROLOG are represented internally as micro-PROLOG terms and how DEC-10 PROLOG programs are stored as micro-PROLOG programs.

7.3.1 Terms

Integers, atoms and variables of DEC-10 PROLOG are represented by micro-PROLOG integers, constants and variables respectively. The scope of a variable name is the term in which it appears. A compound term is represented by a list whose first element is the functor name and subsequent elements are the arguments, e.g. the term **fn(V,23,at,V)** is translated to the list **(fn X 23 at X)**. Since lists are compound terms with functor . , the list term **[a,b]** would be translated to **(. a (. b "[]"))**.

7.3.2 Programs

Depending on the context, a term may be interpreted as a clause, a conjunction or a procedure call. In these cases, the term will be compiled into another internal form. For example, the **assert** procedure recognizes its argument as a clause and translates this into a micro-PROLOG clause before adding it to the database. A clause of the form

H :- B translates to **(H1|B1)**

where **H1** and **B1** are the compiled form of head **H** and body **B** respectively. A unit clause **H** translates to the list **(H1)**.

A conjunction, such as the body of a clause, translates to a list of the compiled forms of the constituent calls, e.g.

A,B,C,... translates to **(A1 B1 C1 ...)**

This means that a clause translates to a list containing the head followed by the body calls.

A goal, or procedure call, is normally compiled simply by changing the relation name to include the arity. The compiled relation name is a micro-PROLOG constant obtained by concatenating a digit (for the arity) to the original relation name, e.g.

append([],X,X)	translates to	**("3append" "[]" X X)**
micro	translates to	**("0micro")**

In the case of a few built-in procedures, the calls are translated to calls to equivalent micro-PROLOG relations. For example the following substitutions are made:

!	**/**
fail	**FAIL**
true	**/***
X = Y	**(EQ X Y)**
var(X)	**(VAR X)**
integer(X)	**(NUM X)**
atom(X)	**(CON X)**

Some built-in procedures of DEC-10 PROLOG take procedure calls or conjunctions as arguments. Calls to these procedures are translated to equivalent micro-PROLOG relation calls, after compiling the procedure calls or conjunctions which are their arguments. In the following, **A1** denotes the compiled form of **A**, and so on. **A**, **B** and **C** denote calls while **P** and **Q** denote conjunctions:

\+ A	**(NOT|A1)**
A,B,C,...	**(? (A1 B1 C1 ...))**
A -> P	**(IF A1 P1 (FAIL))**
A -> P;Q	**(IF A1 P1 Q1)**
P;Q	**(OR P1 Q1)**

The built-in procedure **X**, where **X** is a variable, is equivalent to **call(X)** and so is translated to the internal form **("1call" X)**.

The argument of the **call** procedure is (at call time) a term representing a conjunction. Therefore this procedure performs the compilation described above for conjunctions, when called.

7.3.3 Operators

For each declared operator, including the standard operators, there exists a micro-PROLOG clause in the workspace module. This clause takes the form

(<opname> <priority> <type> <name>)

Here, **<opname>** is either **prefix-op** (if **<type>** is **fx** or **fy**), **postfix-op** (if **<type>** is **xf** or **yf**) or **infix-op** (if **<type>** is **xfx**, **xfy** or **yfx**). **<priority>**, **<type>** and **<name>** are simply the three arguments of the corresponding operator declaration.

These clauses are considered part of the program and are saved along with the program clauses when the program is **saved**.

7.4 Built-in procedures

In this section we briefly describe each of the implemented built-in procedures, in categories according to their use. Where these differ from the real DEC-10 procedures, the differences are underlined. The unimplemented built-in procedures are listed at the end.

7.4.1 Input/output

A filename must be an atom which is a valid name according to the conventions of the host operating system. If no extension is specified, the default extension **.LOG** is assumed.

There may be up to four files open at any time, in addition to the special file **user**, which refers to the terminal.

Terminal output is displayed immediately, whether or not it is followed by a **<cr>**. When input is from the terminal (the micro-PROLOG **CON:** file), the only prompt issued is the micro-PROLOG **.** prompt. There is no character, such as ^Z, which is recognized as end of file from the terminal.

The effects of input/output errors are not defined, nor are they controllable by the user.

consult(F) Read in the DEC-10 PROLOG program contained in file **F**, executing any directives in the file when found.

reconsult(F) Read in the DEC-10 PROLOG program contained in file **F**, deleting any existing definition of procedures for which clauses appear in **F**.

[F|Fs] Consult or reconsult the filenames in the list. If a filename is preceded by the **-** operator, the file is reconsulted.

see(F) Set the current input stream to file **F**, opening the file if it is not already open.

seeing(F) **F** is the current input stream, which is left unchanged.

seen Close the current input stream and set it to the terminal.

tell(F) Set the current output stream to file **F**, opening the file if it is not already open.

telling(F) **F** is the current output stream, which is left unchanged.

told Close the current output stream and set it to the terminal.

close(F) Close file **F**, currently open for input or output.

rename(F,N) Rename file **F** to **N**, unless **N** is **[]** in which case **F** is deleted.

read(X) Read the next term **X**, terminated by a full stop **.** followed by a layout character, from the current input stream. (A layout character is a space or any control character, such as a **<cr>**.) Reports a syntax error if the term does not conform to the current operator declarations. **X** is the term **end_of_file** if the end of file is reached. Further calls to **read** will continue to return **end_of_file**.

write(X) Write term **X** to the current output stream according to the current operator declarations. Variables are written as **_1**, **_2**, etc.

display(X) Write term **X** to the terminal, ignoring any operator declarations and quoting names and functors if necessary.

writeq(X) Write term **X** to the current output stream

according to the current operator declarations, quoting names and functors if necessary.

Using the following character input and output procedures, a carriage return, line feed sequence (<cr>) is represented internally as a single character, ASCII code 13.

nl Write a new line to the current output stream.

get0(N) Read the next character, with ASCII code **N**, from the current input stream.

get(N) Read the next printable (i.e. non-layout) character, with ASCII code **N**, from the current input stream.

skip(N) Skip to immediately after the next character with ASCII code **N** from the current input stream. **N** may be an integer expression.

put(N) Write the character with ASCII code **N** to the current output stream. **N** may be an integer expression.

ttynl Write a new line to the terminal.

ttyget0(N) Read the next character, with ASCII code **N**, from the terminal.

ttyget(N) Read the next printable (i.e. non-layout) character, with ASCII code **N**, from the terminal.

ttyskip(N) Skip to immediately after the next character with ASCII code **N** from the terminal. **N** may be an integer expression.

ttyput(N) Write the character with ASCII code **N** to the terminal. **N** may be an integer expression.

7.4.2 Arithmetic

The range of integers is determined by the underlying micro-PROLOG system.

An integer expression may be given as an argument to the arithmetic procedures and to the character input/output procedures described above. An integer expression is a term constructed from integers and the following arithmetic functors:

X + Y	integer addition
X - Y	integer subtraction
X * Y	integer multiplication
X / Y	integer division
X mod Y	modulo
- X	unary minus
[X]	evaluates to **X** if **X** is an integer, e.g. "f" (= [102]) evaluates to 102. This is useful, for example, in the call **put("f")** which is equivalent to **put(102)**.

Note that the functors **/\ \/ \ << >> ! $** are not recognized.

X is Y **X** is the result of evaluating integer expression

Y.

X =:= Y Integer expressions **X** and **Y** evaluate to the same value.

X =\= Y Integer expressions **X** and **Y** evaluate to different values.

X < Y The value of integer expression **X** is less than that of integer expression **Y**.

X > Y The value of integer expression **X** is greater than that of integer expression **Y**.

X =< Y The value of integer expression **X** is less than or equal to that of integer expression **Y**.

X >= Y The value of integer expression **X** is greater than or equal to that of integer expression **Y**.

7.4.3 Convenience

P , Q **P** and **Q**.

P ; Q **P** or **Q**.

true Succeed.

fail Fail.

X = Y **X** and **Y** unify.

length(L,N) **N** is the length of list **L**, a list terminated by **[]**.

7.4.4 Control

! Cut (translates to the micro-PROLOG **/**).

\+ P **not P**, i.e. goal **P** is not provable, defined as
```
\+ P :- P, !, fail.
\+ P.
```

P -> Q ; R **if P then Q else R**, defined as
```
P -> Q ; R :- P, !, Q.
P -> Q ; R :- R.
```

P -> Q **if P then Q else fail**, defined as
```
P -> Q :- P, !, Q.
```

repeat Defined as
```
repeat.
repeat :- repeat.
```

7.4.5 State of the program

listing Writes to the current output stream all clauses in the program, quoting atoms and functors where necessary.

listing(A) Writes to the current output stream all clauses for **A**, which may be a predicate name, a term of the form name/arity, or a list of these, e.g.

```
[qsort/2,partition,qsort/3].
```

7.4.6 Meta-logical

var(X) **X** is currently an unbound variable.

nonvar(X) **X** is currently instantiated.

atom(X) **X** is an atom.

integer(X) **X** is an integer.

atomic(X) **X** is an atom or an integer.

functor(T,F,N) **T** is a term with functor **F** and arity **N**. If **T** is originally uninstantiated, **F** must be an atom or **F** must be an integer and **N** 0. In this case **T** is the most general term with functor **F** and arity **N**.

arg(I,T,X) **X** is the **I**-th argument of term **T**, if **I** and **T** are instantiated.

X =.. Y **Y** is a list comprising the functor and arguments of term **X**. Either **X** or **Y** may be instantiated.

name(X,L) **L** is a list of the ASCII codes of the characters comprising the atom **X**. Either **X** or **L** may be instantiated. The use where **X** is an integer is not supported.

call(X) Metacall to **X**, which should be instantiated to a term acceptable as the body of a clause.

X (**X** a variable), equivalent to **call(X)**.

7.4.7 Modification of the program

assert(C) Same as **assertz(C)**.

asserta(C) Add term **C** as a new clause in the program, at the beginning of the definition of its procedure.

assertz(C) Add term **C** as a new clause in the program, at the end of the definition of its procedure.

clause(P,Q) **Q** is the body of a program clause whose head matches term **P**, or **true** if the body is empty. The effect is undefined if **P** is a term matching a built-in procedure.

retract(C) Delete the first clause matching term **C**. Cannot be used to delete several clauses by backtracking, due to an idiosyncracy of micro-PROLOG.

abolish(N,A) Deletes all clauses for the procedure for name **N** and arity **A**.

7.4.8 Sets

bagof(X,P,B) **B** is a list of all instances of term **X** such that **P** is provable. **B** may contain duplicates and the order of elements is not defined. The quantifier **Y^Q** is not available.

7.4.9 Environmental

halt Exit to the operating system.

op(P,T,N) Declare atom **N** as an operator of type **T** and priority **P**. The type must be one of **fx, fy, xf, yf, xfx, xfy, yfx**. The priority must be between 1 and 1200 inclusive. If however **P** is 0, all operator declarations for **N** (if any) will be removed. In this case **T** is ignored, but otherwise all arguments must be given.

current_op(P,T,N) Atom **N** is currently declared as an operator of type **T** and priority **P**. None of the arguments need be given.

save(F) Save the state of the program in file **F**, after closing all files. The state consists of the program clauses and the current operators only.

restore(F) Restore the state of the program stored in file **F**, after closing all files and deleting the existing program clauses and operators.

7.4.10 Additional procedures

micro This procedure provides an interface to micro-PROLOG from the DEC-10 PROLOG supervisor. A call to the 0-ary procedure **micro** will read two subsequent micro-PROLOG terms **X** and **Y** from the console and evaluate the call **(X Y)**.

Perhaps the most useful application of this procedure is to access the debugging facilities of micro-PROLOG such as spypoint tracing, described in section 4.2 of this manual. To trace DEC-10 PROLOG programs you need to know the internal form of relation names, explained in section 7.3.

For example, to trace the procedure **append/3**:

```
micro. LOAD SPYTRACE
micro. spy "3append"
```

("3append" is the internal name for this procedure.) Now calls to **append/3** will be traced at the micro-PROLOG level. This means that terms etc. are displayed in internal form.

To cancel the tracing:

```
micro. unspy "3append"
micro. KILL spytrace-mod
```

7.4.11 Unimplemented procedures

The following built-in procedures of DEC-10 PROLOG are not available:

fileerrors/0 nofileerrors/0 log/0 nolog/0

print/1	tab/1	ttyflush/0	== /2
\== /2	@< /2	@> /2	@=< /2
@>= /2	compare/3	sort/2	keysort/2
numbervars/3	ancestors/1	subgoal_of/1	current_atom/1
current_functor/2		current_predicate/2	
recorded/3	recorda/3	recordz/3	erase/1
instance/2	assert/2	asserta/2	assertz/2
clause/3	setof/3	compile/1	incore/1
revive/2	unknown/2	debug/0	nodebug/0
trace/0	leash/1	spy/1	nospy/1
debugging/0	expand_term/2	phrase/2	'C'/3
'NOLC'/0	'LC'/0	break/0	abort/0
save/2	reinitialise/0	maxdepth/1	depth/1
gcguide/3	gc/0	nogc/0	trimcore/0
statistics/0	statistics/2	prompt/2	version/0
version/1	plsys/1		

8. Built-in Programs

A special feature of the built-in programs in micro-PROLOG is that they model as closely as possible program defined relations. For example, the SUM relation can be viewed as though it were defined by a set of facts about addition, and the TIMES relation as though it were defined by the various 'times tables'. This is because the built-in programs attempt to simulate the different patterns of use of the relation; and the SUM built-in program is able not only to add up numbers, but also to subtract them.

For reasons relating to efficient implementation micro-PROLOG compromises on the ideal of supporting every possible use and generally allows only some of the possible uses of its built-in programs. In particular, the assembler coded built-in programs only support the deterministic uses of the relations they represent.

However, in general, each built-in program has several uses. This helps to miminise the number of names the programmer has to know, and also helps to keep micro-PROLOG programs 'invertible' - able to support different patterns of use for the relations they define.

If a particular call to a built-in program is an illegal use (for example if SUM is called with two or more arguments as variables) then the system raises a "Control Error". An error of this kind usually occurs only if there are too many variables in the call.

The 75 or so built-in programs are divided into a number of functional groups: the arithmetic operations, string operations, input/output operations, type predicates, data base operations, logical operators, module construction facilities, program library operations and miscellaneous programs. We take each group in turn and describe the formats and semantics of each built-in program. For the relations that are implemented entirely as micro-PROLOG programs embedded in the supervisor we also give its defining program. It is the program that will be displayed if you LIST the relation.

In introducing each relation we give the form of use, a comment (inside "{}" brackets) which gives a brief description of its meaning, and the restrictions, if any, on its use. The restrictions concern the arguments that must be known, or the arguments that must be variables, when a condition for the relation is evaluated. When the argument can be any term we indicate this by using a "t" or "t1" etc. in that argument position in the form of use. When the argument must always be known at the time of evaluation, and must be a particular type of value, we give the value type in the form of use. For example, if a particular argument to a relation must be an integer at the time of evaluation the type <integer> will appear in that argument position in the form of use.

Remember that each primitive unary relation can also be used as a supervisor command - see Chapter 3.

8.1 Arithmetic Relations

The arithmetic relations SUM, TIMES, SIGN, INT and LESS cater for the normal operations on integer and floating point numbers of addition, subtraction, multiplication, division and comparison.

8.1.1 SUM

(SUM x y z) {x+y=z} atleast two arguments must be given, given arguments must be numbers

SUM is true of three numbers when the first two add up to the third. The numbers involved can be integer, floating point or a mixture of the two types. The SUM primitive can be used to:

1. **Check a sum.** If all arguments are given then SUM succeeds only if the first two numbers add up to the third. For example, (SUM 20 30 50) is true, as is (SUM 1.5 0.3 1.8) and (SUM 23.6 -0.6 23).

2. **Add two numbers together.** If the first two arguments are numbers and the third a variable then the call succeeds by instantiating the third argument to the sum of the first two. For example, (SUM 30 -2 x) binds x to 28, and (SUM 30 2.5 y) will instantiate y to 32.5.

3. **Subtract two numbers.** If the third argument is a number, and either the first or the second is also a number (with the remaining argument a variable) then the call succeeds by binding the variable in the call to the result of subtracting the first number (or second) from the third. For example, (SUM x 3 15) binds x to 12, as does (SUM 3 x 15).

If an addition or subtraction results in an overflow (or underflow), then micro-PROLOG signals an arithmetic overflow (underflow) error. This causes any resident ?ERROR? program to be invoked as for other kinds of signalled error (see Appendix A).

micro-PROLOG uses 8 digits of accuracy in its arithmetic calculations, and the exponent can range from -127 to 127. Truncation (towards zero) rather than rounding is performed if the number of significant digits in a calculation is more than 8.

8.1.2 TIMES

(TIMES x y z) {x * y = z}

at least two arguments must be given, given arguments must be numbers

The TIMES relation can be used to multiply, divide or to check a multiplication.

1. **Check a product.** If TIMES is called with all three arguments numbers, then the product of the first two numbers is checked against the third number. If they are the same then the call succeeds, otherwise it fails. For example, (TIMES 3 4 12) is true, as is (TIMES 0.5 -3 -1.5)

2. **Multiplication.** If TIMES is called with just the first two arguments given, and the third argument a variable, the call succeeds by binding the variable to the product of the two numbers. The call (TIMES 3 -4 x) results in x being bound to -12.

3. **Division.** There are two forms of the TIMES program which can be used for division, both involve the division of the third argument of the TIMES call by either the first or second argument depending on which is known at the time. The remaining argument is instantiated to the quotient of the two given numbers.

(TIMES x 10 30),	x is bound to 3
(TIMES 10 x 25)	x is bound to 2.5

The division of an integer by another integer may of course result in a floating point nimber. Similarly if two floating point numbers are divided then it is possible that the quotient is a integer. Any necessary conversions between the two kinds of numbers are performed automatically.

If a division by zero is attempted then an "Arithmetic overflow" error is signalled.

8.1.3 LESS

(LESS <number1> <number2>)

{<number1> is less than <number2>}

The LESS built-in predicate implements the inequality test for numbers. Only one **arithmetic** usage is allowed, where both arguments are given and are numbers. In this case the call succeeds if the first number is numerically less than the second; if they are equal or if the first number is greater than the second the call fails. For example, (LESS 2 3) is true, as is (LESS -1 1.32); but neither (LESS 10 9) nor (LESS 4.4 4.4) are true.

LESS can also be used to compare constants, see below.

8.1.4 INT

(INT <number> y) {y the nearest integer to <number> between 0 and <number>}

y must be a variable at call

The INT primitive can be used to find the nearest integer to a given number. The nearest integer (truncating towards zero) is returned as the value of y. This two argument form of INT can only be used in this single mode. A one argument form of use is described in 8.7.

The nearest integer to 1.9 (towards zero) is 1: (INT 1.9 x) binds x to 1. The call (INT -134513.456 y) instantiates y to the number -134513.

Note that micro-PROLOG considers any number with no fractional part to be an integer. Thus:

(INT 3.2768E4) succeeds (32768 is an integer).

8.1.5 SIGN

(SIGN <number> y) {<number> > 0, y=1
<number> = 0, y=0
<number> < 0, y=-1}

y must be a variable at time of call

The SIGN primitive returns the sign of its numeric first argument in the second argument. Only one use is permitted where the first argument is a given number (can be integer or floating point), and the second argument is an unbound variable.

For example, (SIGN -3 x) instantiates x to -1, (SIGN 0 y) binds y to 0, and (SIGN 25.67 z) binds z to 1.

8.2 String operations

In micro-PROLOG strings can be represented and manipulated as lists of characters. A string in packed form is a constant. There is a primitive STRINGOF relation that can be used to convert between strings as character lists and constants. LESS can be used to test the lexicographical order of constants and CHAROF can be used to convert between characters and their ASCII codes.

8.2.1 LESS

(LESS <constant1> <constant2>)

{<constant1> lexicographically less than <constant2>}

Similar to the inequality test for numbers, this test for constants tests that the first argument (which must be a given constant) is textually less than the second (which must also be a given constant). The ordering used is the lexicographical ordering, based on the ordering of the underlying character set (namely ASCII).

For example, (LESS FRED FREDDY) succeeds since FRED is lexically less than FREDDY.

8.2.2 STRINGOF

(STRINGOF x y) {x is a list of characters of constant y}

x must be a list or list pattern and y a constant
or x must be a character list and y a variable

The STRINGOF relation can be used convert a constant into a list of its constituent characters, or to pack a list of characters into a single constant. There are essentially two forms of use:

1. **Unpacking**: to produce a list of characters from a constant. In this use the second argument must be a constant (not a number or list) at the time of evaluation. The result is the unification of the first argument with the list of characters of the constant. If the empty constant "" is given its list of characters is the empty list ().

(STRINGOF x fred) results in x being bound to the list (f r e d), and (STRINGOF x "A*") binds x to the list (A *).

For the unpacking use, the first argument may be given as a list or a list pattern. This allows comparison of a list of characters and the constant, and the use of a pattern allows a particular character of the constant to be picked up as the binding of a variable.

```
(STRINGOF (f r x d) fred),   x = e
(STRINGOF (f r|x) fred),     x = (e d)
(STRINGOF (f r|x) gerry)     fails
```

A given list of characters must be just that: a list of constants which have single character names.

2. **Packing**. This takes a list of characters and produces a constant from it. It is the inverse of the unpack use.

```
(STRINGOF (f r e d) x)    x = fred
(STRINGOF () x)           x = ""
```

8.2.3 CHAROF

(CHAROF x y) {x is character with code y}

at least one argument must be given

The CHAROF primitive implements a mapping between single character constants and the ASCII coding sequence. Three uses are allowed: where either x or y or both are known at the time of the call. Some examples of its use are:

```
(CHAROF A 65)
(CHAROF B x)        x is instantiated to 66
(CHAROF y 32)       y is instantiated to " "
```

CHAROF will fail unless its first argument (if already a constant) is exactly one character long.

8.3 Console Input/Output

The input/output facilities are divided into two groups: Console I/O and Disk I/O. Console I/O reads terms from the keyboard and displays them on the console. Disk I/O transfers terms to and from the disk system. In fact the console I/O primitives are defined in terms of the disk I/O primitives as we shall see below.

The I/O facilities described here are the first example of a non-logical feature of micro-PROLOG, this is because they depend on their behaviour (reading and writing terms) for their meaning. However, in large measure the power of PROLOG as a systems programming language arises from its combination of declarative and imperative features.

There are seven built-in programs for dealing with Console I/O, R(Read), P(Print), PP(P-Print), PQ(Print-Quoted), RFILL, RCLEAR and POLL, which respectively read a term from the console, print a sequence of terms, pretty print a sequence of terms, print terms in quoted form, 'pre-fill' the keyboard buffer with a sequence of terms, clear the keyboard buffer and poll the keyboard.

8.3.1 R

(R x) {x the next term typed on keyboard}

x must be a variable at time of call

The Read program reads a single term from the keyboard and binds its argument to the term it reads in. It must be called with a variable as its argument, otherwise a "Control Error" is signalled. If there is already a term in the keyboard buffer (see Chapter 3) this will be the value returned, otherwise the read prompt . is displayed and the evaluation will suspend until a term is entered.

Any variables in the entered term are converted to the special internal form for variables in which the variable name used in the term is discarded. However, different occurences of the same variable in the term will be converted into the same internal form. The internal form for each variable of the term will be different from the internal form of any other variable in the program - i.e. it will be an entirely new variable. It will also be different from the internal form assigned to a varable of any other term that has been read in, or will be read in, even if the variables have the same name. In micro-PROLOG the scope of a variable name is the term in which it appears.

See Section 3.1 for details of how micro-PROLOG accepts terms from the keyboard.

The R primitive side-effects the keyboard buffer removing the first term from the buffer. A call to R only has one solution. A backtracking return to the call will not result in an attempt to find an alternative solution by reading in the next term. The second attempt to solve the call will fail. The call will be re-solved only if an earlier call has an alternative solution and this leads to a fresh attempt to solve the R call. At that point, the next term in the buffer will be read.

8.3.2 P

(P t1 t2 .. tk) {display t1 t2 .. tk on the console}

The Print program displays its sequence of any number of arguments on the console output device. It takes any number of arguments each of which can be any term. The terms will be displayed separated by a single space. There is no automatic new line on completion. A subsequent P or PP will therefore start one character position after the preceding P finished its display.

The P primitive displays constants in its argument terms as the sequence of their component characters. Thus a constant that would have to be quoted on input (see Chapter 2) will be dispayed without the quotes. This means that any control characters in the constant, which appear as ~<char> combinations in the quoted form, are sent to the output device as control characters. A control character in a constant will therefore produce the effect that it is supposed to produce on the display.

For example, if the console uses Control-L to clear the screen then

```
(P "~L")
```

clears it. Using this unary form as a command, the command

```
P "~L"
```

will therefore also clear the screen. By putting other control characters in a quoted constant argument to P you can move the curser to any position on the screen. What control characters are used depends on the terminal.

Variables occurring in the sequence of displayed argument terms are given the names X, Y, Z, x, y ,z,X1,..,z1,X2 and so on, corresponding to the order that the variables are encountered during the Print. (The first variable encountered is given the name X, the second one the name Y and so on.) The same internal form variable appearing in more than one term of the displayed sequence of terms will have the same print name. So, if the first variable that appeared in t1 also appears in t2, it will be displayed as X in both terms. If there are more than 128 different variables, then subsequent variables are displayed as ???.

8.3.3 PP

```
(PP t1 t2 .. tk)    {Pretty Print t1 t2 .. tk on the console}
```

The PP program displays its sequence t1 .. tk of arguments in a standard format. It is very similar to the P program except that a carriage return/line feed automatically occurs after the terms are displayed. In other words, PP always terminates the display of its arguments by sending the <CR> and <LF> pair of characters to the terminal. A subsequent P or PP starts a the beginning of a new line. Also PP displays constants that would need to be quoted on input in quoted form. This means that PP displays the terms in such a way as to guarantee that if it they were read back in the same terms would be re-constructed (except for variables which are always new).

Control characters occurring in the quoted constants are displayed in the ~<char> format. As an example of the difference between P and PP,

```
(P "(The man")
```

displays:

```
(The man
```

on the console, whereas the call:

```
(PP "(The man")
```

displays:

```
"(The man" <CR><LF>
```

on the console.

Since the PP program always finishes by sending a return/line feed pair a call to PP with no arguments:

```
(PP)
```

will just move the cursor to the beginning of a new line.

8.3.4 PQ

```
(PQ t1 t2 .. tk)     {Print Quoted t1 t2 ..tk on the console}
```

The PQ program behaves somewhat like a cross between P and PP, and provides unambiguous output where no line feed is required. All constants that need to be quoted on input are also quoted by PQ (as in PP), but there is no carriage return/line feed at the end of the line (like P).

Control characters are printed as in PP by ~<char>.

```
(PQ "(The man")
```

displays:

```
"(The man"          {no <CR><LF>}
```

8.3.5 RFILL

```
(RFILL (t1 t2 .. tk) x)

{clear then pre-fill keyboard buffer with t1 t2 .. tk
  and then read a term into x, x must be a variable at time of
  call}
```

The RFILL program is used to invoke the built-in line editor with the sequence of terms t1 t2 .. tk given as the elements of its first (list) argument already in the keyboard buffer. The terms, as displayed, can then be edited using the line editor. When <return> is entered the first term in the buffer (usually the edited form of t1) is automatically read in to become the binding of the variable x. The edited forms of t2 .. tk, if they were given in the call, must be explicitly read in using R since they will be left in the keybord buffer. RFILL displays constants in the PP format so that they can be read back in.

RFILL remembers the print names given to each internal form variable in t1. When the edited version of the displayed t1 is read back in as the binding of x, each of these remembered variable names is converted back into the internal form variable that appeared in the original t1. Thus, variables names in the edited form of t1, which are the same after editing, become **the same internal variables** as those that appeared in the t1 argument to RFILL.

This remembering of variable names is necessary for the use of RFILL for editing programs, particularly when it is used from within a structure editor to edit a component of a clause. RFILL is used in this way by the structure editor described in Chapter 4. It is invoked by the t command. RFILL is also used by the e error recovery command of the **errtrap-mod** module described in Chapter 6. Again for this use, the remembering of variable names is essential.

Note that although a list of terms must be given as the second argument to RFILL, the list is displayed without the outer level of parentheses.

RFILL also has the side effect of clearing any previous contents of the keyboard buffer and type-ahead buffers. If several terms had previously been typed on a line, then any 'unused' terms will be discarded when RFILL is invoked.

As we have already mentioned, RFILL is used by the t command of the structure editor. It is also used by the edit commands of both SIMPLE and MICRO. As an example, a simplified version of the edit of MICRO is defined by:

```
((edit x)                          {command: edit relation x}
     (R y)                         {read the clause number}
     (CL ((x|z)|z1) y y)           {find the y'th clause of x}
     (RFILL (((x|z)|z1)) z)        {invoke line editor}
     (ADDCL z y)                   {add edited clause to the program}
     (DELCL x y))                  {delete the old clause for x}
```

For an explanation of the other primitives see Section 8.9.

8.3.6 POLL

POLL {a poll of the keyboard has revealed a pressed key}

The POLL primitive is used to test whether one or more keys have been pressed since the last console read. It succeeds if they have, and fails if not. The keys' values are stored in the type ahead buffer, which is not affected by POLL.

A typical application for POLL is to allow user-definable interruptions in programs. For example, a friendly version of the CPM or MS-DOS 'TYPE' command could be defined as follows:

```
((type X)
  (OPEN X)
  (type-contents-of X))

((type X)
  (CLOSE X))

((type-contents-of X)
  POLL                    {succeed if a key has been pressed}
  (GETB "KBD:" Y)         {gobble up the key}
  (P Pausing ...)
  (GETB "KBD:" Z)         {wait for next key}
  (PP Continuing)
  (type-contents-of X))   {carry on typing the contents}

((type-contents-of X)
  (GETB X Y)              {get a byte from the file}
  (PUTB "CON:" Y)         {display it on the screen}
  (type-contents-of X))
```

The command:

```
type simple
```

would result in SIMPLE.LOG (if present on the current disk) being typed. If any key were pressed, the message 'Pausing ...' would be displayed. A second key would result in 'Continuing', and the typing of the file would resume.

GETB and PUTB have been in this example to transfer the characters from the file to the console. Because they bypass the dictionary, they are faster than RDCH and P, and of course save on dictionary space. (See Section 8.4 for a description of them.)

8.3.7 RCLEAR

```
RCLEAR    {reset the keyboard buffer and type-ahead buffer}
```

The RCLEAR program clears the keyboard input buffers. Its purpose is to allow type-ahead or a long command line to be discarded if not wanted, for instance in an interrupt handler using POLL or a user defined ?ERROR? handler.

The following definition, for example, provides a read without type-ahead facility:

```
((read-direct X)
  RCLEAR
  (R X))
```

8.4 File I/O

micro-PROLOG supports files of text under CP/M, i.e. files of ASCII characters. These are accessed sequentially via the primitives **FREAD, FWRITE, INTOK, READ, W, WQ** and **WRITE**, or randomnly using the **SEEK** primitive. In addition, Byte level input/output on files can be performed using the **GETB, PUTB** and **RDCH** primitives.

Up to four files may be open during an evaluation at any one time, an attempt to have more files open results in the "Too many files opened" error being signalled.

8.4.1 OPEN

(OPEN <file-name>**)** {open named file for reading}

This built-in program opens a file for reading. The <file-name> argument is a constant which names a file according to the CP/M file naming conventions (see Chapter 3 for details).

If the file was previously open for writing then the file buffer is 'flushed' and the file is closed before being re-opened for the read. This means that it is not possible to simultaneously read and write to a file. The first character of the file is read in by the **OPEN** program, so if the file is empty or if it is not there then the "File not found" error is signalled and the **OPEN** call fails.

If the file was already open for reading then the file is 'rewound' to the beginning; however it is not good practice to rely on this feature.

8.4.2 CREATE

(CREATE <file-name>)

{create and open a new file for writing}

The CREATE program opens a new file for writing. Any old file of the same name is first re-named to have extension .BAK, and the new file is then created. This means that files are automatically backed up.

If the file is already open for writing, it is re-CREATEd, and its contents, if any, are lost.

8.4.3 CLOSE

(CLOSE <file-name>) {close down the named file}

In CP/M there are no special actions associated with closing a file which is being read; however a file which is being written to must be explicitly closed down, otherwise the disk file may not contain the right data.

The CLOSE primitive performs this operation and releases the file from micro-PROLOG. It is also used to release, from micro-PROLOG, files opened for read access.

8.4.4 READ

(READ <file-name> x) {x next term on the named file}

x must be a variable at time of call

The READ primitive reads the next term from the named file and binds its argument to the term. It finds the term by reading characters from the current character position for the file. If the end of file is encountered during the READ, then this primitive fails. After the read, the current character position is immediately after the last character of the read-in term. The READ primitive is the same as the R primitive, except that it reads a term from a named file.

8.4.5 WRITE

(WRITE <file-name > (t1 t2 .. tk))

{write the sequence of terms t1 t2 .. tk on the named file
in PP format}

The sequence of terms t1 t2 .. tk are written onto the file in the same form as the PP program. This ensures that any term written onto a disk file can be subsequently read back in as the same term, with the exception of variables which are renamed. At the end of the transfer of t1 .. tk a linefeed/return two character sequence is sent to the file. So the file position at the end of the WRITE is not immediately after the character text for the last term tk, but is two more characters beyond that.

8.4.6 W

(W <file-name > (t1 t2 .. tk))

{write the sequence of terms t1 t2 .. tk on the named file in P format}

Exactly the same effect as WRITE except that the terms are written in the same way that P displays terms on the console. Note that terms written using W will not be re-readable as terms if they contain any constants that would need to be quoted on input. The W does not complete the transfer with a linefeed/return. The file position on completion is therefore immediately after the text for tk.

Both W and WRITE handle variables in the same way as the P and PP primitives. Each occurrence of a variable throughout the list of terms (t1 .. tk) is given the same print name in the sequence of terms written to the file.

8.4.7 WQ

(WQ <file-name> (t1 t2 .. tk))

{write the sequence of terms t1 t2 .. tk on the named file in PQ format}

This is a cross between W and WRITE, and writes terms to the named file in PQ format. Terms thus written can be read back in as the same term, except that variables are renamed as usual. In addition, the last term thus written should be followed by a separator, or it may "merge" with the next term to be written.

The program:

```
((write-quoted X Y)
   (WQ X Y)
   (W X (" ")))
```

will write the terms Y into a file X, and place a <space> character after the last one to ensure they may be read back in. All the terms written by this program will end up on one line in the file.

8.4.8 GETB

(GETB <file-name> X) {X is ASCII code of char in file}

X must be a variable at the time of the call.

The GETB primitive reads the next character from the named file and binds its second argument to the small integer that is the ASCII code of the character. After the read, the current character position is incremented by 1.

8.4.9 PUTB

(PUTB <file-name> X) {write ASCII value on named file}

X must be a small integer (0<=X<=255) at the time of the call.

PUTB writes the character whose ASCII code is supplied as its second argument (0<=X<=255) at the time of the call.

PUTB writes the character whose ASCII code is supplied as its second argument, onto the named file. After the call to PUTB, the current character position in the file is incremented.

8.4.10 INTOK

(INTOK <file-name> x) {x is next token on named file}

x must be a variable at time of call

The INTOK primitive reads the next token from the named file and returns it as the value of its second argument, which must be a variable. The lexical rules used for defining tokens in character files are the same as those for micro-PROLOG terms; for a complete description of the lexical rules see Section 2.10.

If the read-in token represents a number, its number value will be the binding of x. For example, if the next token is the single character 9, then the integer 9 will be the value of x. For any other token, the value of x becomes a constant comprising the characters of the token. Even if the next token read in would normally be interpreted as a variable, a constant comprising the characters of the variable name is the value of x. If such a constant is PPed, then it will be surrounded with quotation marks to signify that it is actually a constant and not the print name of a variable.

INTOK is therefore useful when it is important that the normal micro-PROLOG variable conventions should be ignored; in particular if a y response is read in using a call

(INTOK "CON:" x)

as an allowed short hand for yes, then the constant y is the value of the variable x and a subsequent (EQ x n) test will fail. If (R x) is used, the y response is interpreted as a variable, and x effectively remains unbound. A subsequent (EQ x n) test will now succeed, binding x to n.

For an explanation of the use of the file name CON:, see 8.4.9 below.

8.4.11 RDCH

(RDCH <file-name> X) {X is next character in named file}

X must be a variable at the time of the call.

The RDCH primitive reads the next character from the named file and binds its second argument to the one-character constant that names the character. After the read, the current character position is incremented by 1.

8.4.11 SEEK

(SEEK <file-name> x) {named file is at position x}

x a variable or file position at call

There are two modes of use, eitner the x argument is unbound on entry to SEEK, or it is a file position previously returned by an earlier call to SEEK.

A file position is a |-pair of integers (x|y). The x is a 'block' number within the file. Each block is 128 characters long and a file can contain up to 32K blocks. The y is an integer 'offset' (starting at zero) into this block. The offset is a character position within the block. Hence the first character on a file is in the zeroth block, and has offset zero; it is at position (0|0).

If the position argument is unbound then SEEK returns the current position in the file; if the argument is given then the file is re-positioned to the position given.

The SEEK primitive can be used for files that are either opened for reading or for writing. However, extreme care should be exercised if writing into the middle of a file, as there is no protection against overwriting already existing terms on the file.

SEEK can be used to implement a system where one or more programs can be on disk instead of in memory. The following is a simplified form of the RPRED definition exported by the EXREL utility described in Chapter 5.

```
((RPRED  x y z)              {find clause with head y on opened
                              file x starting search at position
                              z}
     (SEEK x z)              {move file to z}
     (READ x y1)             {read in a candidate clause y1}
     (SEEK x z1)             {find new file position z1}
     (OR                     {either}
      ((EQ (y|Y) y1)|Y)      {unify candidate clause y1 with
                              (y|Y) and evaluated the body of the
                              clause Y}
      ((RPRED x y z1))))     {or find another clause starting at
                              z1}
```

To use this program (ignore the comments between the curly brackets) to keep the clauses for a relation likes on the disk file LFILE.LOG replace the clauses for likes in the program with the single clause:

```
((likes|x)
     (RPRED LFILE (likes|x) (0|0)))
```

The file LFILE must also have been OPENed prior to using the program for likes. The LFILE file can be generated either by using SAVE (see below) or be specially generated by a program that uses WRITE.

The likes clauses in LFILE can be quite general, including recursive clauses, because different invocations of RPRED can be accesing different segments of the file simultaneously. The use of SEEK means that each different use of RPRED remembers where

it is in the file, and then explicitly repositions the file to that position when it is getting its next clause.

You can spread the clauses for a relation over several files (just use more than one rule as above) and you can mix RPRED definitions of relations with ordinary clauses. So, new information about a 'data base' relation can be recorded by a clause in memory until the backing store file can be updated. Programs like RPRED can be used to build intelligent data base systems within micro-PROLOG.

8.4.12 Special file names

micro-PROLOG supports five input/output channels, treating them as special serial files. The first four correspond to the CP/M (and MSDOS) device drivers, and are named in accordance with CP/M, and the fifth is named after the keyboard:

"CON:"	the console device (I/O)
"LST:"	the printer output
"PUN:"	the punch output
"RDR:"	the reader input
"KBD:"	the keyboard input

These special file names can be used in any of the above file I/O primitives, except for SEEK which demands a disk file. Thus if a given CP/M installation connects the LST: device to a printer then WRITEing to the LST: file will actually print directly on to the printer.

Similarly the RDR: and PUN: devices are commonly implemented as serial input/output communication (RS232). It is quite possible to have two computers both running micro-PROLOG programs communicating with each other by sending messages via the RDR: and PUN: devices.

If the RDR: device is used then it is important to ensure that the serial device is interrupt driven. That is the characters coming in from the serial device are queued, and whenever a new character appears on the serial channel the computer is interrupted and the new data automatically put into the queue. **This is not done by micro-PROLOG.**

The automatic queueing is necessary because micro-PROLOG cannot always guarantee to keep up with the incoming information. The the maximum baud rate which can be used is 1200baud on a 4MHz Z80. If a higher baud rate is used, or if the garbage collector happens to be called during the read, characters will be lost and ignored.

"KBD:" is a channel which is connected directly to the keyboard type-ahead buffer, by-passing micro-PROLOG's built-in console editing facilities. Characters typed are not echoed, and none of micro-PROLOG's prompting, keyboard interrupt are present during the read.

The main purpose for the "KBD:" channel is to allow immediate, unechoed input for menu-driven programs, editors written in micro-PROLOG itself, password entry, etc.

For example, the following program allows a five character password to be entered without echo. Any characters typed will become part of the five character password:

```
((get-password X)
  (P "Password: ")
  (FREAD "KBD:" ((CON 5)) (X)))
```

The message 'Password: ' is printed, and the cursor is left after the colon. The next five keys typed, including any control characters or carriage returns, are read without echo, and returned as part of a five character constant.

Used with GETB or RDCH, the "KBD:" channel allows easy one key control of interactive programs. Note that POLL can be used to test the status of "KBD:", and that RCLEAR will clear both "KBD:" and "CON:" input buffers.

Finally, the R, P and PP commands are defined by the following supervisor programs using READ, W and WRITE and the special file name CON:.

```
((R X)
  (READ "CON:" X))

((P|X)
  (W "CON:" X))

((PP|X)
  (WRITE "CON:" X))
```

Note how the use of the meta-variable as the list of arguments (see Chapter 2) makes P and PP multi-argument relations. The sequence of argument terms given in the call is passed on as a single list of terms to the W and WRITE primitives.

8.5 File operations

A number of primitives allow the manipulation of CP/M files directly; such operations include renaming files, erasing them and logging in a new disk.

8.5.1 LOGIN

(LOGIN <disk-name>)

{make disk in named disk drive the logged in disk}

CP/M has an annoying habit of not allowing you to easily change disks. If you do change a disk without telling the system in some way (you have to type control-C on CP/M's top level prompt), then the new disk is marked "read-only" and you cannot write on it. If you attempt to write on the disk (for example by trying to save a PROLOG program) CP/M aborts the micro-PROLOG system and returns you to its top-level prompt.

What the LOGIN primitive allows you to do is to change a disk without leaving micro-PROLOG.

The <disk-name> is a single letter constant which is one of the CP/M (or MSDOS) disk drives. Examples of disk names are A, B etc. The LOGIN primitive logs in the disk named by the parameter, and makes it the new default drive. The default drive is where micro-PROLOG (and every other CP/M (MSDOS) program) looks for a file if the disk drive is not explicitly given in the file name.

As a supervisor command, the use of LOGIN is

LOGIN <disk-name>

To use the LOGIN primitive to change a disk in a drive, first change the disk and then issue the appropriate LOGIN command.

A note of warning: if you issue a LOGIN command for a disk drive which does not exist, CP/M tells you in a message of the form:

BDOS Error: select on drive M

and then aborts micro-PROLOG. (MSDOS is a little friendlier, it gives you the choice of retrying or ignoring the error as well as aborting.) Your workspace program will have been lost and if it has not been saved you will have some retyping to do!

8.5.2 ERA

(ERA <file-name>) {erase the named file from its disk}

The ERA primitive attempts to erase (delete) the named file from the system, and succeeds if successful. If no file name extenstion is given, then a .LOG file is assumed. ERA fails if the file is not present on the disk, or if the disk is read-only.

As a supervisor command, the use is

ERA <file-name>

8.5.3 REN

(REN <file-name1> <file-name2>)

{change <file-name1> to <file-name2>}

The REN primitive renames the disk file with name <file-name1> to the name <file-name2>. If a disk drive specifier is included with either file name then the file on that disk is renamed. If both <file-name1> and <file-name2> specify a disk letter they must both be the same. Note that the renaming is from left to right, as in MS-DOS, and not right to left, as in CP/M.

If <file-name1> is not present on its disk then the REN primitive fails.

Since it is a two argument relation, REN can not be used directly as a supervisor command. You must either use the ? query,

?((REN <file-name1> <file-name2>))

or define your own unary ren relation that reads in the second file name before call REN. (See Chapter 3.)

8.5.4 DIR

(DIR <ambiguous-file-name> x)

{x the list of file x names matching the ambiguous name}

x must be a variable at time of call

The DIR primitive returns a directory in its second argument. The directory is a list of constants which are the file names that match the ambiguous file name given as the first argument. The ambigous file name uses similar conventions to that of CP/M and MSDOS; all files that match the specifier will be returned in the list.

An ambiguous name of * names all the .LOG files on the current disk, and *.* names all the files on the disk. A drive letter can be specified with the ambiguous name causing a directory of the given disk to be searched. The ambiguous file name "A:PROG?.LOG" names all the files on A that are .LOG files with a name PROG followed by atmost one other character.

DIR is unusual in that the directory is returned as a value rather than printed on the console. The normal behaviour in CP/M is just to print it; however returning it as a value allows a micro-PROLOG program to manage its disks if required. For example, all the files of a given name can be searched by a micro-PROLOG program for some property.

We can use DIR to define a command that will display all the matched file names. The following program defines the dir command of MICRO.

```
((dir x)              {display list of file names matching x}
   (DIR x y)          {find the list}
   (PP y))            {pretty print it}
```

The command dir * at the supervisor level of micro-PROLOG will cause a list of all the .LOG files on the default disk to be displayed.

8.6 Record Input/Output

The two primitives FREAD and FWRITE allow items to be read and written in files in a fixed length record format. Using these two primitives a simple record file data base can be constructed and accessed from micro-PROLOG.

An argument to each of these primitives is the format specifier. A format is just a list of two element lists, each pair represents a field in the record. A field is either a numeric field or a constant field.

Numeric fields are signalled by the specifier:

```
(NUM n)
```

where **n** is a small integer in the range 0 to 60; this number is the field width: the number of ASCII characters in the record allocated to this field.

A constant field is signalled by:

```
(CON n)
```

where **n** is the length of the field as a number of characters. Any characters not used in a field are padded with trailing space characters; and if a particular field overflows the width the excess characters are simply truncated; the maximum length of a CON field is 60 characters (the maximum length of a constant).

The total length of the record is given by the total of all the field widths in the format. This length must be greater than 0, and less than 255.

The following format specifies a record of four fields, the total length of the record is 135 characters:

```
((CON 30)(CON 30)(NUM 15)(CON 60))
```

8.6.1 FWRITE

(FWRITE <file-name> <format> <list of constants & numbers>)

{write the given list of values, to the specified format, on named file}

The FWRITE primitive writes a single record as specified by the format with contents the list of constants and numbers. The record consists of a sequence of ASCII characters of length the total length of the format specifier. The file must have been opened with a CREATE. The <format> is a list of field specifiers as outlined above; and the <list of constants & numbers> is just that. The FWRITE call leaves the file pointer immediately after the written record. So the next written record will be adjacent to this one. Before the FWRITE you can position the file using SEEK. But make sure you position it at the beginning of the character sequence for a record. Using SEEK and FWRITE in combination you can selectively update a file of records, overwiting an old record with new field values. But remember that the updated file must be one that has been opened for writing with a CREATE. So you cannot update an old file. To achieve the effect of updating an old file, open a new file for writing, and open the old file for reading. Then transfer all the records from the old file to the new one using a program such as

```
((copyfile X Y)
  (FORALL ((FREAD X <format> Z)) ((FWRITE Y <format> Z))))
```

You can now update the copied file of records using SEEK and FWRITE.

The data list must have the same number of elements as there are fields in the format: for each field in the format there must be a corresponding element in the list. The type of the field and the type of the corresponding element in the data list must also agree: if a constant is specified in the format then the corresponding element of the list must also be a constant. If the corresponding element is an unbound variable, then the "Control error" error is signaled. If the corresponding data element is given, but is of the wrong type, the FWRITE call fails.

The FWRITE primitive can also be used when writing to one of the 'special' files, including the console. Using FWRITE to the console is a simple way of generating formatted displays on the screen.

In the following call we write to the file FOO.LOG a record consisting of a constant (20 characters) and a number (10 characters):

```
(FWRITE foo ((CON 20) (NUM 10)) (Marriene 34512))
```

Note that for numeric fields you should count enough spaces to allow for sign characters and the full E notation for larger numbers.

The call

```
(FWRITE "CON:" ((NUM 10)(NUM 10)(NUM 10)) (45.7 895.8 45.6))
```

displays the numbers, left justified, in fields 10 characters wide across the screen. It should be followed by a (PP) to position the cursor at the beginning of the next line.

8.6.2 FREAD

(FREAD <file-name> <format> <list of vars, constants & numbers>)

{search for a record of the specified format that matches the data list of variables, numbers and constants}

The FREAD primitive is the counterpart to FWRITE. It enables records which have been written to be read back in. Apart from simply reading in a record, FREAD also **searches** for a record which matches the given constants and numbers in the data list of the call.

The constants and numbers in the records that are skipped before a match is found **do not** enter the **micro-PROLOG** data space. So a search down a very large file will not incur a memory turn over and garbage collection overhead. In contrast, the RPRED relation defined in 8.4.12 will turn over the memory when it is used to find a matching clause. But it is more general than FREAD. It searches a file of arbitrary clauses not just records, and it uses unification to find a match.

The relationship between the <format> and the data list is the same for FREAD as it is for FWRITE; except that variables are allowed in the list. When a matching record is found in the file the variables become instantiated with the values found in the corresponding fields in the record.

The FREAD call will fail if no matching record is found starting from the current file position or if there are not enough characters left in the file to fill a record. A successfull call leaves the file at the character immediately following the found record. If SEEK is used to position the file before an FREAD you must make sure that you position it at the beginning of a record.

In the following call the file FOO.LOG is searched (from the current position) for a record whose first component is Marriene:

```
(FREAD foo ((CON 20)(NUM 10)) (Marriene x))
```

If the next record that has Marriene in the first field is the one written by the example FWRITE call above, the call will succeed when the record is found with the variable x becoming bound to the number 34512.

FREAD can be used to read from the special files, such as the console.

8.6.3 Relations defined by files of records

As an example of the use of FREAD we give an example of the definition of a micro-PROLOG relation in terms of a file of formatted records. Suppose that SALARIES.FOR is a file of records all of the format ((CON 20)(NUM 6)) which give employee names and salaries. We can define a salary relation that will search this file whenever the relation is called and the file is OPEN. The definition makes use of an FPRED analogue of the RPRED relation defined in 8.4.12.

```
((salary x y)
  (FPRED "SALARIES.FOR" (0|0) ((CON 20)(NUM 6)) (x y)))

((FPRED X x Y Z)     {find a record with format Y starting at
                          x on file X that matches Z)
  (SEEK X x)         {position the file at x}
  (COPY Z Z1)        {copy the template Z to Z1 replacing
                         variables}
  (FREAD X Y Z1)     {find a record matching the copy template}
  (SEEK X y)         {find new file position}
  (OR ((EQ Z Z1))    {either unify Z with found record Z1}
      ((FPRED X y Y Z)))  {or search for a matching record
                                from new position y}

((COPY () ())        {empty list is copy of empty template}

((COPY (x|y) (x1|y1))  {copy starts with a new variable x1}
  (VAR x)              {if template starts with a variable x}
  (COPY y y1))         {followed by a copy of the tail}

((COPY (x|y) (x|y1))   {copy starts with x}
  (NOT VAR x)          {if this is not a varable}
  (COPY y y1))         {followed by a copy of the tail}
```

The copying of the given pair of arguments of the call to salary is needed in order that the values found for any variables in the call, and returned by the (EQ Z Z1) condition in FPRED, are undone when there is backtracking to find an alternative solution to the call. When backtracking causes the 'else' branch of the OR to be taken the effect of the EQ is undone and new values for the variables in Z are sought by the tail recursive FPRED call.

8.6.4 Mixing records and terms

There is nothing to stop you writing a file using one format and reading it with another - but beware, at least the field widths should be the same because of the packing space characters. You can also write part of a file with one format, part with another. You should keep track of where one group of formatted records ends and the other begins by using SEEK to find the file position when you have finished writing with one format. The formats are, after all, just logical concepts superimposed on a segment of contiguous characters.

In the same way you can mix records with terms. The records are written and read using FWRITE and FREAD and the terms using READ and W. A term on the file is just a sequence of characters satisfying the syntactic constraints of micro-PROLOG. You must be very careful with this mix. A fairly safe mixture is to have the first written thing on the file be the list term that specifies the format for the records on the rest of the file. This can be read using READ and then used in the subsequent FREADs. This is a useful device if you want to program a general purpose formatted file handling utility.

8.7 Term composition and decomposition

Two primitives provide the means to decompose a list of terms into a character list (a list containing zero or more one-character constants, but nothing else), and to create terms from such a list. The two actions are analogous to writing (using WQ), and reading (using READ), except that a character list is used in place of a file. These primitives, RLST (read from list) and WLST (write into list) provide the means for terms to be manipulated at the character level by editor programs written in micro-PROLOG.

8.7.1 RLST

```
(RLST X Y)      {Y is a term read from list X}
(RLST X Y Z)    {Y and X as above; Z is remainder list}
```

X must be a list of single character constants; Y and the optional argument Z must be variables at the time of the call.

At the time of the call, the first argument of RLST must be bound to a list containing nothing but one-character constants. A term is "read" from the list, as if the characters had been in a file, and the second argument is bound to this term. As with the READ predicate, this second argument must be an unbound variable at the time of the call. If the optional third argument, again an unbound variable, is provided, it is bound to a list containing any part of the first argument not used by the read.

For example, the call:

```
(RLST ("3" "2" "7" "6" "7" a b c) X)
```

will bind X to the number 32767. The characters a, b and c are ignored. On the other hand, the call:

```
(RLST ("3" "2" "7" "6" "7" a b c) X Y)
```

will again bind X to the number 32767, but the remaining characters will appear as the list (a b c) bound to Y.

By using the remainder list third argument, it is possible to read successive terms from a list. For example, the following program will return a list of terms from a character list:

```
((terms-from-list () ()))

((terms-from-list X (Y|Z))
  (RLST X Y x)
  (terms-from-list x Z))
```

The first clause states that no terms can be read from a list with no characters in it. The second clause reads the first term Y from the character list X, and then makes a recursive call with the remaining characters x and the output tail Z.

8.7.2 WLST

(WLST X Y) {write list of terms Y into variable X}

X must be a variable at the time of the call, and Y must be a list of terms.

At the time of the call, the first argument of WLST must be an unbound variable, and the second must be a list of terms. The term list is "written" into a list of one-character constants, as if to a file, and the first argument is bound to this list. The "writing" is done as if by WQ, that is, any constants that need to be quoted for reading are quoted, but no carriage return/line feed terminates the list.

For example, the call:

```
(WLST X ((age tom 12)))
```

binds X to the list:

```
("(" a g e " " t o m " " "1" "2" ")")
```

8.8 Type Predicates

The type predicates test a single argument for its type: i.e. whether it is a number, constant, list or unbound variable.

8.8.1 NUM

(NUM x) {x is a number}

The NUM built-in predicate tests to see if its single argument is numeric or not. If it is a number the call succeeds, if it is an unbound variable, a constant or a list then the call fails. For example, (NUM 3) and (NUM -1.3e9) succeed (are true), whereas (NUM bill) and (NUM x), with x unbound, fail (are false).

8.8.2 INT

(INT x) {x is an integer}

The INT predicate, in its single argument form, checks its argument for being an integer. A number is classed as an integer if it contains no digits to the right of the decimal point (ie it is a whole number, with no fractional part). Thus (INT 1.23E9) is true. INT fails if its argument is anything other than an integer number.

8.8.3 CON

(CON x) {x is a constant}

The CON built-in predicate tests if its single argument is a constant. For example, (CON foo) succeeds, whereas (CON ()), and (CON 1) both fail. If the argument is not a constant (including the case where it is a variable) then the call fails.

8.8.4 LST

(LST x) {x is a list}

The LST predicate is true of lists. This includes the empty list. If the single argument is not a list, (again including the case where it is an unbound variable), the call fails.

8.8.5 SYS

(SYS t) {t is an atom for a primitive relation}

SYS tests to see if its argument is a call to a built-in relation (i.e. one of the relations described in this chapter), or some other system constant. It succeeds if it is, it fails if it is an atom for any other relation.

For example:

(SYS FAIL) or (SYS (SUM x y z))

are both true, and succeed.

8.9 Logical operators

The basic clausal form of logic programs, which is limited to the implicit 'and' between the calls in the body of a clause, is extended via the logical operator primitives of micro-PROLOG. These are supervisor programs that implement: disjunction OR, negation-as-failure NOT, conditional alternatives IF, list of all solutions to a query ISALL, test on all the solutions to a query FORALL, identity EQ and the restriction to a single solution !. These can be used to increase the efficiency and the readability of micro-PROLOG programs. They also raise the level of the language, making it more powerful and expressive.

8.9.1 OR

(OR <atom list1> <atom list2>)

{either the query ?<atom list1>
or the query ?<atom list2> can be solved (is true)}

The disjunctive operator OR has two arguments: each of which is a list of atoms. An OR call succeeds if either of its component queries is solved. For example,

(OR ((father-of x y)) ((mother-of x y)))

succeeds if either (father-of x y) or (mother-of x y) succeeds (is true).

An empty goal (named by the empty list ()) always succeeds, and hence if used as an argument to OR acts as a 'true' branch.

The supervisor definition of OR is

((OR X Y)|X)
((OR X Y)|Y)

This uses the 'meta-variable as the rest of the clause' form (see Chapter 2). From the definition we can see that the 'either' branch is tried first (it is the first clause). Only when there are no more solutions to this branch will a solution to the 'else' branch be sought. As we saw in the example program of 8.6.2, the else branch can be used to specify the failure alternative to the 'either' branch. A / placed in the 'either' branch will cut out the 'else' branch option when it is evaluated. Thus, the / in

(OR ((test X)/(process X Y)) ((default X Y)))

will cut out the 'else' branch if (test X) succeeds. See below for more information on /. A / in any of the logical operators only has an effect on the backtracking within the operator. It has no effect on the backtracking evaluation of the other conditions in the clause or query in which the logical operator appears.

8.9.2 NOT

(NOT <relation-name> t1 t2 .. tk) (A)

{the condition (<relation-name t1 t2 .. tk) fails (is false)}

The NOT operator implements negation-as-failure [Clark 1978]. It denotes the negation of the call

(<relation-name> t1 t2 .. tk) (B)

The negation (A) succeeds if, and only if, the unnegated call (B) fails.

There is an implicit assumption that the program definition of the relation is complete; that all the positive instances can be inferred from the program definition. On this assumption, it is correct to assume that a condition is false (hence that its negation is true) if an attempt to prove the condition fails.

A negated condition can only be used for testing, it **cannot** be used to find any values for variables in the condition such that the condition is false. Indeed, the more correct reading of the call is

show that
there are no x1,..,xn such that (<relation-name> t1 t2 .. tk)

where the x1,..,xn are all the variables in the call at the time that it is evaluated. This means that the reading and effect of a program which uses NOT can be effected by the position of the NOT.

As an example,

?((parent-of john x)(NOT male x))

is read: show that john has a child who is not (proveable) male

Whereas

?((NOT male x)(parent-of john x))

must be read:

show that
there is no x such that x is male and show that there is an x who is a child of john

This reading is forced because the x in (NOT male x) will be unbound when the condition is evaluated. The (NOT male x) condition will fail if there is atleast one way of showing that the is a male.

The fact that NOT, implemented as 'failure to prove', is only an approximation to the logical negation is evident in the use of a double NOT. The queries:

?((parent-of tom X)(PP X))
?((NOT NOT parent-of tom X)(PP X))

are logically equivalent. However, with the first, the name of any found child of tom will be printed, with the second the

unbound variable X will be printed. The double NOT succeeds if (parent-of tom X) succeeds but it will leave the variable X unbound. The first query is read:

```
show that
     there is an X such that (parent-of tom X)
          and display the found X
```

The second is read:

> show that there is an X such that (parent-of tom X) and then show that there is an X that can be displayed.

The second reading derives from the fact that the X in the negated condition is unbound when it is evaluated.

The positive aspect of this imperfection of NOT is that double negations can be used to test if a condition succeeds without binding any variable in the condition.

RULE OF THUMB: Place negated, test conditions on a variable (or variables) **after** positive conditions/calls that can be used to find values for the variable(s).

The supervisor definition of NOT is

```
((NOT | X) X
     / FAIL)        {If X is proveable then (NOT|X) must fail}
((NOT | X))              {else, (NOT|X) is proven}
```

Note the essential use of / to prevent the use of the second clause if X succeeds. It also makes sure that X is only proven once. Only when there is no proof of X will the second clause be used. This confirms (NOT X) without instantiating any variables - hence the restriction of NOT to test use.

8.9.3 IF

(IF <atom> <atom list1> <atom list2>)

{either <atom> and <atom list1> can be solved (are true)
or (NOT | <atom>) and <atom list2> can be solved (are true)}

The IF is a conditional alternative. Its use is equivalent to

(OR ((<atom> / <atom list1>)) ((atom list2))

which uses / to prevent the use of the 'or' branch if the <atom> test is solved. The IF form is more declarative. The declarative equivalent using OR would be

((OR ((<atom> <atom list1>)) ((NOT | <atom>) <atom list2>)

with an explicit (NOT | <atom>) on the 'else' branch. This form is much less efficient than the IF or the OR using / because of the repeated evaluation of <atom> in the second branch.

A definition of a relation Rel of the form

((Rel ...)(IF (T ...) (<bodyA>) (<bodyB>))

is (almost) equivalent to a definition using the pair of clauses:

((Rel ...) (T ...) <bodyA>)
((Rel ...) (NOT T ...) <bodyB>)

The difference is that in the IF definition the test (T ...) is only ever evaluated once.

The use of conditionals in this way is a mixed blessing because less use can be made of unification. For example in the two clauses for Rel above it could be that the heads of the two clauses would naturally be slightly different. When the conditional form is used the head must be the 'most general' of the two, with extra equalities in the conditional branches to bind the variables in the head to the terms that they should be. For example,

```
((sort (x y|Z) (x |Z1))
     (LESS x y)
     (sort (y|Z) Z1))
((sort (x y|Z) (y |Z1))
     (NOT LESS x y)
     (sort (x|Z) Z1))
```

must be absorbed into

```
((sort (x y|Z) Z2)
     (IF (LESS x y)
          ((EQ Z2 (x|Z1)) (sort (y|Z) Z1))
          ((EQ Z2 (y|Z1)) (sort (x|Z) Z1))))
```

which is much less readable. A non-declarative solution is to use / after the test of the first clause and to drop the test in the second.

```
((sort (x y|Z) (x|Z1)) (LESS x y) / (sort (y|Z) Z1))
((sort (x y|Z) (y|Z1)) (sort (x|Z) Z1))
```

The supervisor definition of IF uses / in just this way. It is:

```
((IF X Y Z) X / ¦ Y)
((IF X Y Z) ¦Z)
```

As with OR, a / placed inside the 'then' or the 'else' branch of an IF only effects the backtracking within that branch.

8.9.4 EQ

(EQ t1 t2) {t1 is identical to t2}

The supervisor definition of EQ is

((EQ X X))

so the effect of the evaluation of an EQ condition is the attempted unification of its two argument terms.

(EQ (x1 x2) (A B)) results in x1=A, x2=B.
(EQ (a|z) (x y c)) results in x=a, z=(y c).

8.9.5 ?

(? <atom list>) {true if the sequence of atoms in <atom list> can be solved (are all true)}

The supervisor definition of ? is

```
((? x)|x)
```

? can be used when the syntax for a condition requires a single atom but you want to 'pass' a 'conjunction' of atoms. An example is the IF condition of which the test must be an atom. The form,

```
(IF (? <atom list>) (...) (...))
```

enables you to have several conditions for the test.

As a supervisor command ? is the primitive query form of micro-PROLOG. The more elaborate query forms of MICRO and SIMPLE are all defined using ?. For example, the following is the definition of the which of MICRO:

```
((which (X|Y))      {X is the answer pattern, Y the query}
  (? Y)             {solve Y}
  (PP X)            {display answer pattern X for this solution}
  FAIL)             {backtrack to find next solution}

((which (X|Y))      {when first clause fails}
  (PP No (more) answers))  {there are no more answers to Y}
```

8.9.6 FORALL

(FORALL <atom list1> <atom list2>)

{for all the solutions of <atom list1>, <atom list2> can be solved}

FORALL is a very high level concept, and can often replace explicit recursions in a program.

The following program defines 'prime number' using FORALL. It is a specification that can be used as a prime checking program.

A positive prime number x is a number such that none of the integers y in the range 2 <= y < x divide x. That is, for each y in this range it is not the case that y divides x. This definition is formalised as:

```
((prime x)
     (FORALL ((in-range 2 x y))
               ((NOT divides y x))))
```

where in-range and divides are:

```
((in-range x y x))
((in-range x y z)
     (SUM x 1 x1)
     (LESS x1 y)
     (in-range x1 y z))

((divides x y)
     (TIMES x z y)
     (INT z))
```

This program is not a very effecient program for checking prime numbers, but it is an obviously correct one.

A (FORALL <atom list1> <atom list2>) condition is solved if, and only if, the pair of conditions:

(? <atom list1>) (NOT ? <atom list2>)

does **not** have a solution. In other words, if there is no way of solving <atom list1> so that <atom list2> cannot be solved. Hence, the supervisor definition of FORALL is

```
((FORALL X Y) (NOT ? ((? X)(NOT ? Y))))
```

After the evaluation of a FORALL all variables in the <atom list> arguments of the condition are left unbound.

8.9.7 ISALL

(ISALL t t1 <atom1> <atom2> .. <atomk>) k>0

{t is the list of all the t1's such that the query
?(<atom1> ... <atomk>) is solved}

ISALL can only be used to instantiate varables in t

Each element in the list t is a copy of the value the term t1 given by each different solution to the query. At the end of the evaluation all variables in t1 and the <atom> conditions are left unbound.

The solutions found are neither unique nor sorted: if a different solution to the query results in the same value of t1 then a second copy of this value appears on the list t. The values for t1 appear on t in the reverse of the order in which the solutions to the query condition are found.

The first value of t1 on t corresponds to the last solution of the query, the last value of t1 on t corresponds to the first solution of the query. t is usually given as a variable in the call and the evaluation binds the variable to the list of solutions. However, t can be a list or a list pattern. If it is a list, the elements on t must be in the order that they would be found by an evaluation in which t was given as a variable, which is the reverse of the order in which solutions to the query are found. Since this order is not easy to predict, this checking role for ISALL is not very useful.

Example uses of ISALL are:

(ISALL x y (father-of tom y)(male y))

{makes x the list of all the sons of tom in the reverse of the order they are found}

(ISALL (x|y) (z1 z2) (gives bill z1 z2))

{checks that bill gives at least one thing z1 to someone z2 and makes x the last (z1 z2) pair found, y the other solutions in reverse order}

(ISALL (x1 y1) y (mother-of mary y))

{checks that mary has exactly two children, and finds there names in the list (x1 y1)}

(ISALL (bill) y (father-of tom y))

{checks that bill is the only child of tom}

ISALL is not defined entirely as a micro-PROLOG program. The following definition approximates the built-in definition:

```
((ISALL  X Y|Z)
  (init x ())                          {initialise value assertion
                                        for x to ()}
  (FORALL ((? Z)) ((update x Y)))      {for all the solutions to (?
                                        Z) update the value assertion
                                        for x with the value of Y}
  (DELCL ((value x X))))               {X is the final value of x}

((init x Y)
  (DELCL ((index x)))          {find and delete index
                                    assertion to get}
  (SUM x 1 Z)                   {an index value for x}
  (ADDCL ((index Z)))          {add new index assertion}
  (ADDCL ((value x Y))))       {add initial value of x assertion}

((update x Y)
  (DELCL ((value x Z)))         {find and delete old value
                                    assertion for x}
  (ADDCL ((value x (Y|Z)))))   {add new value assertion for
                                    x with added Y}

((index 1))                    {initial index assertion}
```

The use of the index assertions allows nested ISALLs.

The built-in definition of ISALL does not use the relatively slow additions and deletions to the data base to keep track of the partial list of solutions to the query. It directly updates a list of partial solutions. Its evaluation is very fast. The time taken to find the list of solutions is only a little longer than the time taken to search for all the solutions to the query condition.

You can use ISALL to define a count relation that counts the number of different solutions to a query. The following definition, which uses a tail recursive list-count, will take little longer than the time to search together with the time to count to the number of found solutions:

```
((count X Y|Z)
  (ISALL X1 Y|Z)
  (list-count X1 0 X))

((list-count () y y))
((list-count (X|Y) y z)
  (SUM y 1 y1)
  (list-count Y y1 z))
```

8.9.8 !

(! <relation name> t1 .. tk)

{the first solution to (<relation name> t1..tk)}

The evaluation of the ! call reduces to the evaluation of the atom that follows the ! in the call. However, it restricts the evaluation to just one solution. On backtracking, no further ways of solving the condition are sought. The call

(! likes x tom)

should be read "the first x who likes tom".

! provides useful control information when you know that there will only be one way of solving the condition. It cuts out the redundant search on backtracking. It is particularly useful for test calls that will be evaluated against a large number of assertions. In the MICRO which query

which(x (parent-of tom x)(male x))

each found child of tom is checked for being male. The backtacking search results in alternative and redundant 'proofs' of the (male x) condition being sought before another child of tom is found. In consequence, the entire set of male assertions will be scanned for each found child. By using

which(x (parent-of tom x)(! male x))

the scan of the male assertions is abandoned as soon the found x is confirmed as a male.

The supervisor definition of ! is:

((! | X) X /)

It is the / that prevents the search for a second solution.

8.10 Data base operations

micro-PROLOG has three primitives that enable clauses to be accessed, added and deleted from the user's work-space at run-time. The ability to add and delete clauses is needed in order to implement extensions to the supervisor. It also enables the data base to be used as a scratch pad memory. An example of this latter use is the definition of ISALL given above. Being able to pick up the clauses for a relation allows the definition of alternative query evaluation strategies. An example of an alternative evaluator is given below.

8.10.1 CL

This has two forms of use, a single argument form and a three argument form:

(CL X)	{X is a clause in the progam}
(CL X Y Z)	{X is a clause at position Z in the sequence of clauses for its relation with Z >= Y}

At time of evaluation of either call X must be a clause or a clause pattern in which at least the relation name of the head atom is given as a constant. For the three argument form Y must also be given as an positive integer, Z can be a variable or be given.

This program accesses clauses from the user's work-space (or the currently opened module). It is one of the few built-in programs that is at all non-deterministic as it can be used to backtrack through an entire relation. The important constraint on CL is that the relation name of the head atom of the clause to be found must be given.

For example,

```
(CL ((At|x)|X))
```

succeeds if there are any At clauses in the workspace so this form of use can be used to test if a relation is defined before a call to the relation is made. (A call to an undefined relation signals an error.)

In the example call, if there are clauses for At, variable x is bound to the arguments of the head atom of the first clause, and the variable X is bound to the (possibly empty) list of atoms that make up the body of the clause. Backtracking will result in an alternative (later) clause being sought for the At relation.

For the most general use, the clause argument is a pattern of the form

```
((<relation name>|Y)|Z)
```

The three argument form of CL can be used to find particular clauses in the program, the second argument must be given. It gives the position of the clause from which the search commences. The last argument is the position of the found clause.

```
(CL ((likes John |x)|y) 1 X)
```

binds X to the position of the clause that matches ((likes John|x)|y) with the search starting at the first clause. Backtracking results in an alternative clause being sought that matches the clause pattern. If there is one, its (later) position will be given as the value of X and the rest of its structure will be given in the bindings for x and y.

We can also use the three argument form to pick up a specific clause. To do this, we use the most general pattern for a clause for the relation and give the clause position.

```
(CL ((likes|x)|y) 4 4)
```

will bind x and y to the argument list and the body of the 4'th clause for likes if it exists. If it does not, the call fails.

The single argument CL behaves almost as if a micro-PROLOG program is stored as a sequence of CL clauses with the actual program clauses as argument terms. The evaluation of a CL call is then a search through these CL clauses. This is almost true. The sequence of CL clauses is implicitly repesented by the relation names in the dictionary which 'point' to the sequence of clauses that define them.

However the restriction that the predicate symbol must be known at the time of the call, means that CL can only be used to search through the clauses of a **single** relation, it cannot be used to search through all the clauses in the workspace.

CL can be used to define a query evaluator.

```
((question ())          {a question with no conditions is true}

((question (X|Y))       {a non-empty question is true}
   (CL (X|Z))            {if there is a clause (X|Z) matching X}
   (question Z)           {whose body Z is true}
   (question Y))          {and the remaining conditions Y are true}
```

This makes use of CL to find a clause that solves X in such a way that the rest of the question can be solved. Failure to solve Y will first result in backtracking on the evaluation of the body Z, and finally on the search for an alternative matching clause. For questions and programs that do not use /, it is equivalent to the supervisor ?.

By collecting all the matching clauses as a list, we can try the clauses in an order different from their order in the program. An alternative recursive clause for question is:

```
((question (X|Y))
   (ISALL z (X|Z1) (CL (X|Z1)))  {z are the clauses matching X}
   (select (X|Z) z)              {(X|Z) is a selected clause}
   (question Z)
   (question Y))
```

The definition of select determines the order in which clauses for the condition X are tried. As an example,

```
((select x z)
  (sort z z1)
  (member-of z z1))
```

can be used to select the clauses in order of increasing number of atoms in the body given suitable definitions of sort and member-of.

Elaborations of this approach enable one to program breadth first evaluation of queries (as distinct from depth first with backtracking).

8.10.2 ADDCL

This also has two uses:

```
(ADDCL X)          {add X as a new last clause for its relation}

(ADDCL X <int>)    {add X as a clause after clause
                        <int> for its relation}
```

For both uses, at the time of evaluation X must be a list term that satisfies the syntax of a clause. In particular the relation name of the head atom must be given as a constant. For the second use, <int> must be a non-negative integer.

The clause added is a copy of the list term X in which any unbound variables of the term become variables in the added clause. This convention, that unbound varaiables in the 'name' X denote variables in the clause to be added is logically not very satisfactory. However, all PROLOG implementations use this convention. It enables clauses to be read in using the R primitive and then added to the program using ADDCL.

R converts variable names in the read-in clause term into internal form unbound variables. ADDCL then copies the clause term, mapping the unbound variables into special variable names in the added clause. (This R, ADDCL cycle is how the supervisor accepts new program clauses - see the definition of <SUP> below.)

When a clause is picked up by the micro-PROLOG interpreter during an evaluation, or when it is retrieved using CL, the special variable names of the clause are converted back into entirely new intrernal form variables, just as though the clause had been read-in. So each use of the clause gets a fresh copy, with a new set of variables different from any other variables currently in the evaluation. This allocation of new internal form variables (which are actually locations where pointers to values for the variables will be stored when the variables are bound) for the variable names of an accessed clause is exactly the same as the allocation of new locations for the variables of a procedure that takes place in a conventional recursive programming language.

If ADDCL is used with a single argument then the clause is added to the end of the appropriate program. Otherwise it is inserted after the clause whose position is given as the second argument. If 0 is used as the clause number, the clause is inserted at the front of the program.

```
(ADDCL ((append () x x)) 0)
```

adds the clause

```
((append () x x))
```

to the front of the append program. If a position is given that is beyond the last clause for the relation the clause is added as a new last clause.

RESTRICTION: clauses cannot be added for primitive relations nor for relations exported by some loaded module. An attempt to do so signals an error.

8.10.3 DELCL

(DELCL X) {delete the first clause matching X}

(DELCL <relation name> <int>) {delete the <int>'th clause for <relation name>}

X must satisfy the syntax of a clause, in particular, the relation name of the head atom must be given.

The primitive DELCL is used to delete clauses from the workspace (or currently opened module). In the first form the program is searched for a clause matching X. The first one found is deleted. If none is found, the call fails. In the second form the clause to be deleted is specified by a relation name and a clause position. Again, if the specified clause does not exist, the call fails.

(DELCL ((append | x1) | x2))

will cause the first clause for append (if there is one) to be deleted. However, it will also bind the variables x1 and x2 to the the head arguments and body of the clause respectively. So this form of DELCL can retieve information from the deleted clause. An example of this use is in the definition of ISALL given above. In particular, the definition of the auxiliary relation update uses ADDCL and DELCL to manipulate the data base as a scratch pad memory.

RESTRICTION: clauses for primitive relations or relations exported from loaded modules cannot be deleted. An attempt to do so signals an error.

8.10.4 Undoing the effect of ADDCL or DELCL

The effect of an ADDCL or a DELCL is not undone on backtracking over the call. The adding or deleting of a clause is a side effect on the state of the program in the same way that R and PP are a side-effect on the state of the terminal. We can never undo the effect of a R or PP, but we can undo the effect of ADDCL or DELCL - by doing the opposite.

The following clauses define 'soft' addcl and delcl relations whose effect is undone on backtracking. This is subject to the proviso that a / has not been evaluated after the call that cuts out their 'else' branches.

```
((addcl X)
  (OR ((ADDCL X)) ((DELCL X))))

((delcl X)
  (OR ((DELCL X)) ((ADDCL X))))
```

Both relations need the clause to be unambiguously specified - to be uniquely determined by the argument X. If it is not, the DELCL of the addcl definition may delete a different clause that happens to match X, and the ADDCL of the delcl definition may add a more general clause than the one deleted.

Notice that delcl may not add the clause back in the same position so it is only useful when the position of the clause is not important. This is usually the case when you are manipulating a data base of single atom clauses.

8.10.5 KILL

```
(KILL R)                  {delete all clauses for relation R}
(KILL (R1 .. Rk))         {delete all clauses for each of R1..Rk}
(KILL ALL)                {delete all clauses from workspace or
                           all those owned by the currently opened
                           module}
(KILL <module name>)      {delete the named module}
```

R and R1 .. Rk must be relation names.

The KILL primitive deletes all clauses for a single relation, all those for a list of relations, or all the clauses that can be deleted. When working in the workspace (the supervisor prompt is &.) only user relations in the workspace can be KILLed. A KILL ALL will delete all the clauses from the workspace but will not delete any loaded module. This must be deleted with the last form of use KILL <module name>.

When working in an opened module (see below) KILL can be used to delete all clauses for relations that are owned by the module. The main use of KILL is as a supervisor command.

8.11 Library procedures

These allow saving of programs, loading programs and listing programs at the console.

8.11.1 LIST

```
(LIST R)              {list program for relation R}
(LIST (R1 .. Rk))     {list program for each of R1 .. Rk}
(LIST ALL)            {list programs for all workspace
                       relations or all relations owned by
                       currently opened module}
(LIST <module name>)  {list the named module}
```

R R1 .. Rk must be relation names

The LIST primitive lists the specified programs, in a standard format, at the console.

```
(LIST ALL)
```

lists the whole program, (apart from any loaded modules), and

```
(LIST (Likes Fred Angie))
```

lists the programs for Likes, Fred & Angie.

Modules are listed in the form in which they are SAVEd - see below.

8.11.2 SAVE

```
(SAVE <file name>)
        {save entire program in named file}
(SAVE  <file  name> (R1 .. Rk))
        {save only programs for given relations}
(SAVE <file name> <module name>)
        {save named module in named file}
```

For the first form of use the entire program saved will be the workspace program if working in the workspace. If working in an opened module it will be all the clauses owned by the module. The supervisor command

```
SAVE "A:TEST.LOG"
```

saves the entire program on the disk file TEST.LOG on drive A. If there is already a file with that name, it is renamed with extension .BAK. This ensures automatic backing up of programs.

Programs are saved as a sequence of clauses in the same format in which they are dispayed by LIST. Modules are saved in a special format - see the next section on modules. It is also the format in which modules are displayed by LIST.

The second two forms of use cannot be used directly as supervisor commands as they have two arguments. For a command to save a module, you must use a query of the form:

```
?((SAVE <file name> <module name>))
```

SAVE does not delete the saved program(s). It also automatically opens the file for writing and then closes it on successful completion.

WARNING: File names, relation names and module names must be distinct. If you inadvertantly use a name for more than one of these roles you will get an error. If you attempt to save a program on a file, the file name you use must not be the same as any current relation name or any loaded module. You must be wary, especially when you use an allowed abbreviated name that does not give the drive or the .LOG extension (see Chapter 3).

The error can occur when you are loading a file with the LOAD command described below and the LOAD reaches a clause for a relation that has the name of a loaded module or a currently opened file. On the error the LOAD will be abandoned with the file left open. So you should CLOSE the file from which you were LOADing if this occurs. If you are using an error handler (see Appendix A) the offending relation name will appear in the ADDCL call that caused the error.

To avoid this type of error use different forms of name for relations, modules and files. Most of the micro-PROLOG modules on the distribution disk have a of the form <name>-mod, where <NAME>.LOG is the file in which they are supplied. If you always use the .LOG form for the file name, and have module names ending with -mod, you should avoid the error.

8.11.3 LOAD

(LOAD <file name>) {load the program from named file}

This program reads the disk file, and adds all the clauses in the file to the workspace or the currently opened module. If the file contains a saved module, the clauses are loaded as a module and do not enter the worlspace. Note: a module can only be loaded when working in the workspace (the supervisor prompt is &.). You cannot load a module when working in an opened module. The attempt to do so signals an error. You can only load into an opened module files consisting entirely of program clauses. The supervisor command

LOAD TRACE

loads the program in the disk file TRACE.LOG on the currently logged in disk. TRACE is an example of an abbrevated file name. micro-PROLOG converts all file names given without an extension into names with the .LOG extension.

As each clause on the file is read in, it is added to the end of the current program for its relation. If there are clauses for the relation before the load, all the loaded clauses will be added after the existing clauses.

Queries may be embedded in a source file for automatic execution by LOAD. The format of these queries is exactly the same as ? queries enterred at the keyboard, and they are executed as soon as they are encountered in the file. The following example shows a small file with embedded queries:

```
?((PP Loading the append program))
((append () X X))
((append (X|Y) Z (X|x))
  (append Y Z x))
?((PP Append program loaded))
```

The message Loading the append program will be displayed as soon as the file begins loading. The two clauses will then be added to the micro-PROLOG workspace, and finally the message Append program loaded will be displayed. Any micro-PROLOG query can be embedded in a file by using ?<goal list>, including requests to load other files. Remember, however, that micro-PROLOG can only support four open files at any one time, and that any "nesting" of load files must be limited to this number.

LOAD automatically opens the file and then closes it on successful completion of the LOAD. See the warning given 8.11.2.

8.11.4 LISTP

```
(LISTP <file name>)
          {list entire program to named file}
(LISTP <file name> (R1 .. Rk))
          {list only programs for given relations to file}
(LISTP <file name> <module name>)
          {list named module to named file}
```

LISTP is the built-in program used to implement both LIST and SAVE, and can be used to list the entire program, selected programs or individual modules to any file. Its arguments are exactly the same as in SAVE, as can be seen from the way SAVE is defined in micro-PROLOG:

```
((SAVE X|Y)
  (CREATE X)
  (LISTP X|Y)
  (CLOSE X))
```

For completeness, it is interesting to note that LIST is defined as:

```
((LIST ALL)
  /
  (LISTP "CON:"))
((LIST X)
  (LISTP "CON:" X))
```

LISTP is used whenever program clauses are to be written in a reasonably readable format, and is available so that user-defined versions of SAVE and LIST programs can be written.

8.12 Module Construction Facilities

micro-PROLOG has facilities for constructing modules. These are named micro-PROLOG programs (sequences of clauses) which communicate with workspace programs and other modules via import/export name lists. Names used in the module that are not in the import/export lists are local to the module and are invisible from outside the module. Different modules can therefore use the same local names with no name clash. On the other hand, constants that do need to be communicated across the module must be in the import or export list.

A module has five components:

a name (which is a micro-PROLOG constant)

an export list : a list of constants which are being 'made available' outside the module. These are usually the names of relations of the module. An exported relation can be used in a workspace program or command as though it were a primitive relation when the module is loaded. An exported relation name can also be imported by another module and used by the other module as though it were a primitive.

an import list : a list of constants that the module imports from the outside. This must include the names of relations defined in the workspace or exported from some other module that need to be accessed from inside the module. It must also include all the 'data' constants used in the module that need to be communicated across the module e.g. constants which may be used in calls to exported relations of the module and must be recognised by the module or constants used in the module to calls to imported relations which will need to be recognised outside the module. Such communicated 'data' constants can be given in either the import or export list, but it is good practice to restrict the export list to exported relation names.

a local dictionary : constants appearing in the module which are private to that module

the module program : all the clauses owned by the module. These are the programs for all the relation names of the export list and the local dictionary.

The export list, the import list, and the local dictionary have no names in common. The relations **accessible** by a module are the relations defined by the clauses it owns and the relations with names in the import list.

Modules are LOADed and SAVEd automatically by the LOAD and SAVE programs. For the LOAD the same form of of call is used, (LOAD <file name>), even if the file contains a module. This is possible because files containing modules have a different structure to ordinary program files and this is recognised by the LOAD which then handles the file in a special way. For the SAVE there is a special three agument form for modules:

(SAVE <file name> <module name>)

This saves the named module on the specified file in the form:

<module name>

```
<export list>
<import list>
.
.    {clauses owned by the module}
.
CLMOD
```

The local dictionary is not saved because this is automatically reconstucted by the LOAD.

Warning: if you use a text editor to develop a module program file the terminating CLMOD must be followed by a <return>.

The LIST program can also be used to list the contents of a module:

```
(LIST <module name>)
```

will display the module at the console in the form that it is saved on a file.

You can enter and exit loaded modules with the OPMOD and CLMOD commands described below. Entering a module makes it the **current** module.

The supervisor uses the current module's name as its prompt, so if the current module is called my-mod then instead of the &. prompt we get the prompt:

```
my-mod.
```

The top-level prompt &. is in fact the name of the root module & which is also the workspace. The root module has a special role. On loading micro-PROLOG the root module becomes the current module. It exports no names but it imports all the names exported by the loaded modules. As a module is loaded, the import list of & grows. Finally, other modules can only be loaded when & is the current module.

A supervisor LIST ALL will list all the clauses owned by the current module, and all clauses entered at the keyboard or added using ADDCL are added to the current module. An attempt to add or delete a clause for an imported name of the current module signals an error.

It **is** possible to have a program in a module which when called adds clauses to an imported relation of the module but the program **cannot** be called while the module is the **current** module. For example, the SIMPLE front end program imports the relation name dict. It maintains this relation for the user by adding and deleting clauses from it. It can do this because when the dict clauses are added and deleted the root module & is the current module and dict is not an imported relation of the workspace - it is a relation owned by the workspace.

The local dictionary of the current module is the dictionary used by all the I/O primitives of micro-PROLOG. When a constant is read-in, it is looked up in the local dictionary of the current module. If it is not present, it is added to the local dictionary. This means that any module program that is to be called from a workspace query, which reads in and tests for certain constants in the input, must import all the constant

names it needs to recognise. For, when they are read-in, & will be the current module and the constants will enter the local dictionary of the workspace. The program in the module will not be able to recognise them unless it imports their names.

There are four primitives connected with modules: CMOD, CRMOD, OPMOD and CLMOD.

8.12.1 CMOD

(CMOD x) {x is the name of current module}

x must be a variable at call

The CMOD program simply returns the name of the current module. It is used, for example, by the supervisor to print out the name of the module as part of its top-level prompt.

8.12.2 CRMOD

(CRMOD <module name> <export list> <import list>)

{create an empty module and make it the current module}

CRMOD creates a new module with name <module name> and with the given export and import constant lists. It then enters it, i.e. makes it the current module. The <export list> and the <import list> are as defined above.

CRMOD can only be used when & is the current module. The <module name> cannot be the same as the name of any relation accessible by &. It must also be different from the name of any other current module and any opened file. Finally, none of the exported names can be the names of workspace relations or relations exported by other current modules. If any of these constraints are flaunted the "Illegal use of modules" error is raised.

Having created a module you can enter clauses into the module using all the facilities of the resident supervisor described in Chapter 3. But note that you will not be able to LOAD and use the structure editor (of Chapter 4) or any of the other program development utilities whilst in the new module. The only way you can use the editor to help develop or modify a program inside a created module is to import the name EDIT and all the names of the edit commands into the module. The editor must be loaded whilst at the root module (&) level, but it can be called from inside the new module.

A more convenient method of developing a program that is to be wrapped up in a module is to develop it first as a workspace program which is saved in the normal way. You then use CRMOD to create the shell for the new module. On entry, LOAD the saved workspace program, then exit the module with the CLMOD described below. You can now SAVE the new module using the special form for modules. Alternatively, use the MODULES utility described in Chapter 4 which supports the construction and modification of modules.

CRMOD is used by the LOAD primitive when it encounters a module name in the file. It creates a module using the name and the export and import lists that immediately follow the name. It then reads in all the clauses that follow up to the end of module mark CLMOD in the file. Each clause is added to the newly created module, which temporarily becomes the current module. On reaching the CLMOD the module is exited and the current module is again the & workspace module. If there is an error on loading, or you interupt the load with a ^C, you will find that you are in the temporarily entered module.

RESTRICTION: CRMOD has one feature that makes it very different from all other micro-PROLOG programs, and that is that its arguments must be ground terms. What this means in practice is that CRMOD cannot generally be used in micro-PROLOG programs such as:

```
((create-mod X)
  (R Y)
  (R Z)
  (CRMOD X Y Z))     {X Y and Z are variables - not ground}
```

When CRMOD is included in a program, its arguments must be written in as fully bound terms, and not as variables. This restriction is to prevent spurious entries being admitted into the micro-PROLOG dictionary.

8.12.3 OPMOD

(OPMOD <module name>) {make named module the current module}

OPMOD enters the already existing named module and makes it the new current module.

8.12.4 CLMOD

```
CLMOD   {close current non-root module and return to &}
```

CLMOD drops out of the current module back into the root & module. It is not possible to drop out of the root module. As a supervisor command OPMOD must be given an (ignored) argument. E.g.

```
CLMOD.
```

with the . the ignored argument.

8.13 Miscellaneous Predicates

In this section we draw together a rag-bag of primitives not covered above. These include the dictionary relation and some control primitives.

8.13.1 DICT

```
(DICT x y z | X)  {y z and X are respectively, the export
                    list, the import list, and the local
                    dictionary of the current module x}
```

The DICT relation defines the dictionary of the current module. If you do a LIST DICT you will get a clause of the above form listed. You can also call DICT to pick up any of its arguments. Note that DICT is a multi-argument relation. After the import list z is a sequence X of all the local constants of the current module. Garbage collection will remove from X all constants no longer in use.

8.13.2 SDICT

```
(SDICT !X)      {X is a list of all system constants}
```

The SDICT relation defines the system dictionary, and its 80 or so arguments consist of all constants used by micro-PROLOG.

8.13.3 QT

QT {quit micro-PROLOG and return to CP/M}

Execution of this program will cause an exit from the micro-PROLOG system into CP/M. This is the only recommended method of exiting the micro-PROLOG system. As a command it must be given an (ignored) argument.

8.13.4 /

/ {always true but with a side effect on evaluation}

The / primitive is used to control backtracking. When executed as a call in the body of an invoked clause its effect is to cut out all the as yet untried clauses for the call which invokes the clause, and all the alternative untried evaluation paths for the calls that precede the / in the clause.

Suppose that a clause of the form

((Rel ...)(Rel1 ...)(Rel2 ...)/(Rel3 ...))

is invoked by some Rel-atom call. The calls (Rel1 ...) and (Rel2 ...) are evaluated in the normal way with any necessary backtracking in order to find a solution to both calls. If they can both be solved, the / is executed. Slash always 'succeeds'; it is used for its side effect.

It suppresses all further backtracking on the evaluation of the (Rel1 ...) and (Rel2 ...) calls that would normally occur on a subsequent failure or when trying to find all the solutions to a condition. It also prevents any later as yet untried clauses for Rel from being used to solve the particular Rel-atom call that invoked the clause.

In other words, if the (Rel3 ...) call should now fail, then the call that invoked the clause also immediately fails. If the slash was not there, a failure of (Rel3 ..) would result in alternative ways of solving the (Rel1 ...) and (Rel2 ...) calls being explored, and then to in alternative clauses for Rel being tried. The / cuts out all these alternatives.

The slash is useful for 'telling' micro-PROLOG that there are no alternative solutions to be found once the evaluation has reached the / point in the clause. This saves wasted time searching for non-existant alternative solutions, and also enables micro-PROLOG to save space.

The / actually side effects the evaluation stack. It discards all the activation records back to the activation record for the invoked clause containing the /. This removes all the backtracking information for the evaluation of the calls that precede the / in the clause. Finally, it side-effects the backtracking information associated with the invoked clause so that it appears to be the last clause for the call. The / is also used in an essential way to implement some of the logical primitives of micro-PROLOG.

Used in a ? query a / prevents backtracking on the calls that precede it in the query once a solution to each of them has been found. This is because the ? is defined by

((? X)|X)

and so a query

?(A1 .. Ak / ...)

becomes the evaluation of the body

A1 .. Ak / ...

for the single clause for ?. The / cuts out the backtracking options for A1 .. Ak. There are no other clauses for ? to be suppressed.

You can use a ? call when you want to cut out backtracking on preceding calls but not prevent the use of later clauses. Thus, the evaluation of the / in

```
((Rel ...) (? ((Rel1 ...)(Rel2 ...)/)) (Rel3 ...))
```

will cut out alternative solutions to (Rel1 ..)(Rel2 ..) but will allow the use of untried clauses for the invoking Relcall. A / placed inside an atom list argument to a logical primitive has a similar 'local' effect.

8.13.5 FAIL

FAIL {false}

The FAIL predicate always evaluates to false. This is used to fail a branch of the proof, FAIL has no clauses, but the interpreter knows about it and does not signal a "No clauses for" error.

8.13.6 ABORT

```
ABORT          {abort the current supervisor command}
```

The ABORT primitive cancels the supervisor command that is being currently executed, and clears (resets) the keyboard buffers. Execution is returned to the supervisor, and both the keyboard input buffers are cleared. The main use of ABORT is when terminating a program after an error has occurred (see Appendix C).

8.13.7 /*

```
(/* t1 t2 .. tk)          {t1 ... tk is true}
```

The /* is the comment predicate. It ignores its sequence of any number of argument terms (including none) and always succeeds with no side-effect. /* can be used within clauses to provide comments or as a 'no-op' relation.

Its definition is equivalent to the program

```
((/* !X))
```

8.13.8 SPACE

(SPACE x) {x is the no. of K bytes left in workspace}

The SPACE primitive returns in its single argument the number of kilobytes(1024 bytes) of space that are currently left in the work space.

Before actually returning this number it calls the internal garbage collector, which has the effect of making sure that all the known garbage is removed.

8.13.9 <SUP>

<SUP> {the ever running supervisor program}

The supervisor program is run automatically by micro-PROLOG as soon as the system is initialised, and continues to run until QT is executed to return to the host operating system. It contains two clauses, as follows:

```
(("<SUP>")
  (DEF "<USER>")
  ("<USER>")
  FAIL)

(("<SUP>")
  (CMOD Y)
  (P Y)
  ("<R>" X)
  ("<>" X)
 /("<SUP>"))
```

The first clause tests to see whether a user supervisor is defined (see Chapter 3), and if so, runs this in place of the default supervisor. Since <SUP> itself must never terminate, a FAIL is placed after the call to <USER> so that if the user supervisor is not a loop and succeeds, micro-PROLOG will back-track into the second clause for <SUP>.

The second clause prints out the name of the current module (initially '&'), and then reads a term from the console. The <R> program is a special case of read designed to prevent the <SUP> program failing. This could happen if Control-C was typed at the call to R, and a user-defined error handler (see Chapter 3) then failed. Since the <SUP> program is the first program on the stack, there is nothing to back-track to if it fails, and micro-PROLOG hangs up. <R> is defined as follows:

```
(("<R>" X)
  (READ "CON:" X)/)

(("<R>" X))
```

The first clause is defined in the same way as R, with the slash / to ensure that it is deterministic. If an error handler, invoked by a Control-C at the READ, fails, then the second clause succeeds, returning a variable to <SUP>.

The <> program checks to see if it is a valid command or a clause in standard form. If it is a command then it executes the command (after reading in a single argument) and prints ? if the command fails.

```
(("<>" X)
    (CON X)        {read-in term is a constant i.e. a
                       unary relation/command name}
    (R Y)          {read in its single argument}
    (X Y))         {execute command by calling the relation}

(("<>" (X|Y))      {read-in term is a micro-PROLOG clause}
    (ADDCL (X|Y))) {add it to the program}

(("<>" X)          {command fails, or illegal input}
    (PP ?))        {display ?}
```

The <SUP> primitive is invoked as soon as the micro-PROLOG interpreter and the supervisor have been loaded. Its evaluation only terminates after a System Abort or on the evaluation of QT.

8.13.10 TIME

```
(TIME X Y)      {X and Y are the current hour and minute}
(TIME X Y Z)    {X and Y as above; Z is second}
(TIME X Y Z x) {X, Y and Z as above; x is 100ths of second}
```

All arguments must be unbound variables at the time of the call, and the last two are optional.

TIME may be called with two, three or four arguments. It binds its first argument to the current hour of the day, using the 24 hour clock. The second argument is bound to the minute of the hour. The third argument, if supplied, is bound to the second of the minute, and the fourth, if supplied, to the 100th of the second.

Various implementations of MS-DOS give the time to different degrees of resolution, so the usefulness of the 100ths argument will vary. On some systems, the 100ths argument will always be 0, on others either 0 or 50, while at the other extreme some systems will provide time to the nearest 2/100ths or even 1/100th of a second.

Under CP/M86 the TIME primitive returns zero for each of its arguments: this is because CP/M does not maintain a real time clock.

8.13.11 DATE

```
(DATE X Y)      {X is day of month and Y is month number}
(DATE X Y Z)    {X and Y as above, Z is year number}
```

All arguments must be unbound variables at the time of the call. The last one is optional.

DATE can be called either with two or with three arguments, and binds them to the day number, month number and, if the third argument is supplied, year number. The date is therefore supplied in British format.

Under CP/M86 the DATE primitive returns zero for each of its arguments: this is because CP/M does not maintain a real time clock.

Appendix A

Entering micro-PROLOG

The files contained on your micro-PROLOG 3.1 distribution disk vary according to which system you have. These are described below:

The micro-PROLOG interpreter is one of the following files:

PROLOG.COM	(CP/M80 systems)
PROLOG.CMD	(CP/M86 systems)
PROLOG.EXE	(MS-DOS systems)

The utility modules and supervisor extensions are in the following files: (all systems)

TRACE.LOG	SPYTRACE.LOG
EDITOR.LOG	MODULES.LOG
EXREL.LOG	
SIMPLE.LOG	DEFTRAP.LOG
EXPTRAN.LOG	TOLD.LOG
SIMTRACE.LOG	PROGRAM.LOG
MICRO.LOG	ERRTRAP.LOG

The DEC-10 front end is only supplied on 8086 systems:

DEC.LOG

The user interface for micro-PROLOG is supplied only for CP/M80 and MSDOS - CP/M80 has one support file:

PROLOG.SYM	(symbol map information)

MS-DOS micro-PROLOG is supplied with the following user assembler code support files:

USERCODE.ASM	(assembler file for user extensions)
USERMAKE.BAT	(batch file for USERPROL.EXE creation)
USERMESG	(user interface prompting message)
USERLINK	(object linker instructions)
.OBJ files:	STACK,MAIN,BUILTIN,USERCODE,FLOAT, IO,FORMIO,CONIO,DISKIO,SUPVISOR (MS-DOS relocatable object files

PROLOG.COM/CMD/EXE is the PROLOG interpreter with the built-in micro-PROLOG supervisor program. All the .LOG files contain micro-PROLOG programs wrapped up as modules. They provide optional loaded extensions to the built-in supervisor. Their facilities are described in various sections of the Manual. The remaining files, variously .OBJ, .SYM and USER*.*, where supplied (see above), form the support for the assembler interface, and need not concern most users.

The facilities of the first five .LOG files are described in Chapter 4, the next six are described in Chapter 5, the last two (MICRO.LOG and ERRTRAP.LOG) are the subject of Chapter 6.

To enter the micro-PROLOG system:

1. Insert the micro-PROLOG distribution disk (or the back-up copy disk) into a suitable disk drive (the B drive say).

2. Log in to that drive (not strictly necessary but it simplifies the loading and saving of programs from micro-PROLOG).

3. Type the command PROLOG.

For example, if your computer has two drives: the A drive and the B drive, to enter micro-PROLOG from the B drive, with the system disk in A, type:

```
A>B:
B>PROLOG
```

When micro-PROLOG has been loaded the following banner should appear at the console:

<screen is cleared>

```
micro-PROLOG r.vv - created dd mmm yy
(c) 1984 Logic Programming Associates Ltd.
hhhhh + ttttt Bytes Free
&.
```

The first two lines form the micro-PROLOG banner, and give details of the release (r) and version (vv) number, and the day (dd), month (mmm) and year (yy)of creation. The message "hhhhh + ttttt Bytes Free" indicates how much heap/stack (hhhhh) and text (ttttt) memory is available for the storing and execution of micro-PROLOG programs.

For Z80 versions of micro-PROLOG a single free space number is displayed: this space is divided into the two fixed areas: approximately 19% of the available memory is allocated to the text area, and the rest is the heap and stack area.

The heap is where the user programs are stored, and the stack is where the evaluation of programs takes place. All constants used in the programs are stored in the text or dictionary area and all occurences of the constants in the program are replaced by references to the dictionary.

Notice that this means that there is no great penalty in using long relation names. No matter how many times the name appears in the program only one copy of the text of the name is kept.

There is no fixed division between the stack and the heap. They grow towards each other and garbage collection of the heap occurs when they are about to collide. When garbage collection does not create enough space to continue, you get a "No space left" error message and the current evaluation is aborted with a return to the supervisor.

Because of the trade-off between the heap and stack you can create space for an evaluation by deleting all unnecessary relation definitions and modules before the evaluation. Thus, utility modules that have been used to help develop and/or edit the program can be deleted to make room for the evaluation. This ability to load, then kill, then re-load support software as required is a significant feature of the program development

environment of the micro-PROLOG system.

The last line of the banner starts with a &.. This is the system level prompt which is output by the supervisor. It indicates that the supervisor is waiting for input from the console keyboard.

micro-PROLOG commands can also be given in the operating system command line. Any characters that are typed on the command line after the word PROLOG are taken to be the initial input to the micro-PROLOG system. For example,

```
B>PROLOG LOAD SIMPLE
```

is equivalent to:

```
B>PROLOG
micro-PROLOG r.vv - created dd mmm yy
(c) 1984 Logic Programming Associates Ltd.
hhhhh + ttttt Bytes Free
&.LOAD SIMPLE
```

Appendix B

Keyboard control and line editor

When reading from the keyboard micro-PROLOG prompts the user for input with a . prompt and then backspaces the cursor over the . (the top-level &. prompt that micro-PROLOG gives you on entry is made up of the workspace dictionary name & printed out by the supervisor followed by the . read prompt issued when the supervisor attempts to read in the first command). The positioning of the cursor over the . means that on certain terminals the . will be not be seen. Of course, the first character typed always erases the . prompt.

As characters are typed in response to the read prompt they are stored in a special keyboard buffer and are only 'read' by micro-PROLOG after the RETURN or ENTER is pressed. Until you hit RETURN, you can edit the sequence of characters using the line editor described below. You are actually in the input mode of this editor as you are typing in the characters up to the point that you hit RETURN.

The keyboard buffer holds up to 1840 characters (256 on Z80 systems), so up to 23 lines (3.2 on Z80 systems) of a standard 80 column screen can be edited by the line editor. Of course, all these characters will not appear on the same console display line. When the display reaches the end of a line, the display should automatically move to a new display line without your having to hit RETURN.

The cursor backspace of the edit mode of the line editor will move back over different display lines. So, only hit the RETURN when you are confident that you do not want to edit the sequence of characters you have typed in response to the read prompt. Hitting RETURN makes that sequence an entered line which cannot be edited.

Note: the automatic transition from one display line to another is a function of the terminal/computer. micro-PROLOG has no knowledge of the transition - it is not a token boundary (see section 2.10 of the Manual). If the token that finishes at the right end of one dispay line needs to be separated from the one that starts the next line you need to type a space in front of the token on the second line.

The following control keys have special significance in the input mode of the line editer:

<Backspace> or <Rubout>	will delete the last character typed in
<Return>	exits the editor and passes the current line to micro-PROLOG
<Escape>	echoes a **$** and enters **edit mode** (see below)
<Control-P>	toggles the printer (the first time this is is used all subsequent screen display is echoed on the printer until the next Control-P)

Certain other control key instructions that may be supported by the host operating system are **not** supported by the line editor.

Edit mode

You enter the edit mode from the input entry mode by hitting <escape>. In the edit mode all commands are single letters. These letters can be in either upper or lower case and are never echoed to the screen. The edit commands provide fairly simple character level editing functions such as cursor movement, character substitution, character search etc.

In the descriptions of the commands below we shall talk about a 'cursor'. This is similar in principle to the cursor on a screen, except that since the line editor is one dimensional the cursor can only move to the left or to the right. The cursor can only be 'over' an existing character in the keyboard buffer. Any attempt to move it outside existing text will cause the computer's bleeper to be sounded.

Similarly, if a character is typed as an edit command which is not recognised, or is illegal for some reason the bell is sounded on the console, and the command ignored. The edit commands are summarised as follows:

i	Insert mode (start accepting characters)
<Return>	Exits the line editor after displaying rest of line. Edited line passed to micro-PROLOG.
<space>	Move 'cursor' one character to the right. The character is echoed to the screen. If already at the end of the line then the bell is sounded instead.
<backspace> or <Rubout>	Move the 'cursor' left one character. A backspace is echoed to the screen. If already at the start of the line then the bell is sounded. Note that unlike in input mode the backspace does **not** delete the char under the cursor.
s <char>	Searches the keyboard buffer rightwards from the current position for <char>. Text between the cursor and the target is displayed on the screen. If the <char> is not found then the bell is sounded and the cursor is left at the right end of the line.
c <char>	Replaces the character under the cursor with <char>.
d	Deletes the character under the cursor. Positions occupied by deleted characters are indicated by a # which is now skipped over by the <space> and <Rubout> commands.
k <char>	Similar to search, except that the characters between the cursor and

	the target are **deleted.** As with delete, the positions of deleted characters are indicated by #'s.
l	Lists the entire line and positions the cursor at the beginning of the line. #'s marking deleted characters are removed by this command.
<Control-P>	Toggles print mode.
x	This is used to extend the line. The rest of the line is displayed and insert mode is entered at the end of the current text.
z	This cancels the rest of the line from the cursor position and enters input mode. Useful when retyping a whole line.
r	Review line: all of the line from the current cursor position onwards is listed, but the cursor is left in the same position.
b <char>	Searches the keyboard buffer backwards from the current position for <char>. There is no effect on displayed text. If the <char> is not found then the bell is sounded and the cursor is left at the beginning (left end) of the line.
n	Advances 80 characters, and on a standard 80 column screen positions the cursor at the same position on the next screen line. If the end of the line is found before 80 characters have been skipped then the bell is sounded and the cursor is left at the end of the line.
p	Retreats 80 characters, and on a standard 80 column screen positions the cursor at the same position on the previous screen line. If the beginning of the line is found before 80 characters have been skipped then the bell is sounded and the cursor is left at the beginning of the line.

Note: where the micro-PROLOG line exceeds one screen line, the visual behaviour of various edit commands may differ between machines. In particular, any command involving a backwards cursor movement (<backspace> or <rubout>, b, p and r) will cause different behaviour when the beginning of a screen line is passed.

Many screens perform an inverse line feed when the cursor back-spaces past column 1; on these screens r will work on any

line, and p will behave as a cursor-up command.

Not all screens behave this way, and backward movements may leave the cursor stranded at the beginning of the current screen line. This does not affect the internal keyboard buffer, only the screen appearance

Any number of terms can be typed on a line, and a term can be spread over many lines. Any excess terms (terms are read one at a time) are saved in the buffer until the next console read is executed, in which case the next term in the buffer is read and no prompt is displayed. However, excess terms in the input buffer are discarded if any of the primitives ABORT, RCLEAR or RFILL are called, or if an error (other than "Syntax Error") occurs before they are read, and where there is no user definition of ?ERROR?. Any of these events causes the keyboard and type-ahead buffers to be flushed.

Type ahead

Even before an input prompt is displayed, i.e. before an input request is given, you can enter up to 208 characters (16 on Z80 versions) by typing ahead. The characters will not be echoed until the input request is given. If more than 208 (16) characters are typed ahead then the computer's bleeper will be sounded, if it has one. All characters after the first 208 (16) are lost.

Multi line terms and right bracket prompts

Constants, variable names and numbers cannot be split across entered lines because <return> is a separator. List terms can be split over more than one entered line.

If you hit ENTER before the list term is complete you will get a prompt of the form n., where n is the number of right brackets needed to complete the list. For example, we might have entered the App clause

```
((App () x x))
```

over four entered lines:

```
&.(( <return>
2.App( <return>
3.)x x <return>
2.)) <return>
&.
 ^(cursor position)
```

The 2, 3 and 2 on the second, third and fourth lines are the bracket count components of the read prompts.

The . of these three lines will actually not be seen when the text is entered. It will have been erased by the first character typed. However, we shall always show the . in our example interactions.

The bracket count prompt is very useful when entering lists, in particular, clauses. If you are unsure about the number of closing right brackets you need, and you are sure that you do not want to do any editing of the current line, enter a <return>. The prompt will tell you how many right brackets you

need to finish of the list.

Appendix C

Error messages

There are two types of errors in micro-PROLOG, numbered errors, and unnumbered ones. Numbered errors can be recovered from by micro-PROLOG programs using the user defined error handler "?ERROR?". Unnumbered errors can not be recovered from and cause a return to the top-level supervisor.

The numbered errors

In the 8086 versions of micro-PROLOG, numbered errors are accompanied by short explanatory messages when there is no "?ERROR?" relation. The error numbers, their messages (for 8086 systems) and brief explanations are printed below:

0 **Arithmetic Overflow.** If a call to an arithmetic primitive results in a number which cannot be represented then an arithmetic overflow is signalled. This includes the case of division by zero.

1 **Arithmetic Underflow.** This error arises when a number becomes too small to represent (the exponent becomes too negative).

2 **Predicate Not Defined.** There are no clauses defined for the call being executed. Some PROLOG systems merely fail the call if there are no clauses for its relation. In micro-PROLOG you can simulate that behaviour by having a special clause in the "?ERROR?" program to FAIL the "?ERROR?" call for error number 2.

3 **Control Error.** The built-in primitives in micro-PROLOG often require a minimum number of arguments to be bound at the time of the call. If the arguments to a call to such a primitive are underspecified, this error occurs. The error is also signalled if the evaluation encounters any goal which is not of the correct form, such as a number, or list without a constant as its first element. This is most likely to happen when the program uses meta-variables (see Chapter 2) and the meta-variable is unbound or has a value of the wrong form. In this case there is a strong possibility that the calls in some clause or query are incorrectly ordered, and that the call that would bind the unbound variable has not yet been evaluated.

4 **Predicate Protected.** This error is signalled when you try to add to, delete from or kill a relation name which is either a primitive of micro-PROLOG, or is imported to the current module, or is the name of a currently opened file.

5 **File Handling Error.** This error is signalled when an error arises during a file operation. For

example, if you try to open a file using a file name which is also the name of a program relation you will get this error. Other examples include CREATEing a file already open, trying to SEEK to one of the special serial files like "CON:", or trying to SEEK to an unopened file.

6 **Too Many Files Open.** micro-PROLOG only allows four files to be opened at any one time. If you try to open more than four files you will get this error message.

7 **Disk Login Error.** You will get this error if you try to LOGIN a new disk with files on the current disk still open. The LOGIN is supposed to allow disks to be changed; so all files on the disk to be replaced have to be closed before the LOGIN.

8 **Disk Read Error.** You will get this message if you position into a file using SEEK to a position in which there is no data and you then try to read from that position. Other instances of bad data on the disk will usually be trapped the operating system and this will abort micro-PROLOG.

9 **Disk Write Error.** You may get this error when a write error is detected by the operating system. In fact, you probably will never get the error since the operating system will nearly always aborts micro-PROLOG in such circumstances.

10 **Disk or Directory Full.** You get this error if the disk becomes full, or no more directory space is available for a new file.

11 **Break!** This error is signalled when the user types ^C at the console.

12 **Module Handling Error.** This error is signalled whenever there is an illegal use of modules. It occurs when you try to CRMOD or LOAD a module other than at the root module level, or if the new module has a relation name in its export list and the relation is already defined by some program.

Message errors

There are some errors from which it is not possible to recover. When these errors occur, a message is displayed and and there is a default effect that cannot be changed. The error messages and the effects are:

Dictionary Full — There is no space left in the dictionary for new constants. The evaluation is ABORTed and you are returned to the supervisor.

No Space Left — Garbage collection is not able to free enough space for the current evaluation to continue. You are ABORTed to the supervisor.

File Not Found — There has been an attempt to OPEN a file not on the currently logged in disk. The OPEN call is failed but the evaluation continues.

Syntax error — Occurs when a term is being read in. It is displayed if there are too many right brackets or there is more than one term following a | or .. list constructor. In either case the read continues with the extra brackets or terms ignored.

System Abort - Fatal Error Encountered At hhhh

This arises when micro-PROLOG detects an internal inconsistency within the system. It means that a vital internal data structure has been destroyed and micro-PROLOG cannot precede. You are aborted out of micro-PROLOG to the operating system.

Note that a four digit hexadecimal address hhhh is given stating where the error was discovered. This address is of little interest to the user, but is used by LPA if an unexpected System Abort occurs. If you report any such aborts, please note down this address.

You should actually never get a system abort, though there are situations where programmer action can cause one. The simplest case where a programmer can cause a system abort is in trying to execute the following program:

```
((abort-micro x)
     (abort-micro (x)))
```

(This causes overflow in the garbage collector and cannot reliably be recovered from)

Another situation which can cause system aborts is in certain uses of DELCL or KILL. If you are not careful you may delete a clause while the clause is still being used during an evaluation. In this situation you may or may not get a system abort depending on whether the garbage collector is called. If the garbage collector was called between the DELCL of the clause and micro-PROLOG's attempt to continue with the evauation of its conditions you will get the system abort.

If you only delete clauses whilst at the supervisor level using either of the front end programs SIMPLE or MICRO you will be safe. Deleting clauses during an query evaluation is the thing to be wary of. You must only delete a clause for a relation that you know will not still be being used when you do the deletion. An example of a use of KILL that will cause a System Abort follows:

```
((abort-micro2)
  (KILL ALL)              {kills off whole program}
  (SPACE X)               {calls garbage collector}
  FAIL)                   {fails, causing backtracking}
((abort-micro2))          {second clause for backtracking}
```

In this example, the program KILLs itself, and then calls the garbage collector. When it FAILs, the interpreter attempts to back-track to the second clause. Since this has been removed from

the workspace by the garbage collector, the interpreter detects corruption and aborts micro-PROLOG.

Appendix D

Pragmatic Considerations for Programmers

The principal limiting resource in micro-PROLOG is space. To help to conserve space micro-PROLOG incorporates a number of space saving features. To maximise their effect the programmer should be aware of them, so this section describes some of them and how they operate. Note that space saving does not affect the logic of the running program; it may only affect whether a program can run in the space available.

The features of micro-PROLOG which affect the space used by a program are:

1. **Organization.** The evaluation area in micro-PROLOG is organised as a stack and a heap. The stack contains the activation records and the locations for the variables of the evaluation. The stack grows with recursion and pops normally only on backtracking. It records the state of the evaluation of the current supervisor command. The heap contains the values of variables. It also contains the program clauses and other permanent data objects.

Periodically the stack and heap collide, at which time the heap is garbage collected. The garbage collector is actually called whenever the stack and heap grow too close to each other; the point at which this is done is automatically computed by the system depending on the available memory and the relative sizes of the stack and heap.

The garbage collector is a 'Mark and Collect' garbage collector, which means that all the free space in the heap is collected together into a list. The heap is also 'cut down' if there is free space at the end of it. This has the effect (hopefully) of leaving a clear region of memory between the stack and heap, allowing execution to continue.

If the garbage collector fails to find sufficient space then the evaluation aborts with the message "No space left".

Note that the allocation algorithm means that as memory gets tight the garbage collector gets called more and more often; this can have a dramatic effect on the performance of the system. Normally garbage collection takes a very short time (about 0.25 secs) and is not a big overhead.

2. **Success Popping.** micro-PROLOG performs special actions when a procedure call has been deterministic - when it has been solved using the last clause for its relation and the evaluation of each of the calls in the body of the clause has been deterministic. When such a deterministic call is solved, the activation record for the clause that solved the call is popped off the stack (it will always be at the top of the stack) in exactly the same way that the record of a procedure invocation is popped in a conventional recursive programming language. The activation record can be discarded because it will not be needed to determine what next clause to try in order to solve the call should there be backtracking to the call.

The alternative situation, where either the evaluation of one of the calls in the body of the clause was not deterministic or it is not the last clause, means that the activation record

is left on the stack.

The expert programmer can give control information that allows a success popping even when the evaluation of the call appears to have been non-deterministic. That is, when there are still untried clauses for the call or untried clauses for one or more calls solved during the evaluation of the call. He can do this by inserting the / backtracking control primitive in the clause (see Chapter 8).

If a / is evaluated in the body of an invoked clause it has the effect of popping from the stack any activation records left there by the evaluation of the calls that precede the / in the clause, so the evaluation of these calls is now deemed to have been deterministic. It also makes micro-PROLOG treat the clause as though it were the last clause for the call that invoked the clause. In consequence, a / at the end of a clause always results in a success popping of the stack if the use of the clause solves some call.

3. **Tail recursion** is the name given to that form of recursion which is actually equivalent to a loop. micro-PROLOG can detect this special case of recursion, and when a tail recursive call is also deterministic then micro-PROLOG does not grow the stack when entering the call.

A classic example of the power of tail recursion in saving space is during a list append. If we write the append program as:

```
((append () x x))
((append (x¦X) Y (x¦Z))
     (append X Y Z))
```

then for all the deterministic uses of the program the stack does not grow during the evaluation **for any length of input list.** The recursive definition of append is executed as though it were written as a WHILE loop.

The general conditions for a tail recursion optimisation are as follows. Consider a clause of the form

```
((R t1..tk) (A1)...(An))
```

in which (A1) .. (An) are atoms in the body of the clause. Suppose that it is invoked by some call (R t'1..t'k). If the evaluation of the calls (A1)..(An-1) is deterministic, success popping of their evaluation traces will leave the activation record corresponding to the use of the clause at the top of the stack.

Further suppose that there are no other clauses to try for the call (R...) that invoked the clause, in other words, the above is either the last clause for R or a / was executed in the body of the clause. In this situation, the activation record for the clause is not needed for backtracking on the call. (If the last but one atom in the clause is / these first two conditions will be satisfied because of the effect of its evaluation.

Finally, let us suppose that (An) is now matched with the last clause for its relation, so the activation record of this new clause is does not need to be left on the stack for possible backtracking on (An). In this circumstance, the activation

record is thrown away and replaced by the activation record of the clause invoked by the last call (An).

Note that (An) need not be a call of the relation R. So the tail recursion optimisation of micro-PROLOG is a generalisation of the tail recursion that corresponds to iteration.

4. **Non-structure sharing**. micro-PROLOG is a so-called 'non-structure sharing' implementation. Briefly this means that when a variable is bound during a unification its value is explicitly computed and placed, if necessary, in the heap.

The effect of this, together with garbage collection, success popping and tail recursion, is to limit the amount of data currently in the stack and heap to that which is actually needed, though it does lead to an overall increase in memory turn-over. It also has a space benefit in that for certain simple, but common, cases the value of a variable takes occupies less space than in the more normal 'structure-sharing' implementations of PROLOG.

To take full advantage of the success popping and tail recursion space saving optimisations the programmer should try to ensure that micro-PROLOG can always detect determinism in a program. This means, for example, putting the base case of a program (such as that for **append**) before the general case, and using the IF condition and / where they are applicable (see Chapter 8). Programs optimised for space in this way tend to be less optimal with respect to speed of execution, and vice versa.

Appendix E

Adding assembler coded subroutines

It is part of the philosophy of micro-PROLOG that it should be as extensible as possible. This is reflected in the flexibility of the syntax, as well as in the inherent extensibility of PROLOG. A further kind of extension provided for in micro-PROLOG is the ability to add programs to the system that are written in other languages, in particular assembly coded programs, and have them automatically executed by the system like any other program.

To this end we have an interface which, if followed exactly, allows a 'foreign' program to be called by the system and parameters to be passed between it and micro-PROLOG. This interface is also used by the bulk of the built-in programs, so this chapter also gives a flavour of how they are implemented.

Any new builtin programs have to be written in assembler; while it is possible to add in a program written in FORTRAN (say) it would be necessary to sort out the machine code interface to allow the micro-PROLOG system to call the FORTRAN subroutine. This requires detailed knowledge of the particular FORTRAN compiler, and is beyond the scope of this manual.

A user coded program is invoked in the normal way, by an atom in a goal statement, or in a clause. Like the built-in machine coded programs the extent to which it behaves like a normal program, written as clauses, depends on how many of the program's uses have been catered for, though the interface only handles deterministic uses. If a non-deterministic use is to be handled, then it can be programmed up using a micro-PROLOG program that explicitly sequences through the non-deterministic choices.

The principal interface between micro-PROLOG and a user coded (or any other) machine language program consists of three components. A number of data registers are provided through which parameter values are passed between micro-PROLOG and the machine coded program. A Type tree is used to specify what types of arguments the program can accept, how many of them, and what patterns of use are supported. The type tree also specifies the actual entry points into the program, so that depending on the particular call different entry points may be entered.

The third component of the interface is the predicate symbol declaration. This declares to micro-PROLOG a constant which describes the name to be used to access the program and its initial entry point. The predicate symbol has to have a different name from any already existing in the micro-PROLOG system.

Z80 and 8086 Differences

The Z80 and 8086 implementations of micro-PROLOG have broadly similar interfaces for assembler code, but do differ in a few respects. The following is a brief summary of the differences:

Z80 System	8086 System

Any 8080 or Z80 assembler can be used to encode new primitives.	Only Microsoft's Macro86 assembler may be used.
The user creates a new file with his assembler coding, and submits it to the assembler, and then to the linking loader.	The user inserts his assembler code into a pre-written dummy file prior to submission to the assembler.
Linking into micro-PROLOG is performed with a debugging tool such as DDT or ZSID.	Linking into micro-PROLOG is performed with the MS-DOS Object Linker
Use is made of a supplied symbol table for hooking into micro-PROLOG subroutines.	No use of a symbol table is needed, since the hooks up with micro-PROLOG subroutines.

In addition to the above details, certain differences exist within micro-PROLOG itself. In particular, the segmented memory map of the 8086 version means that certain data buffers and all constants are accessed through the code segment (CS:) register. In addition, the structure of constants is different in the 8086 version: their text portion consists of a one-byte character count, followed by the text. On the Z80 version, there is no counter, and the text is terminated by a FFh byte.

The following general correspondence exists between Z80 and 8086 registers, as they have been used in micro-PROLOG:

Z80		8086/8088
A	(8 bit accumulator)	AL
HL	(16 bit general reg.)	BX
H & L	(8 bit parts of HL)	BH & BL
BC	(16 bit general reg.)	CX
B & C	(8 bit parts of BC)	CH & CL
DE	(16 bit general reg.)	DX
D & E	(8 bit parts of DE)	DH & DL
IX	(index register)	SI
IY	(index register)	DI

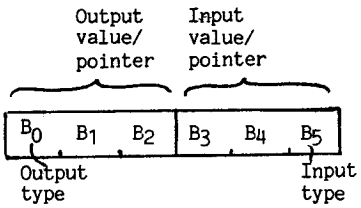
In this chapter, we first examine the principles involved in adding assembler coded primitives, without specific reference to any one machine, then a case study is provided both for the Z80 and 8086 versions of micro-PROLOG to illustrate these principles. Where Z80/8086 differences exist, the 8086 version is given, in parentheses, after the Z80 version.

E.1 Data registers

Each argument of a call to an assembler coded primitive is left in a Data register on entry to the call. There are eight of these registers provided in the system, corresponding to up to eight arguments in a call. No user coded program may have more than eight arguments, though the system does not check this. Of course most programs have considerably fewer than eight arguments, in which case not all of the registers are used. However, those that are not used must not be altered in any way

by the user program.

Each data register is six bytes long, and has the format:



The eight data registers are labelled SLOT1 .. SLOT8.

A Data register has two separate components, one for input data to the user program, and one for returning results. The output component is of the same format as a micro-PROLOG **value cell.**

The input component specifies what the argument to the built-in primitive is at the time of the call; and the output component is used to the hold the returned values of the primitive.

By assigning to the output component of the data register a value is returned to the PROLOG program which called the primitive. The output component is only significant if the input component holds a variable.

The input component of the data register is determined by the type tree (see below). It can be either a variable, number, constant or list pointer.

Generally, if the type tree has been followed the invoked program already knows what is contained in a given data register and can act accordingly without further checking. The user must under no circumstances affect the value in the input register: the value can be read, but not modified.

The output type type field is initially set to OFFH. To pass back a value it is necessary to assign the type of the answer to this field, and to place the appropriate value in the value field. If the type field is left at OFFH then no value is passed back, and the corresponding variable is left unbound.

E.2 Value cells and terms in micro-PROLOG

A value cell consists of a one byte tag field, and a two byte integer or pointer value. Value cells are used internally by micro-PROLOG in, for example, list cells. Each value cell is effectively a term in the system; it can be a list, an integer, a floating point number, a constant or nil.

If it is a list then the value cell is a pointer to a pair of value cells (which must be on an even byte boundary); if it is an integer then the value cell contains the value of the integer as a 16bit two's complement number; if it is a floating point number then the value cell points to a pair of value cells in a special format (see below); if it is a constant then the value cell points to a constant data structure (see below); if it is

nil then only the tag is important.

The various data types that are recognised by micro-PROLOG include:

NUMBER	=	4	Data field holds a 16 bit number in two's complement form.
FLOAT	=	10	value is a pointer to a packed fpn
NIL	=	16	The empty list. Data field ignored.
CONSTANT	=	8	Data field points to a constant structure
LIST	=	3	Data field points to a list cell

E.2.1 micro-PROLOG internal data structures

There are only three data structures used to construct terms in micro-PROLOG (apart from the scalars: integers and nil), these are list cells, constants and floating point numbers. We give a brief description of each of these. Note that there are actually other objects in the micro-PROLOG system, but these are not part of the general interface.

In fact it is suggested that built-in primitives do not directly manipulate list structures but only objects such as constants and numbers.

A Constant has a structure of the form:

Value Cell Name of Constant FF

(Value Cell Char-Count Name of Constant) on 8086 systems

New constants can be made very simply, by filling a special buffer (CONBUF) within micro-PROLOG with the characters of the constant, terminated by a 0 byte, and calling the internal routine MAKCON (on the 8086, the first byte of CONBUF is set to the character count, and no terminator is used). This routine returns in the HL (BX) register a pointer to the constant; if the constant already existed in the dictionary then the existing constant is returned; otherwise a new one is constructed.

A list cell consists simply of two value cells contiguous in memory, with the head cell first and on an even byte boundary.

Head Value Cell Tail Value Cell

List cells are created by using the internal routine CONS (KONS on the 8086) which returns a pointer to a list pair in the HL (BX) register. The head and tail of the list are both initialised to nil.

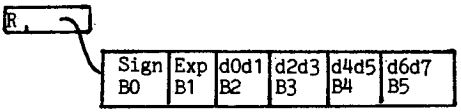
Note that during the execution of CONS (KONS) (and MAKCON) the garbage collector may be called. It is imperative that the system be made aware of any lists you are constructing. This is quite simple to do: construct the list from the outside in (i.e. construct the outermost list pair first, then build the inner parts all the while linking them to the outer list pair); and assign the output part of one of the data registers to the top list pair constructed. This data register does not have to be one of the ones used to pass arguments; though if you do use another one be sure to reset the output type field back to 0ffh before returning to micro-PROLOG.

Floating point numbers come in two flavours, packed and unpacked. A floating pointer number has to be unpacked before any computations may be performed on it, and re-packed if it forms part of the output value of the primitive.

A packed floating point number occupies the same space as a list cell, and are garbage collected along with other list cells. In the 6 bytes available are packed the fraction field (8 digits packed BCD), the exponent field (one byte containing exponent as $10^{-127}..10^{127}$ using offset 128 (80H)).

The sign of the fraction is held in bit 3 of the first byte of the cell, bit3=1 means negative, bit3=0 means a positive number.

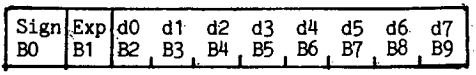
The fraction is held as 8 consequetive digits, i.e. four bytes of packed BCD. The most significant digit is the upper nibble of the first byte, and the least significant digit is the lower nibble of the last byte. The format of the floating point number looks like:



The floating point number thus represented is

$$\text{Sign} * 0.\text{d0d1d2d3d4d5d6d7} * 10^{\text{Exp}-128}$$

For computation on floating point numbers (fpn's) a special unpacked layout is used. This is similar to the packed form, except that each digit of the fraction part occupies a single byte:



Also it is wise to leave some free bytes (9 bytes) at the end of an unpacked number to allow for unnormalised numbers and excess numbers from results of multiply & divide.

To pack a floating point number, call CONS (KONS) to create some space, and then call PACK to load the value into the space created.

E.2.1 Warning

There are other types recognised by micro-PROLOG, but all other values are reserved by micro-PROLOG. The type field is checked at various points in the system, and an invalid type may result in micro-PROLOG being aborted.

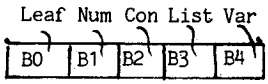
In fact it is envisaged that the type most commonly used by user programs is that of number. It is for the sake of completeness that the other types have been described.

E.3 Type tree

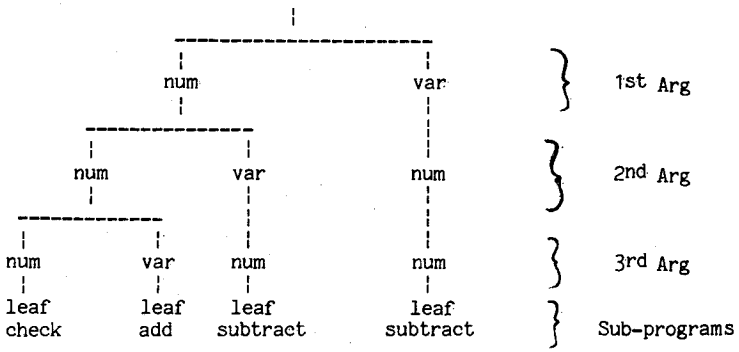
Type checking of arguments to a machine coded program is controlled by the type tree. This is a data structure that is part of the program, and must be provided with it. Only if no arguments are expected to a call may this tree be omitted, but if the programmer wants the system to check that it is called with no arguments then a tree can be specified to check for this.

Each node in the tree has 5 fields, corresponding to the possible types that an argument in the call can have. Each different type of argument leads to a sub-tree of the type tree, with an empty subtree signifying that a particular type of argument is not allowed. The empty subtree is marked by having the value OFFH in the corresponding field of the node. The depth of the tree corresponds with the argument position in the call: the root of the tree deals with the first argument, and the nodes in the second level (i.e. those immediately descended from the root) deal with the second argument position.

Type tree node:



For example the type tree for the SUM predicate may be represented as follows:



The **Leaf** field refers to the end of the argument list: i.e. no argument. The subtree rooted at the leaf field is actually an entry point into the code of the user program proper. At this point all of the parameters to the call will have been parsed and the appropriate values placed in the data registers. Furthermore, since the path from the root node of the tree to the entry point is unique the code can simply access the values in the knowledge that the types are as expected. All that is left for the program to do is to compute the answer values, place the result in the output halves of the data registers and return.

When returning from a leaf program (by executing a RET instruction) the system checks the return code for success or failure. If the Z flag is set then the system assumes success, and the variables are bound as specified, if however, the Z flag is reset then the call is assumed to have failed. In this case the micro-PROLOG system backtracks in the normal way.

The **Num** field has rooted from it a non-empty subtree if a number was allowed in the current argument position. If a number is present, and the number subtree is non-empty then the number in the call is loaded into the appropriate data register, the number subtree followed and the next argument considered.

Note that to decide whether an integer or floating point number is present the input type byte will have to be examined in the relevant data register. If it is an integer the input type value will be 4, if a floating point number it will be 10.

If the **Con** subtree is non-empty then a constant is allowed as a legal argument. If a constant appears as an actual parameter then the constant's address is loaded into the input data register.

If the **List** subtree is non-empty then a list is allowed as an actual parameter. Note that this means that a non-empty list as well as the empty list is allowed. If a list is encountered as an actual parameter then a pointer to a value cell which points to the list (or has NIL as a type) is placed in the data register: not a pointer to the list itself.

If the **Var** subtree is non-empty then a variable is allowed as an actual parameter. If a variable is used where one is not allowed then a "CONTROL ERROR" is reported, similarly if only a variable is allowed but a variable not used as an actual parameter, then a "CONTROL ERROR" also results. The Variable subtree is used when the programmer expects to return a result in that argument position, although there is no actual compulsion to return a value. Note that, of course, values can not be returned other than through a variable!

Each field in the node is a single byte unsigned number in the range 5..255. If a non-empty subtree is rooted at a particular field then the number in the field is a relative offset: it is the distance, in bytes, between the target node or entry point and the base of the current node. If an actual parameter is of a type which has no legal subtree for it, for example if a number is supplied as a parameter but a number is not allowed, then the call fails, unless the actual parameter was a variable, or a variable was the only type allowed.

E.4 Predicate symbol declaration

The predicate symbol declaration is used to describe the name of the new program, and its initial entry point, to the micro-PROLOG system. The predicate symbol is defined by a constant structure like that seen above. Note that the declaration of a constant is not in itself sufficient, since micro-PROLOG does not yet 'know' about it. The new constant has to be patched into the system dictionary before the program can be used.

E.5 Extending micro-PROLOG

It will be appreciated that any one attempting to augment micro-PROLOG by adding new assembler built-in programs should be reasonably proficient in (a) programming in assembler, (b) interfacing to CP/M or MS-DOS and (c) using micro-PROLOG.

Finally, be very careful as it is very easy to damage micro-

PROLOG. (Never modify in any way the original distribution disk.) The interface described above is a very simple and powerful one; it is used by the great majority of the built-in programs in standard micro-PROLOG.

Adding built-in programs does not invalidate the licence agreement; however it is not permitted to sell or otherwise distribute an augmented version of micro-PROLOG without the written permission of the copyright holders of micro-PROLOG. Of course any augmentations that you build are not the property of the copyright holders.

E.6 Case Studies

The principles discussed above will now be illustrated with an example for each of the Z80 and 8086. Most of the information will be fairly specific to the chip concerned, so it is best to concentrate only on the example relevant for your machine.

E.6.1 Z80 Case Study - the LENGTHOF program

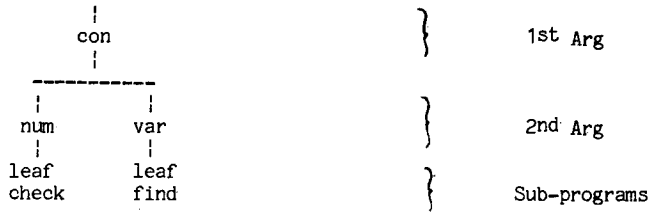
To illustrate the Z80 method for inserting a new program into micro-PROLOG we take as a case study a simple program which finds the length of a constant. We shall call the new builtin primitive LENGTHOF, and it is read as:

(LENGTHOF constant integer)

{the number of chars in constant is integer}

We shall allow two possible uses of the LENGTHOF program, the first is to count the number of characters in a symbol and return the result as an integer, and the second verifies that a given constant has the correct number of characters in its name.

First we must define a type tree for our LENGTHOF program; given our two intended uses it is:



To set up the type tree interface for our LENGTHOF program we must start the initial entry point of the program as follows:

```
        ORG  <BOS>          ;Where <BOS> is the contents of BOS
LENGTH: LD   IX,LENTRE      ;load IX with type tree for this prog
        JP   TRWALK         ;entry point inside micro-PROLOG
                            ;which processes the type tree
```

The type tree for the LENGTHOF program is:

```
LENTRE:  DEFB  -1,-1,LTR2-LENTRE,-1,-1
LTR2:    DEFB  -1,LTR3-LTR2,-1,-1,LTR4-LTR2
LTR3:    DEFB  LCHECK-LTR3,-1,-1,-1,-1
LTR4:    DEFB  LFIND-LTR4,-1,-1,-1,-1
```

The main program for LENGTHOF is:

```
INDATA    EQU  3              ;define the relevant offsets in
INTYPE    EQU  5              ;the data registers
OUTDTA    EQU  1              ;output value cell
OUTYPE    EQU  0
;
NUMBER    EQU  4              ;type value for integer
;
LEN:      LD   HL,(SLOT1+INDATA)   ;look at the input constant
          INC  HL                  ;move to the text part
          INC  HL
          INC  HL
          LD   BC,0                ;start the counter for the
          LD   A,0ffh              ;length at zero
LOOP:     CP   (HL)                ;look for the terminating
          RET  Z                   ;byte, length in BC
          INC  HL                  ;look at the next character
          INC  BC                  ;and increment the length
          JR   LOOP
;
LCHECK:   LD   A,(SLOT2+INTYPE)    ;check the length
          CP   NUMBER              ;is the given an integer?
          RET  NZ                  ;can't be non-integer length
          CALL LEN                 ;find out the actual length
          LD   HL,(SLOT2+INDATA)   ;see what its supposed to be
          OR   A
          SBC  HL,BC
          RET                      ;return with the result flag
;
LFIND:    CALL LEN                 ;find out how long it is
          LD   (SLOT2+OUTDTA),BC   ;store the result in register
          LD   A,NUMBER            ;its an integer
          LD   (SLOT2+OUTYPE),A
          CP   A                   ;set Z for success
          RET                      ;all constants have a length
```

Next we must make a constant declaration for LENGTHOF. This can be coded in assembler as follows:

```
LNGTHF: DEFB 4                ;Number type to signify M/C code
        DEFW LENGTH           ;Initial entry to LENGTHOF program
        DEFM 'LENGTHOF'       ;Text string of name of symbol
        DEFB 0FFH             ;Byte terminator of name string
```

The entry in the dictionary takes the form of a list cell, and can be coded as:

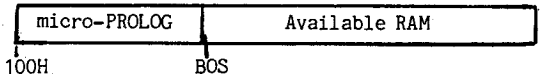
```
NEWDCT: DEFB 8                ;Constant type
        DEFW LNGTHF           ;Point to new constant
        DEFB 3                ;List type
        DEFW <SDICT>          ;Point to top of system dictionary
;
;Where <SDICT> is the contents of SDICT
```

This completes the definition of the LENGTHOF program; all that is needed now is to assemble it for the right place, and link it in to micro-PROLOG. Until the new predicate symbol is inserted into the system dictionary it cannot be referenced by a micro-PROLOG program.

Inserting a program

In the micro-PROLOG system there are two pointers which are necessary to adjust and know about when inserting a new program. The first is BOS, which points to the first available byte of memory. The second is a pointer to the top of the system dictionary SDICT.

When micro-PROLOG is loaded into memory the Transient Program Area (TPA) of CP/M looks something like:



The BOS pointer points to the first available byte in memory above the main micro-PROLOG system. micro-PROLOG builds its data structures above this pointer. The new LENGTHOF primitive has to be added in to the micro-PROLOG system at or above the BOS pointer. This pointer has also to be adjusted to point above the end of the new primitive.

The procedure for adding a new program to micro-PROLOG (once it is assembled into the right location) involves loading the new program starting at (BOS), updating the BOS pointer, and updating the system dictionary pointer.

E.6.2 8086 Case Study - the CHARIN program

The method of writing new built-in primitives for the 8086 version of micro-PROLOG involves inserting code and data into a specially written "dummy" file called USERCODE.ASM. This is a file which contains references to all necessary routines and structures within micro-PROLOG, and some macro definitions to facilitate dictionary linking and constant declaration. All user entries into this file are made between special comments as described below. USERCODE.ASM is comprehensively commented, and may well be sufficient documentation for the assembler interface once the user has understood the background information earlier in this Chapter.

The memory map of 8086 micro-PROLOG is arranged as follows:

SS:	0000h - 0100h	MS-DOS stack
CS:	0000h - INIPRO	code and data buffers
	INIPRO - INIPRO+4000h	text dictionary
DS:	0000h - HEPBOT	supervisor, dict links + data
	HEPBOT - HEPTOP	prolog stack and heap

The use of code and data (CS: and DS:) segments allows a nearly full 64 kilobytes of memory to be available for user programs and evaluation space, while removing the play off between assembler code programs and evaluation space.

Constants are stored in the code segment, a fixed 16 kilobyte space above INIPRO being used for "user" constants. Note that this means any references to constants must be prefixed in the code with a CS: segment overide (see assembler example below). All list structures, including dictionary links, are stored in the data segment, the space between HEPBOT and HEPTOP

being used for micro-PROLOG's heap and stack.

In the file USERCODE.ASM the data segment is called SUPV (because it includes the micro-PROLOG supervisor), and the code segment is called MAIN, because the main body of the code lives there. Your entries for dictionaries, predicate code, etc., must be in the correct segment, as outlined above and in the CHARIN example below.

To illustrate the 8086 method of inserting a new program into micro-PROLOG we take as a case study a simple program which takes three arguments. The first is a single character constant, the second some other constant, and the third is the number of occurrences of the single character in the other constant. We shall call the new built-in primitive CHARIN, and read it as:

(CHARIN character constant integer)

{there are integer of occurrences of character in constant}

We shall allow two possible uses of the CHARIN program, the first is to count the number of occurrences of the character in the constant and return the result as an integer, and the second verifies that a given constant has the correct number of occurrences of the character in its name.

The first job is to create a dictionary link for our program. Dictionary links are made in the data segment, called SUPV, and are inserted between the following two comment blocks:

```
;=============================================================
;*****                                                 *****
; ***   U S E R   D I C T   L I N K S   A N D   D A T A   ***
;  *                                                     *
;-------------------------------------------------------------
;
        dlink   chlink,chpred,niltyp,nil        ; dictionary link
;
;-------------------------------------------------------------
;  *                                                     *
; ***   U S E R   D I C T   L I N K S   A N D   D A T A   ***
;*****                                                 *****
;=============================================================
```

The dictionary link is created using a macro dlink, defined in USERCODE.ASM. Each dlink has four arguments: the first names the link entry, the second names the predicate declaration concerned, and the third is either niltyp for end of dictionary, or listyp if another link follows. The fourth argument names the next link (if any). Any other data areas may be placed between these two comments if required.

micro-PROLOG uses the contents of a three-byte field in the code segment (MAIN) to terminate the normal system dictionary, or to direct it to any user dictionary links. Initally USRDCT is set to "db niltyp" and "dw nil" to indicate that there is no more dictionary. In order to link in the user's dictionary, its definition should be changed to point at the first user link. In our example, the following definition will suffice:

```
;=============================================================
;*****                                                 *****
; ***          U S E R   D I C T   P O I N T E R          ***
```

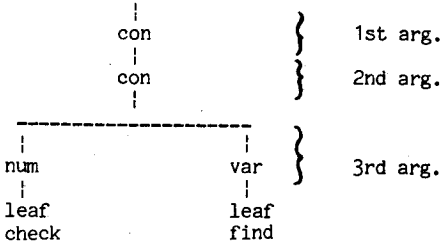
```
;  *                                                              *
;---------------------------------------------------------------
;
USRDCT  db      listyp  ;list points to first dictionary entry
        dw      chlink  ; this is first entry in dictionary
;
;---------------------------------------------------------------
;  *                                                            *
; ***          U S E R   D I C T   P O I N T E R              ***
;*****                                                        *****
;===============================================================
```

Optionally, a message may be displayed as part of the micro-PROLOG sign-on banner. Such a message displays underneath the LPA copyright message, and above the "Bytes Free" message. Any sequence of 7-bit characters may be defined with the db at the following point in USERCODE.ASM:

```
;===============================================================
;*****                                                        *****
; ***       U S E R   S T A R T - U P   M E S S A G E        ***
;  *                                                            *
;---------------------------------------------------------------
;
USRMSG  db      'Documentation Example - Brian D Steel - 29 Feb 84'
                                ; any message in single quotes
;
;---------------------------------------------------------------
;  *                                                            *
; ***       U S E R   S T A R T - U P   M E S S A G E        ***
;*****                                                        *****
;===============================================================
```

Next we must declare the name by which our new built-in program will be known. Any name may be used, but a predicate must begin with an UPPER case letter. It is probably best to use micro-PROLOG's convention, and use a completely upper case name for any built-in predicates. Predicates are defined using a macro called dname, which is defined in USERCODE.ASM. dname takes three arguments: the first is the name of the program as referred to by the dlink entry (see above), the second is its type-tree interface entry point (see below), and the third is its upper case predicate name.

Now we are ready to define the type tree and write the code for CHARIN itself. Given our intended uses of CHARIN, the following type tree will represent the legal argument combinations:



The type tree interface is arranged so that its main entry point (that mentioned in the dname declaration - see above) loads

up the address of the type tree into the SI register, and then jumps into trwalk.

```
;=============================================================
;*****                                                 *****
; ***   U S E R   P R E D   N A M E S   A N D   C O D E   ***
;  *                                                       *
;-------------------------------------------------------------
;
        dname   chpred,centry,CHARIN    ; constant declaration
;
centry: mov     si,offset chrtre ; load up type tree address
        jmp     trwalk          ; enter the tree walker program
;
; The type tree below allows args as (CON CON NUM) or (CON CON VAR)
;
                                ; first arg. is a constant
chrtre  db      -1,-1,chrtr2-chrtre,-1,-1
                                ; second arg. is a constant
chrtr2  db      -1,-1,chrtr3-chrtr2,-1,-1
                                ; third arg. num or var
chrtr3  db      -1,chrtr5-chrtr3,-1,-1,chrtr4-chrtr3
                                ; entry if third arg. a var
chrtr4  db      chrvar-chrtr4,-1,-1,-1,-1
                                ; entry if third arg. a num
chrtr5  db      chrnum-chrtr5,-1,-1,-1,-1
;
; Count up occurrences of char in arg. 1 in arg. 2,
;and return count in arg. 3
;
chrvar: call    ctally          ; count up occurrences
        jz      $+3             ; skip if successful
        ret                     ; something was wrong - fail
        mov     slot3+sltdta,cx ; load up output with count
        mov     byte ptr slot3+sltbnd,numtyp    ; load output type
        ret                     ; return with success
;
; Count up occurrences of char in arg. 1 in arg. 2, and compare with arg. 3
;
chrnum: call    ctally          ; count up occurrences
        jz      $+3             ; skip if successful
        ret                     ; something wrong - fail
; make sure input is an integer
        cmp     byte ptr slot3+sltint,numtyp
        jz      $+3             ; skip if successful
        ret                     ; only integers allowed - fail!
; compare count with that given by user
        cmp     slot3+sltskl,cx
        ret                     ; return with result
;
; Do the counting: arg1 must be 1 char constant.
; CX contains char count at end
;
ctally: mov     bx,slot1+sltskl         ; get first arg.
        cmp     byte ptr cs:3[bx],1; make sure its one char long
        jz      $+3             ; skip if successful
        ret                     ; arg. 1 is wrong length - fail
        mov     al,cs:4[bx]     ; get char from arg. 1 into AL
        mov     bx,slot2+sltskl ; get second arg. into BX
        mov     ah,cs:3[bx]     ; get the char count for arg. 2
        add     bx,4            ; point to the text of arg. 2
        xor     cx,cx           ; clear the CX register for counting
;
```

```
; while still some chars do: if char in al same as cs:[bx], then
; increment cx; point to next char;
; decrement count of chars to do
;
cloop:  or      ah,ah           ; see if all chars in arg. 2 used
        jnz     $+3             ; carry on if not
        ret                     ; go home with the count in CX
        cmp     al,cs:[bx]      ; see if char in AL same as [BX]
        jnz     $+3             ; skip count up if not
        inc     cx              ; increment the cx counter
        inc     bx              ; point to next char from arg. 2
        dec     ah              ; decrement the rem. chars count
        jmp     cloop           ; and loop back for rest of chars
;
;-----------------------------------------------------------------
;  *                                                            *
; ***   U S E R   P R E D   N A M E S   A N D   C O D E       ***
;*****                                                        *****
;================================================================
```

Having inserted all the code as described above, a new version of USERPROL.EXE is created as follows:

Microsoft's MACRO86 assembler, and the LINK program should be present on drive A. The files USERMAKE.BAT, USERMESG, USERLINK and the new version of USERCODE.ASM, as well as all the .OBJ files (STACK, MAIN, BUILTIN, FLOAT, IO, FORMIO, CONIO, DISKIO, SUPVISOR) should be on drive B.

Type USERMAKE: a message will be displayed, and then you will be asked to type any key when ready to proceed. Control-C can be used to abort the process. After assembly, you will be asked whether you with to proceed with linking. Type Control-C if any errors have been found during assembly.

If all goes well, your new version of micro-PROLOG will now be present, under the name USERPROL.EXE. Type USERPROL, and try out your new primitives.

Appendix F

System requirements

The following configuration is required to use micro-PROLOG:

Either: A Z80 micro-computer with CP/M 2.0 or later version with at least 48K (preferably 64K).

Or: A 8088 or 8086 computer with MS-DOS (PC-DOS) or CP/M86 (any version) with at least 128K RAM. Note: Some computers running MS-DOS or CP/M86 may require more than 128K, depending on their memory map. When running, micro-PROLOG occupies about 96K, leaving 32k on such machines for the operating system, screen memory, etc.

One floppy disk drive (two is handier)

Keyboard able to generate the full ASCII character set, in particular it should preferably be able to generate all the lower case letters. In addition, it is very helpful to have the bar symbol "¦", which is used as the list constructor, and tilde "~", which is used for quoting control characters.

Console display with a non-destructive cursor backspace (this is used by the line editor).

Display with auto line feed on lines >80 characters long (or whatever the display width of the console is).

Preferably auto inverse line feed when backspacing past column 1 of the console (not essential).

These requirements are subject to alteration as new versions of micro-PROLOG for different computers become avialable.

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