Comparison of C vs Pascal Version of Enhanced Chapter 1 Interpreter

This document describes the issues and changes involved in translating the Pascal version (chap1.pas) of the enhanced interpreter into C (chap1.c).

The grammar (section 1 below) and instruction syntax (section 2 below) did not change.
Section 3 below discusses some of the translation issues and presents a side by side comparison of the Pascal and C source code in part 8 of that section.

Section 1. Grammar for Enhanced Chap1 Interpreter

The grammar for chap1.c is still the same as it was for chap1.pas and is as follows.

userinput → input $
input → quit | cmdline | fundef | expr
cmdline →) command
note: the right parenthesis must be first char of input line
command → load filename | sload filename
filename → any valid filename for the operating system

fundef → fun name (paramlist) := expr nuf
paramlist → null | name [, name]*

expr → ifex | whileex | seqex | exp1
ifex → if expr then expr else expr fi
whileex → while expr do expr od
seqex → seq explist qes
explist → expr [; expr]*
exp1 → exp2 [:= exp1]*
exp2 → [prtop] exp3
exp3 → exp4 [relop exp4]*
exp4 → exp5 [addop exp5]*
exp5 → [addop] exp6 [mulop exp6]*
exp6 → name | number | funcall | (expr)

funcall → name (arglist)
arglist → null | expr [, expr]*
prtop → print
relop → = | < | >
addop → + | -
mulop → * | /

number → sequence of digits
name → any sequence of characters not a number and not containing a delimiter.
delimiter → '(', ')', ';', '+', '-', '*', '/', ':', '=', '<', '>', ',', '$', '!' or space
note: [and] enclose optional parts of a production.
[ ] indicates the option may occur once
[ ]* indicates the option may occur more than once
The exclamation point begins a comment.

Section 2. Syntax for Enhanced Chap1 Interpreter

The syntax for chap1.c is still the same as it was for chap1.pas and is illustrated in the following examples.

```
~$ ./chap1
-> 3$
3

-> 4+7$
11
```

Assignment is done via the := operator.

```
-> x:=4$
4

-> x+x$
8

-> print x$
4
4

-> y:=5$
5

-> seq print x; print y; x*y qes$
4
5
20

-> if y>0 then 5 else 10 fi$
5

-> while y>0 do
>    seq x:=x+x; y:=y-1 qes
>  od$
0

-> x$
128

-> fun #1 (x) := x + 1 nuf$
#1

-> #1(4)$
5

-> fun double(x):=x+x nuf$
double

-> double(4)$
8

-> x$
128
```

```
-> fun setx(x,y):= seq x:=x+y; x qes nuf$
setx

-> setx(x,1)$
129

-> x$
128

-> fun not(boolval):= if boolval then 0 else 1 fi nuf$
not
```

<> cannot be a function name since <, > are now delimiters.

```
-> fun <> (x, y):= not(x=y) nuf$
mutate: found <  where nameid or funid is expected.
```

is not a delimiter and can be used in a name.

```
-> fun ## (x,y):= not(x=y) nuf$
##

-> fun mod(m,n):=m-n*(m/n)nuf$
mod

-> fun gcd(m,n):=
>    seq
>      r:=mod(m,n);
>      while ##(r,0) do
>        seq
>          m:=n;
>          n:=r;
>          r:=mod(m,n)
>        qes
>      od;
>      n
>    qes
>  nuf$
gcd

-> gcd(6,15)$
3

-> fun gcd(m,n):=
>    if n=0 then m else gcd(n,mod(m,n)) fi nuf$
gcd

-> gcd(6,15)$
3
```

Normal operator precedence and associativity are implemented.

```
-> 5*3+7$
22

-> 5+3*7$
26
```

```
-> 14-7-3$
4

-> 48/12/2$
2
```

Keywords cannot be redefined.

```
-> fun if (x) := x+5 nuf$
mutate: found if  where nameid or funid is expected.
```

Keywords cannot be reused as variable names.

```
-> if := 20$
Error parsing expr.  Found := where one of the following is expected: "if", "while", "seq", "print", nameid, funid, number, or "("
```

Names are any sequence of chars not a number and not containing a delimiter.

```
-> ~12#ab:=25$
25
-> ~12#ab$
25
-> x:=15-~12#ab+7$
-3
```

A string of digits is not a valid name.

```
-> fun 222 (x):= x+22 nuf$
mutate: found 222  where nameid or funid is expected.
-> fun 2#2 (x):=x+22 nuf$
2#2
-> 2#2(33)$
55
-> a:=55-2#2(33)$
0
```

Inserting a delimiter in a name confuses the parser and causes erroneous results.

```
-> a(b:=25$
Undefined variable: a
```

Function name may not be reused as a variable name.

```
-> fun inc10 (x) := x+10 nuf$
inc10
-> inc10 := 50$
Error in match. Found :=  where ( is expected.
```

Multiple assignment. **:=** is the only right associative operator.

```
-> i:=j:=k:=25$
25
-> i$
25
-> j$
25
```

```
-> k$
25
```

New load from file commands are illustrated below.
They must be entered on a single input line. The $ end of input marker may be omitted since it is appended by the program.

load echoes the text read from the file.

```
-> )load mod.txt

Current Directory is : /home/dawsond/pascal/proglang/chap1
 Loading file : mod.txt

 fun mod(m,n):=
 m-n*(m/n)
 nuf$
mod
```

sload (silent load) does not echo the text read.

```
-> )sload not.txt

Current Directory is : /home/dawsond/pascal/proglang/chap1
 Loading file : not.txt

not
-> )load gcd_only.txt$

Current Directory is : /home/dawsond/pascal/proglang/chap1
 Loading file : gcd_only.txt

fun gcd(m,n):=
 seq
  r:=mod(m,n);
  while not(r=0) do
   seq
    m:=n;
    n:=r;
    r:=mod(m,n)
   qes
  od;
  n
 qes
nuf$
gcd

gcd(51,34)$
17

gcd(225,300)$
75

mod(10,7)$
3

mod(100,50)$
```

```
0

not(3)$
0

not(0)$
1
```

Section 3. Program organization, Translation Considerations and Program Changes

Part 1. Program Organization

The main program is a Read-Eval-Print-Loop (REPL) which reads user input, parses it, evaluates it, prints its value then returns to the beginning of the loop.
If an error occurs then the errmsg() function displays error information and calls longjmp() to return to the main program and restart the REPL.

The code is still organized as it was in the Pascal version with the main function at the bottom of the file and the other functions listed in the same order under the following sections: DECLARATIONS, DATA STRUCTURE OPS, NAME MANAGEMENT, INPUT, NEW PARSING ROUTINES, ENVIRONMENTS, NUMBERS, EVALUATION.

Lower-level functions are still, for the most part, defined before higher-level ones that call them which helps reduce the need for forward declarations. For example, consider the grammar rules for expressions and their associated function prototypes in the following table. The rules are presented in a top-down, recursive-descent order but the corresponding functions are in reverse, bottom-up order from the lowest-level function to the highest.

Top-Down Order of Grammar Rules.	Bottom-Up Order of Functions in Source Code
expr −→ ifex | whileex | seqex | **exp1** **exp1** −→ exp2 [:= exp1]* exp2 −→ [prtop] exp3 exp3 −→ exp4 [relop exp4]* exp4 −→ exp5 [addop exp5]* exp5 −→ [addop] exp6 [mulop exp6]* exp6 −→ name | number | funcall | (**expr**)	function parseExp6:EXP; function parseExp5:EXP; function parseExp4:EXP; function parseExp3:EXP; function parseExp2:EXP; function parseExp1:EXP; function parseExpr;

So to obtain a top-down view of the program logic, it may be best to read the NEW PARSING ROUTINES and other sections from the bottom up, after reviewing the DECLARATIONS section.

Part 2. Translation of Structure Pointers using Typedef

The *REC names in the Pascal version are only used to declare the REC structure type and to obtain a pointer to it.
For example, we have the following.

```
EXPLIST = ^EXPLISTREC;
EXPLISTREC = record
               head: EXP;
               tail: EXPLIST
             END;

FUNCTION mkExplist (e: EXP; el: EXPLIST): EXPLIST;
   var newel: EXPLIST;
BEGIN
   new(newel);
   newel^.head = e;
   newel^.tail = el;
   mkExplist = newel
END; /* mkExplist */
```

EXPLISTREC is not used anywhere else except in the above red text.

EXPLIST is used throughout the program to declare variables, arguments, function return types.

There is a debate at http://stackoverflow.com/questions/252780/why-should-we-typedef-a-struct-so-often-in-c about whether or not typedef should be used in C.
I decided to use it and rewrite the above Pascal code as shown below in the middle column.
I like the cleaner look and that it made it easier to visually confirm that my C code is equivalent to the Pascal code.
If I did not use typedef then the C code would be written as shown in the last column below.

Pascal Code

```
EXPLIST = ^EXPLISTREC;
EXPLISTREC = record
             head: EXP;
             tail: EXPLIST
           END;



FUNCTION mkExplist (e: EXP; el: EXPLIST): EXPLIST;


  var newel: EXPLIST;
BEGIN
  new(newel);

  newel^.head = e;
  newel^.tail = el;
  mkExplist = newel
END; /* mkExplist */
```

C Code with typedef

```
struct EXPLISTREC {
  EXP head;
  struct EXPLISTREC *tail;
};

typedef struct EXPLISTREC* EXPLIST;

EXPLIST mkExplist (EXP e, EXPLIST el)

{
  EXPLIST newel;

  newel = (EXPLIST)
          malloc(sizeof(struct EXPLISTREC));
  newel->head = e;
  newel->tail = el;
  return newel;
}; /* mkExplist */
```

C code without typedef

```
struct EXPLISTREC *mkExplist (EXP e,
                              struct EXPLISTREC *el)
{
  struct EXPLISTREC *newel;

  newel = (struct EXPLISTREC *)
          malloc(sizeof(struct EXPLISTREC));
  newel->head = e;
  newel->tail = el;
  return newel;
}; /* mkExplist */
```

Part 3. Translation of Pascal Variant Record using C Union

Expressions may be of type number (integer constant), variable or application (of a function or operator).
The Pascal variant record structure that was used to store expressions will now be represented with a C union construct as shown below.

Pascal Variant Record

```
  EXPTYPE = (VALEXP,VAREXP,APEXP);
  EXPREC = record
            case etype: EXPTYPE of

               VALEXP: (num: NUMBER);
               VAREXP: (varble: NAME);

               APEXP: (optr: NAME;
                       args: EXPLIST)
           end;
```

C Union

```
enum EXPTYPE {VALEXP,VAREXP,APEXP};
struct EXPREC {
    enum EXPTYPE etype;
    union {
        NUMBER num;
        NAME varble;
        struct {
            NAME optr;
            EXPLIST args;
        } ap;
    } u;
};
```

Part 4. Translation of Pascal Sets

The following Pascal sets were defined.

```
addop, mulop, relop:set of token; // sets of operators
```

And they were initialized in initParse as follows.

```
addop = [addsy,subsy];
mulop = [mulsy,divsy];
relop = [lssy,eqsy,gtsy];
```

For the C conversion, I replaced tests for set membership like the following

```
if toksy in mulop then
```

with tests of the specific values as follows.

```
if (toksy == mulsy || toksy == divsy)
```

Part 5. Translation of Pascal eoln() and eof()

Functions eoln() and eof() were replaced with booleans named eoln and eof respectively.
These booleans are set to true in the nexchar() function as eoln and eof conditions are encountered.

Part 6. Scattered gotos replaced single longjmp()

In the Pacal version, the Read-Eval-Print-Loop (REPL) was preceded by label 99. Each error message was followed by a “goto 99” statement. Then the REPL would restart.

In the C version, a call to setjmp() replaces label 99 prior to the REPL. All error messages are now inside an errmsg() function which calls longjmp() at the end to return to the setjmp location and restart the REPL.

Part 7. Space-padded strings replaced with null-terminated strings

The printNames array is used to store the names of all operators, variables and functions.

In the Pascal version, all such names are padded with trailing spaces to a length of 20 characters. In the C version, the trailing spaces are omitted and the names are null-terminated. So all the loops that compared and inserted trailing spaces in the Pascal version have been removed in C version.

Part 8. Side by Side Comparison of Pascal vs C source code

Pascal code is in column 1 and corresponding C code is in column 2 of the table below.
The formatting differs from the actual source code in places due to adjusting spacing or moving lines so that corresponding source lines are side by side.

I added some clarifying comments in bold blue text below which are not contained in the actual source code.
They are prefixed by my initials and a colon. Search for “DD:” to read them.

```
(*****************************************************************
 *                    DECLARATIONS                               *
 *****************************************************************)
PROGRAM chapter1 (input, output);

Uses sysutils;









label 99;

CONST
 NAMELENG = 20;      (* Maximum length of a name *)




 MAXNAMES = 100;     (* Maximum number of different names *)
 MAXINPUT = 500;     (* Maximum length of an input *)


 CMDLENG = 8;       (* Maximum length of a command name *)
 NUMCMDS = 2;       (* Number of commands currently defined *)
 ARGLENG = 40;      (* Maximum length of a command argument *)



 PROMPT = '-> ';     (* Initial prompt *)
 PROMPT2 = '> ';     (* continuation prompt *)

 TABCODE = 9;
 LINEFEED = 10;
 CR = 13;

 COMMENTCHAR = '!';
 DOLLAR = '$'; (*marks end of expr or fundef input by the user*)


TYPE
   NAMESIZE = 0..NAMELENG;
   NAMESTRING = packed array [1..NAMELENG] of char;
   NAME = 1 .. MAXNAMES; (* a NAME is an index in printNames *)

 CMDSIZE = 0..CMDLENG;
```

```
/*****************************************************************
 *                    DECLARATIONS                               *
 *****************************************************************/
#define _POSIX_C_SOURCE 200809L
#include <stdio.h>
#include <stddef.h>
#include <string.h>
#include <setjmp.h>
#include <stdlib.h>
#include <ctype.h>
#include <errno.h>
#include <limits.h>
#include <unistd.h>

DD: setjmp(JL99) replaces label 99: in main. errmsg() does a longjmp back
to that point after an error message is displayed.
jmp_buf JL99;


#define NAMELENG 20    // Max length of a name

#ifdef TESTSIZE
#define MAXNAMES  29    // Max no. of names to test err_max_names
#define MAXINPUT  50    // Max input length to test err_input_len
#else
#define MAXNAMES 100    // Max number of different names
#define MAXINPUT 500    // Max length of an input
#endif

#define MAXCMDLENG 8    // Max length of a command name
#define MAXCMDS 3      // Max number of different commands
#define ARGLENG 40     // Maximum length of a command argument
#define MAXDIGITS 19    // Max digits in LONG_MAX in limits.h
                        // for __WORDSIZE == 64

#define PROMPT     "-> "  // Initial prompt
#define PROMPT2    "> "   // continuation prompt

#define TAB 9
#define LF 10
#define CR 13

#define COMMENTCHAR '!'
#define DOLLAR     '$'  // marks END of expr or fundef input by user
#define SPACE      ' '
#define RPAREN     ')'  // marks beginning of a Cmd

typedef short int NAMESIZE;
typedef char *NAMESTRING;
typedef short int NAME;

typedef short int CMDSIZE;
```

```
 CMDSTRING=packed array [1..CMDLENG] of char;
 CMD = 1..NUMCMDS;     (* a CMD is an index in printCmds *)

 NUMBER = integer;
 ARGSIZE = 0..ARGLENG;
 ARGSTRING = packed array [1..ARGLENG] of char;


 BUILTINOP =  (IFOP,WHILEOP,ASSIGNOP,SEQOP,ADDOP,SUBOP,MULOP,DIVOP,
EQOP,LTOP,GTOP,PRINTOP);
 VALUEOP = ADDOP .. PRINTOP;
 CONTROLOP = IFOP .. SEQOP;
```

DD: Below are symbolic names for each token. They are stored in the toktable array at the same index as the corresponding token in the printNames array by the initNames() & install() functions.

```
 TOKEN = nameidsy,numsy,funidsy,ifsy,thensy,elsesy,fisy,
whilesy,dosy,odsy,seqsy,qessy,funsy,nufsy,assignsy,rparsy,
lparsy,semsy,comsy,addsy,subsy,mulsy,divsy,eqsy,lssy,
gtsy,printsy,quitsy,dollarsy);
```

```
  EXP = ^EXPREC;
  EXPLIST = ^EXPLISTREC;
  ENV = ^ENVREC;
  VALUELIST = ^VALUELISTREC;
  NAMELIST = ^NAMELISTREC;
  FUNDEF = ^FUNDEFREC;

  EXPTYPE = (VALEXP,VAREXP,APEXP);
  EXPREC = record
            case etype: EXPTYPE of

              VALEXP: (num: NUMBER);
              VAREXP: (varble: NAME);

              APEXP: (optr: NAME;
                      args: EXPLIST)
           end;
```

```
typedef char *CMDSTRING;
typedef short int CMD;

typedef long NUMBER;
typedef short int ARGSIZE;

typedef enum {false, true} BOOLEAN;

typedef enum {IFOP,WHILEOP,ASSIGNOP,SEQOP,ADDOP,SUBOP,MULOP,DIVOP,
EQOP,LTOP,GTOP,PRINTOP} BUILTINOP;
```

DD: VALUEOP range replaced with firstValueOp, lastValueOp indexes. CONTROLOP range replaced with firstControlOp, lastControlOp indexes.

```
typedef enum {nameidsy=1,numsy,funidsy,ifsy,thensy,elsesy,fisy,
whilesy,dosy, odsy,seqsy,qessy,funsy,nufsy,assignsy,rparsy,
lparsy,semsy,comsy,addsy,subsy,mulsy,divsy,eqsy,lssy,
gtsy,printsy,quitsy,dollarsy} TOKEN;
```

DD: Error messages in the Pacal version were displayed at the point of occurrence and followed by a goto label 99 in the main function. Those are now replaced with a call to errmsg() which is passed one of the error codes below. errmsg() prints the associated message then calls longjmp(JL99, errnum) to return to main to read the next input.

```
typedef enum {err_arglist=1, err_function, err_exp6, err_expr, err_cwd,
 err_open, err_max_names, err_input_len, err_cmd_len, err_no_cmd,
 err_bad_cmd, err_arg_len, err_no_name, err_name_len,
 err_no_name2, err_digits, err_no_name3, err_mismatch,
 err_not_var, err_num_args, err_undef_func, err_num_args2,
 err_undef_var, err_undef_op, err_nested_load
} ERROR_NUM; // error codes passed to errmsg()
```

```
typedef struct EXPREC* EXP;
typedef struct EXPLISTREC* EXPLIST;
typedef struct ENVREC* ENV;
typedef struct VALUELISTREC* VALUELIST;
typedef struct NAMELISTREC* NAMELIST;
typedef struct FUNDEFREC* FUNDEF;

enum EXPTYPE {VALEXP,VAREXP,APEXP};
struct EXPREC {
   enum EXPTYPE etype;
   union {
      NUMBER num;
      NAME varble;
      struct {
         NAME optr;
         EXPLIST args;
      } ap;
   } u;
```

```
  EXPLISTREC = record
            head: EXP;
            tail: EXPLIST
          end;

  VALUELISTREC = record
            head: NUMBER;
            tail: VALUELIST
          end;

  NAMELISTREC = record
            head: NAME;
            tail: NAMELIST
          end;

  ENVREC = record
            vars: NAMELIST;
            values: VALUELIST
          end;

  FUNDEFREC = record
            funname: NAME;
            formals: NAMELIST;
            body: EXP;
            nextfundef: FUNDEF
          end;

var
  fundefs: FUNDEF;
  numval:NUMBER;
  globalEnv: ENV;
  currentExp: EXP;

  punctop: set of char;    (* set of punctuation & operator chars *)

  userinput: array [1..MAXINPUT] of char;
  inputleng, pos: 0..MAXINPUT;

  printNames: array [NAME] of NAMESTRING;
  printCmds:array [CMD] of CMDSTRING;

  tokstring:NAMESTRING;  (* string & length for display in error msgs *)
  tokleng:NAMESIZE;

  infilename:ARGSTRING;
  infile:text;    (* file variable for input source file *)

  load,sload:CMD;



  numNames, numBuiltins, tokindex, mulsy_index: NAME;
```

```
};

struct EXPLISTREC {
   EXP head;
   EXPLIST tail;
};

struct VALUELISTREC {
   NUMBER head;
   VALUELIST tail;
};

struct NAMELISTREC {
   NAME head;
   NAMELIST tail;
};

struct ENVREC {
   NAMELIST vars;
   VALUELIST values;
};

struct FUNDEFREC {
   NAME    funname;
   NAMELIST formals;
   EXP     body;
   FUNDEF   nextfundef;
};


FUNDEF fundefs;
NUMBER numval;
ENV globalEnv;
EXP currentExp;

char punctop[] = "()+-*/:=<>;,$!";  // punctuation and operator chars

char userinput[MAXINPUT];
short int j, inputleng, pos;

NAMESTRING printNames[MAXNAMES];  //built-in & user-defined names
CMDSTRING  printCmds[MAXCMDS];    //built-in command names

char tokstring[NAMELENG+1];  // token string for display in error messages
NAMESIZE tokleng;

char infilename[ARGLENG];
FILE *infp;     // input source file pointer

CMD load,       // load file, echo characters
   sload,      // silently load file, no echo
   user;       // print user defined names


NAME numNames, numCmds, numBuiltins, tokindex, mulsy_index,
    // initNames() saves index of first/last ControlOp & ValueOp
    // in following variables for checking which range Op is in.
```

```
  toksy: TOKEN;   (* current token returned from getToken or install *)
  toktable: array [NAME] of TOKEN; (*holds symbolic name of each token
                                    in printNames array. Corresponding
                                    toktable & printNames entries have
                                    same index. *)

  addops,mulops,relops:set of token;  (* sets of operators *)


  quittingtime,
  dollarflag,  (* true = $ was input. $ marks end of current expr or
                  fundef being input *)
  echo,        (* true = echo characters during a load command *)
  readfile:boolean; (* true if an input file is being loaded *)




(*****************************************************************
 *                  DATA STRUCTURE OP'S                          *
 *****************************************************************)

(* mkVALEXP - return an EXP of TYPE VALEXP with num n          *)
function mkVALEXP (n: NUMBER): EXP;

var e: EXP;
begin
  new(e);
  e^.etype := VALEXP;
  e^.num := n;
  mkVALEXP := e
end; (* mkVALEXP *)

(* mkVAREXP - return an EXP of TYPE VAREXP with varble nm       *)
function mkVAREXP (nm: NAME): EXP;

var e: EXP;
begin
  new(e);
  e^.etype := VAREXP;
  e^.varble := nm;
  mkVAREXP := e
end; (* mkVAREXP *)

(* mkAPEXP - return EXP of TYPE APEXP w/ optr op and args el    *)
function mkAPEXP (op: NAME; el: EXPLIST): EXP;

var e: EXP;
begin
  new(e);
  e^.etype := APEXP;
  e^.optr := op;
```

```
    firstValueOp, lastValueOp, firstControlOp, lastControlOp;


TOKEN toksy;     // symbolic name of token
TOKEN toktable[MAXNAMES]; // symbolic name of each token in printNames.
                          // Corresponding toktable & printNames elements
                          // have same index
```

DD: The Pascal sets on the left were replaced with direct comparison to the set values as indicated in Section 3 part 4 above.

```
BOOLEAN quittingtime, // true = exit program
        dollarflag,   // true = $ was entered which marks end of input

        echo,        // true = echo chars during a load command
        readfile,    // true = an input file is being loaded
        eof,         // eof and eoln are used to mimic the boolean
        eoln;        // Pascal functions eof() and eoln()

void errmsg(ERROR_NUM, char[], int); // forward declaration

//----------------------------
// DATA STRUCTURE OPERATIONS
//----------------------------

// mkVALEXP - return an EXP of type VALEXP with num n
EXP mkVALEXP (NUMBER n)
{
   EXP e;

   e = malloc(sizeof(struct EXPREC));
   e->etype = VALEXP;
   e->u.num = n;
   return e;
} // mkVALEXP

// mkVAREXP - return an EXP of type VAREXP with varble nm
EXP mkVAREXP (NAME nm)
{
   EXP e;

   e = malloc(sizeof(struct EXPREC));
   e->etype = VAREXP;
   e->u.varble = nm;
   return e;
} // mkVAREXP

// mkAPEXP - return EXP of type APEXP with optr op and args eL
EXP mkAPEXP (NAME op, EXPLIST eL)
{
   EXP e;

   e = malloc(sizeof(struct EXPREC));
   e->etype = APEXP;
   e->u.ap.optr = op;
```

```
   e^.args := el;
   mkAPEXP := e
end; (* mkAPEXP *)

(* mkExplist - return an EXPLIST with head e and tail el       *)
function mkExplist (e: EXP; el: EXPLIST): EXPLIST;

var newel: EXPLIST;
begin
   new(newel);
   newel^.head := e;
   newel^.tail := el;
   mkExplist := newel
end; (* mkExplist *)

(* mkNamelist - return a NAMELIST with head n and tail nl      *)
function mkNamelist (nm: NAME; nl: NAMELIST): NAMELIST;

var newnl: NAMELIST;
begin
   new(newnl);
   newnl^.head := nm;
   newnl^.tail := nl;
   mkNamelist := newnl
end; (* mkNamelist *)

(* mkValuelist - return an VALUELIST with head n and tail vl    *)
function mkValuelist (n: NUMBER; vl: VALUELIST): VALUELIST;

var newvl: VALUELIST;
begin
   new(newvl);
   newvl^.head := n;
   newvl^.tail := vl;
   mkValuelist := newvl
end; (* mkValuelist *)

(* mkEnv - return an ENV with vars nl and values vl            *)
function mkEnv (nl: NAMELIST; vl: VALUELIST): ENV;

var rho: ENV;
begin
   new(rho);
   rho^.vars := nl;
   rho^.values := vl;
   mkEnv := rho
end; (* mkEnv *)
```

```
   e->u.ap.args = eL;
   return e;
} // mkAPEXP

// mkExplist - return an EXPLIST with head e and tail eL
EXPLIST mkExplist (EXP e, EXPLIST eL)
{
   EXPLIST newel;

   newel = malloc(sizeof(struct EXPLISTREC));
   newel->head = e;
   newel->tail = eL;
   return newel;
} // mkExplist

// mkNamelist - return a NAMELIST with head n and tail nl
NAMELIST mkNamelist (NAME nm, NAMELIST nl)
{
   NAMELIST newnl;

   newnl = malloc(sizeof(struct NAMELISTREC));
   newnl->head = nm;
   newnl->tail = nl;
   return newnl;
} // mkNamelist

// mkValuelist - return an VALUELIST with head n and tail vl
VALUELIST mkValuelist (NUMBER n, VALUELIST vl)
{
   VALUELIST newvl;

   newvl = malloc(sizeof(struct VALUELISTREC));
   newvl->head = n;
   newvl->tail = vl;
   return newvl;
}

// mkEnv - return an ENV with vars nl and values vl
ENV mkEnv (NAMELIST nl, VALUELIST vl)
{
   ENV rho;

   rho = malloc(sizeof(struct ENVREC));
   rho->vars = nl;
   rho->values = vl;
   return rho;
} // mkEnv

// prEnv - print vars & values in an ENV - for debugging
void prEnv(ENV env)
{

   NAMELIST nl;
   VALUELIST vl;

   int i;
```

```
(* lengthVL - return length of VALUELIST vl                    *)
function lengthVL (vl: VALUELIST): integer;

var i: integer;
begin
   i := 0;
   while vl <> nil do begin

      i := i+1;
      vl := vl^.tail
   end;
   lengthVL := i
end; (* lengthVL *)

(* lengthNL - return length of NAMELIST nl                     *)
function lengthNL (nl: NAMELIST): integer;

var i: integer;
begin
   i := 0;
   while nl <> nil do begin

      i := i+1;
      nl := nl^.tail
   end;
   lengthNL := i
end; (* lengthNL *)
```

```
   i=0;
   nl = env->vars;
   vl = env->values;

   while (nl != 0)
   {
      i = i + 1;
      printf("%d.  %s = %ld", i, printNames[nl->head], vl->head);
      nl = nl->tail;
      vl = vl->tail;
   }
} // prEnv

// lengthVL - return length of VALUELIST vl
int lengthVL (VALUELIST vl)
{
   int i;

   i = 0;
   while (vl != 0)
   {
      i = i+1;
      vl = vl->tail;
   }
   return i;
} // lengthVL

// lengthNL - return length of NAMELIST nl
int lengthNL (NAMELIST nl)
{
   int i;

   i = 0;
   while (nl != 0)
   {
      i = i+1;
      nl = nl->tail;
   }
   return i;
} // lengthNL

void prExplist(EXPLIST); //forward declaration

DD: Below are more print functions for debugging

// print an EXP
void prExp(EXP e)
{
   switch (e->etype)
   {
      case VALEXP:
         printf("etype = VALEXP\n");
         printf("  num = %ld\n", e->u.num);
         break;
```

```
(*****************************************************************
 *                  NAME MANAGEMENT                              *
 *****************************************************************)

(* fetchDef - get function definition of fname from fundefs     *)
function fetchDef (fname: NAME): FUNDEF;
var
   f: FUNDEF;
   found: Boolean;
begin
   found := false;
   f := fundefs;
   while (f <> nil) and not found do
      if f^.funname = fname
      then found := true

      else f := f^.nextfundef;
   fetchDef := f
end; (* fetchDef *)

(* newDef - add new function fname w/ parameters nl, body e   *)
procedure newDef (fname: NAME; nl: NAMELIST; e: EXP);

var f: FUNDEF;
begin
   f := fetchDef(fname);
   if f = nil (* fname not yet defined as a function *)
   then begin
          new(f);
```

```
       case VAREXP:
          printf(" etype = VAREXP\n");
          printf("varble = %s\n", printNames[e->u.varble]);
          break;

       case APEXP:
          printf(" etype = APEXP\n");
          printf("  optr = %s\n", printNames[e->u.ap.optr]);
          prExplist(e->u.ap.args);
          break;

       default:
          printf("Invalid etype = %d", e->etype);
          break;
    }
}

// prExplist - print an Explist
void prExplist(EXPLIST eL)
{
   prExp(eL->head);

   if (eL->tail != 0)
      prExplist(eL->tail);
   return;
} // prExplist

//-----------------
// NAME MANAGEMENT
//-----------------

// fetchDef - get FUNCTION definition of fname from fundefs
FUNDEF fetchDef (NAME fname)
{
    FUNDEF f;
    BOOLEAN found;

    found = false;
    f = fundefs;
    while (f != 0 && !found)
       if (f->funname == fname)
          found = true;
       else
          f = f->nextfundef;
    return f;
} // fetchDef

// newDef - add new FUNCTION fname with parameters nl, body e
void newDef (NAME fname, NAMELIST nl, EXP e)
{
   FUNDEF f;

   f = fetchDef(fname);
   if (f == 0)  // fname not yet defined as a FUNCTION
   {
      f = malloc(sizeof(struct FUNDEFREC));
```

```
        f^.nextfundef := fundefs; (* place new FUNDEFREC *)
        fundefs := f                    (* on fundefs list *)
      end;
  f^.funname := fname;
  f^.formals := nl;
  f^.body := e
end; (* newDef *)
```

```
      f->nextfundef = fundefs;   // place new FUNDEFREC
      fundefs = f;             // at front of fundefs list
   }
   f->funname = fname;
   f->formals = nl;
   f->body = e;
} // newDef
```

DD: Null-terminated strings are used in initNames below instead of the space-padded strings used in the Pascal version. So all the loops that deal with space-padding are removed in the C version.

```
(* initNames - place all pre-defined names into printNames
            and corresponding token symbols in toktable. *)

procedure initNames;

var i: integer;
begin
  fundefs := nil;
  i := 1;
  printNames[i]:= 'if               '; toktable[i]:=ifsy;     i:=i+1;
  printNames[i]:= 'while            '; toktable[i]:= whilesy; i:=i+1;
  printNames[i]:= ':=               '; toktable[i]:= assignsy; i:=i+1;


  printNames[i]:= 'seq              '; toktable[i] := seqsy;   i:= i+1;


  printNames[i]:= '+                '; toktable[i] := addsy;    i:= i+1;
  printNames[i]:= '-                '; toktable[i] := subsy;    i:= i+1;

(* To handle negative numbers (unary minus), we build an expr with the
multiply operator and operand -1. Below we save the multiply symbol index
for this purpose. This avoids a lookup later to obtain the index. *)

  mulsy_index:=i;
  printNames[i] := '*               '; toktable[i] := mulsy;   i := i+1;
  printNames[i] := '/               '; toktable[i] := divsy;   i := i+1;
  printNames[i] := '=               '; toktable[i] := eqsy;    i := i+1;
  printNames[i] := '<               '; toktable[i] := lssy;    i := i+1;
  printNames[i] := '>               '; toktable[i] := gtsy;    i := i+1;


  printNames[i] := 'print           '; toktable[i] := printsy; i := i+1;
  printNames[i] := 'quit            '; toktable[i] := quitsy;  i := i+1;
  printNames[i] := 'then            '; toktable[i] := thensy;  i := i+1;
  printNames[i] := 'else            '; toktable[i] := elsesy;  i := i+1;
  printNames[i] := 'fi              '; toktable[i] := fisy;    i := i+1;
  printNames[i] := 'do              '; toktable[i] := dosy;    i := i+1;
  printNames[i] := 'od              '; toktable[i] := odsy;    i := i+1;
  printNames[i] := 'qes             '; toktable[i] := qessy;   i := i+1;
  printNames[i] := 'fun             '; toktable[i] := funsy;   i := i+1;
  printNames[i] := 'nuf             '; toktable[i] := nufsy;   i := i+1;
  printNames[i] := '(               '; toktable[i] := lparsy;  i := i+1;
  printNames[i] := ')               '; toktable[i] := rparsy;  i := i+1;
```

```
// initNames - place all pre-defined (built in) names into printNames
// and corresponding token symbols in toktable. user-defined names
// (functions, variables) are also kept here
void initNames()
{
   int i;

   fundefs = 0;   //empty list of fundefs
   firstControlOp = i = 0;
   printNames[i] = "if";     toktable[i] = ifsy;     i = i+1;
   printNames[i] = "while"; toktable[i] = whilesy;  i = i+1;
   printNames[i] = ":=";     toktable[i] = assignsy; i = i+1;

   lastControlOp = i;
   printNames[i] = "seq";   toktable[i] = seqsy;    i = i+1;

   firstValueOp = i;
   printNames[i] = "+";     toktable[i] = addsy;   i = i+1;
   printNames[i] = "-";     toktable[i] = subsy;   i = i+1;

// To handle negative numbers (unary minus), we build an APEXP with the
// multiply operator and operand -1. Below we save the multiply symbol
// index so we can insert it into the APEXP later.

   mulsy_index = i;
   printNames[i] = "*";     toktable[i] = mulsy;   i = i+1;
   printNames[i] = "/";     toktable[i] = divsy;   i = i+1;
   printNames[i] = "=";     toktable[i] = eqsy;    i = i+1;
   printNames[i] = "<";     toktable[i] = lssy;    i = i+1;
   printNames[i] = ">";     toktable[i] = gtsy;    i = i+1;

   lastValueOp = i;
   printNames[i] = "print"; toktable[i] = printsy;  i = i+1;
   printNames[i] = "quit";  toktable[i] = quitsy;   i = i+1;
   printNames[i] = "then";  toktable[i] = thensy;   i = i+1;
   printNames[i] = "else";  toktable[i] = elsesy;   i = i+1;
   printNames[i] = "fi";    toktable[i] = fisy;     i = i+1;
   printNames[i] = "do";    toktable[i] = dosy;     i = i+1;
   printNames[i] = "od";    toktable[i] = odsy;     i = i+1;
   printNames[i] = "qes";   toktable[i] = qessy;    i = i+1;
   printNames[i] = "fun";   toktable[i] = funsy;    i = i+1;
   printNames[i] = "nuf";   toktable[i] = nufsy;    i = i+1;
   printNames[i] = "(";     toktable[i] = lparsy;   i = i+1;
   printNames[i] = ")";     toktable[i] = rparsy;   i = i+1;
```

```
   printNames[i] := ';                ';toktable[i] := semsy;   i := i+1;
   printNames[i] := ',                ';toktable[i] := comsy;   i := i+1;
   printNames[i] := '$                 '; toktable[i] := dollarsy;
   numNames := i;
   numBuiltins := i
end; (* initNames *)

(* initCmds -  place all pre-defined commands into printCmds  *)
procedure initCmds;

var i: integer;
begin
   i := 1;
   printCmds[i] := 'sload   '; sload  := i; i := i+1;
   printCmds[i] := 'load    '; load   := i; i := i+1;

(* printCmds[i] := 'xxxxxx  '; xxxxxx := i; i := i+1; *)
end;  (* of initCmds *)

(* prName - print name nm                                    *)
procedure prName (nm: NAME);
var i: integer;
begin
   i := 1;
   while i <= NAMELENG
   do if printNames[nm][i] <> ' '
      then begin
             write(printNames[nm][i]);
             i := i+1
           end
      else i := NAMELENG+1  (* exit while loop *)
end; (* prName *)
```

```
(* install - insert new name into printNames                 *)

function install (nm: NAMESTRING): NAME;
var
   i: integer;

   found: Boolean;
begin
   i := 1;
   found := false;
```

```
   printNames[i] = ";";    toktable[i] = semsy;    i = i+1;
   printNames[i] = ",";    toktable[i] = comsy;    i = i+1;
   printNames[i] = "$";    toktable[i] = dollarsy; i = i+1;

   numNames = numBuiltins = i;  // no. of entries in 0 to numBuiltins-1
} // initNames

// initCmds - place all pre-defined commands into printCmds
void initCmds()
{
   short int i;

   i = 0;
   printCmds[i] = "sload"; sload = i; i = i+1;
   printCmds[i] =  "load";  load = i; i = i+1;
   printCmds[i] =  "user";  user = i; i = i+1;
   numCmds = i;
} //initCmds

// prName - print name nm
void prName(NAME nm)
{
   printf("%s",printNames[nm]);
} // prName
```

DD: Following function implements command "user" which is for debugging

```
// prUserList - List user-defined names and token type id
void prUserList()
{
   int i;

   for(i = numBuiltins; i < numNames; i++)
   {
      printf("printNames[%d]= ", i);
      prName(i);
      printf("   toktable[%d]= %d\n", i, toktable[i]);
   }
} // prUserList

// install - insert new name into printNames, set its type in toktable
//         - save its type in toksy, return its index in printNames array
NAME install(char *nm)
{
   NAME i;
   int result;
   BOOLEAN found;

   i = 0;
   found = false;
```

```
  while (i <= numNames) and not found



  do if nm = printNames[i]
     then found := true

     else i := i+1;


  if not found
  then begin
         if i > MAXNAMES
         then begin
                writeln('No more room for names');
                goto 99
              end;
         numNames := i;
         printNames[i] := nm;
         toktable[i] := nameidsy
       end;
  toksy := toktable[i];   (* return token symbol in global var *)
  install := i
end; (* install *)


(* initParse - initialization of variables *)
procedure initParse;

begin
  initCmds;
  readfile:=false;
  echo := false;
  addops := [addsy,subsy];
  mulops := [mulsy,divsy];
  relops := [lssy,eqsy,gtsy];
  punctop := ['(', ')', '+', '-', '*', '/', ':', '=', '<', '>', ';', ',',
'$', COMMENTCHAR];
end;

(* primOp - translate NAME optr to corresponding BUILTINOP      *)
function primOp (optr: NAME): BUILTINOP;
var
   op: BUILTINOP;
   i: integer;
begin
   op := IFOP; (* N.B. IFOP is first value in BUILTINOPS *)
   for i := 1 to optr-1 do op := succ(op);
   primOp := op
end; (* primOp *)

(*****************************************************************
 *                     INPUT                                     *
 *****************************************************************)
```

```
   result = 0;

   while (i < numNames && !found)
   {
      result = strcmp(nm, printNames[i]);

      if (!result)
         found = true;
      else
         i = i+1;
   }

   if (!found)
   {
      if (i == MAXNAMES)
         errmsg(err_max_names, null_str, null_int);

      printNames[i] = malloc(sizeof(char *));  //alloc memory for a ptr
to char
      numNames = i + 1;
      strcpy(printNames[i], nm);  //insert name in printNames
      toktable[i] = nameidsy;    //set its type in toktable
   }
   toksy = toktable[i];   //save current token symbol type
   return i;   //return index of name
} // install


// initParse - initialization of variables
void initParse()
{

   readfile = echo = eoln = eof = dollarflag = false;
   userinput[0] = tokstring[0] = 0; //null terminate
   inputleng = tokleng = pos = 0;
}

//------------
// INPUT
//------------
```

DD: The functions parseCmd, parseName and isNumber each call the isDelim function below. parseCmd and parseName read chars until a delimiter is encountered in order to obtain the command/variable/function name. isNumber reads digits until a nondigit is encountered and requires that the nondigit be a delimiter for the number to be valid. Digits followed by non-delimiter chars are treated as names of variables or functions.

```
(* isDelim - check if c is a delimiter                          *)
function isDelim (c:char): Boolean;
begin
  isDelim := (c = ' ') or (c in punctop)
end;
```

```
// isDelim - check if c is a delimiter
BOOLEAN isDelim (char c)
{
   if (c == SPACE || strchr(punctop, c) != NULL)
      return true;
   else
      return false;
} // isDelim
```

```
(* skipblanks - return next non-blank position in userinput     *)
function skipblanks (p: integer): integer;
begin
   while userinput[p] = ' ' do p := p+1;
   skipblanks := p
end; (* skipblanks *)
```

```
// skipblanks - return next non-blank pos in userinput
int skipblanks (int p)
{
   while (userinput[p] == SPACE)
      p = p + 1;
   return p;
} // skipblanks
```

```
(* reader - read char's into userinput; be sure input not blank  *)
procedure reader;

(* readInput - read char's into userinput                        *)
   procedure readInput;

   var c: char;
```

DD: New code was added to the nextchar function below to deal with reading input chars from a file instead of the terminal.

DD: Global boolean variables eoln and eof are added to the C version to mimic the Pascal eoln and eof functions. The nextchar function below sets their values appropriately.

```
(* nextchar - read next char - filter tabs and comments. Also filter CR/LF
which were returned in input stream under WSL/Cygwin. *)
     procedure nextchar (var c: char);
     begin



       if readfile then
         begin
           read(infile,c);  (* read file *)
           if eof(infile) then
             begin
               readfile:=false;
               echo:=false;
```

```
// nextchar - read next char - filter tabs,LF, comments
//   Also filter CR/LF which were returned in input stream under WSL/Cygwin
char nextchar()
{
   int c;

   eoln = false;

   if (readfile)
   {

      if ((c = getc(infp)) == EOF) // read from file
      {
         readfile = false;
         echo = false;
         eoln = true;
         eof = true;
```

```
(*
The next line below assigns a '$' to c to mark the end of the input.
This causes the main prompt to be displayed. Displaying the continuation
```

```
prompt at EOF is undesirable because it would prohibit the user from
entering another load command since such commands are only checked for
in response to the main prompt.
*)
              c := DOLLAR;
              CLOSE(infile)
            end;
          if echo then write(c);

        end
      else
        read(c);  (* read standard input *)



(* Replace tab and eoln chars with space, skip comments *)
      if (c = chr(TABCODE)) or (c = chr(LINEFEED)) or (c = chr(CR))
      then c := ' '
      else if c = COMMENTCHAR then
          begin
            if readfile then

              while not eoln(infile) do
                begin
                  read(infile,c);
                  if echo then write(c)  (*echo comment *)
                end
            else
              while not eoln do read(c);


            c := ' '   (* replace eoln char *)
          end

    end; (* nextchar *)
```

```
          c = DOLLAR; // exit read loop in readDollar and readInput
          fclose(infp);
       }
       else if (echo)
          printf("%c", c); // echo char
    }
    else
       c = getc(stdin); // read from stdin

    if (c == LF)
       eoln = true;

// replace tab and eoln chars with space, skip comments
    if (c == TAB || c == LF || c == CR)
       c = SPACE;
    else if (c == COMMENTCHAR) // skip comment chars
    {
       if (readfile)
       {
          while ((c = getc(infp)) != LF)
             if (echo) printf("%c", c); // echo comment chars
          if (echo) printf("%c", c);    // echo LF

       }
       else
          while ((c = getc(stdin)) != LF)
             ;
       eoln = true;
       c = SPACE; // replace LF with space
    }
    return c;
} // nextchar
```

DD: The readDollar function below replaces readParens.
readInput used to call readParens to read chars until a closing right parenthesis was entered which marked the end of the current expr or fundef. Now readDollar is used to read until a dollar sign is entered which marks the completion of the current input.

```
(* readDollar - read char's, ignoring newlines, till '$' is read  *)
(*            '$' marks end of the fundef or expr that is being input *)
     procedure readDollar;
     var
       c: char;
     begin
       c := ' ';
       repeat

         if not readfile and eoln then write(PROMPT2);
```

```
// readDollar - read char's, ignoring newlines, till '$' is read
//            '$' marks END of the fundef or expr that is being input
void readDollar()
{
    char c = SPACE;
    char str[2]="";

    do
    {
       if (!readfile && eoln)
       {
```

```
          nextchar(c);
          pos := pos+1;
          if pos = MAXINPUT
          then begin
                 writeln('User input too long');
                 goto 99
               end;
          userinput[pos] := c
        until c = dollar;
        dollarflag := true;
      end; (* readDollar *)
```

DD: The next four functions, readCmd, parseCmd, parseCmdArg and processCmd handle reading, parsing and executing the new load and sload commands. If readInput detects a right parenthesis as first character of the input line then it calls processCmd (which calls the others) to open the file and set readfile to true. While readfile is true, the nextchar function will read input chars from the opened file instead of the terminal.

```
(* readCmd - read command line into userinput buffer for processing. *)
procedure readCmd;
var
 c:char;
begin
  c := ' ';
  while not eoln do  (* commands are assumed to be entered on one line *)
    begin
      pos:=pos+1;
      nextchar(c);
      userinput[pos]:=c;
    end;

  inputleng:=pos;
  if userinput[inputleng] = DOLLAR then
     inputleng := inputleng - 1;  (* exclude $ from command line, if any
*)
(*
  Next read removes the LF (under WSL) or CR (under Cygwin)
  that follows the $ in the input stream so it is not
  accepted as input once the main prompt is displayed
*)
  read(c)
end; (* of readCmd *)

(* parseCmd - return Cmd starting at userinput[pos] *)
function parseCmd: CMD;
var
   nm: CMDSTRING; (* array to accumulate characters *)
```

```
            printf(PROMPT2); //continuation prompt
            fflush(stdout);
         }
         c = nextchar();
         pos = pos+1;
         if (pos == MAXINPUT)
         {
            str[0] = c;     //last char read
            errmsg(err_input_len, str, MAXINPUT);
         }
         userinput[pos] = c;
      } while (c != DOLLAR);
      dollarflag = true;
} // readDollar
```

```
/* The next four functions, readCmdLine, parseCmdName, parseCmdNameArg
and processCmd handle reading, parsing and executing the new load and sload
commands. If readInput detects a right parenthesis as first character of
the input line then it calls processCmd (which calls the others) to open
the file and set readfile to true. While readfile is true, the nextchar
function will read input chars from the opened file instead of the terminal.
*/

// readCmdLine - read command line into userinput buffer.
//             When readInput detects RPAREN as first char of input,
//             it calls processCmd which calls readCmdLine to read
//             rest of the cmd line. On entry to this function,
//             pos==0 and userinput[0]==RPAREN.
void readCmdLine()
{
   char c = SPACE, *dollarPtr;


   while (!eoln)
   {
      c = nextchar(); // sets eoln true on LF & returns SPACE
      pos = pos + 1;
      userinput[pos] = c;
   }

// use dollar position (if any) or LF position to determine input length

   if ((dollarPtr = strchr(userinput, DOLLAR)) != NULL)
      inputleng = dollarPtr - userinput;
   else
      inputleng = pos;

} // readCmdLine



// parseCmdName - return Cmd starting at userinput[pos]
CMD parseCmdName()
{
   char nm[MAXCMDLENG+1]; // for accumulating characters in Cmd
```

```
   leng: CMDSIZE; (* length of CMD *)
   i:integer;
   found: Boolean;

begin
   nm[1] := #0;
   leng := 0;


   while (pos < inputleng) and not isDelim(userinput[pos])
   do begin
        if leng = CMDLENG
        then begin
               writeln('Command Name too long, begins: ', nm);
               goto 99
             end;
        leng := leng+1;
        nm[leng] := userinput[pos];
        pos := pos+1
      end;

   if leng = 0
   then begin
          writeln('Error: expected Command name, instead read: ',
                  userinput[pos]);
          goto 99
        end;
   for leng := leng+1 to CMDLENG do nm[leng] := ' ';



   i := 1;
   found := false;
   while (i <= NUMCMDS) and not found
   do
      if nm = printCmds[i]

      then found := true

      else i := i+1;


   if not found then
     begin
       writeln('Unrecognized Command Name  begins: ',nm);
       goto 99
     end;

   pos := skipblanks(pos); (* skip blanks after command name *)
   parseCmd := i;
end; (* parseCmd *)

(* parseCmdArg - return the character string argument starting at
userinput[pos]. This function is currently used to parse the filename
argument from the load & sload commands *)
function parseCmdArg: ARGSTRING;
```

```
   CMDSIZE leng;
   CMD i;
   BOOLEAN found;
   int result;

   nm[0] = 0;
   leng = 0;
   result = 0;
DD: Command names contain only alpha chars
   while (pos < inputleng && isalpha(userinput[pos]))
   {
      if (leng == MAXCMDLENG)
      {
         nm[leng] = 0;
         errmsg(err_cmd_len, nm, MAXCMDLENG);
      }
      nm[leng] = userinput[pos];
      leng = leng+1;
      pos = pos+1;
   }

   if (leng == 0)
      errmsg(err_no_cmd, null_str, null_int);




   nm[leng] = 0;  //null terminate Cmd name

// Determine Cmd index in printCmds

   i = 0;
   found = false;
   while (i < MAXCMDS && !found)
   {
      result = strcmp(nm, printCmds[i]);
      if (!result)
         found = true;
      else
         i = i+1;
   }

   if (!found)
      errmsg(err_bad_cmd, nm, null_int);




   pos = skipblanks(pos); /* skip blanks after command name */
   return i;
} // parseCmdName

/* parseCmdArg - return the character string argument starting at
   userinput[pos]. This function is currently used to parse the
   filename argument from the load & sload commands */
void parseCmdArg(char nm[])
```

```
var
   nm: ARGSTRING; (* array to accumulate characters *)
   leng: ARGSIZE; (* length of name *)
begin
   nm[1] := #0;
   leng := 0;
   while (pos <= inputleng) and not (userinput[pos] = ' ')
   do begin
        if leng = ARGLENG
        then begin
               writeln('Argument name too long, begins: ', nm);
               goto 99
             end;
        leng := leng+1;
        nm[leng] := userinput[pos];
        pos := pos+1
     end;

   if leng = 0
   then begin
          writeln('Error: expected argument name, instead read: ',
                 userinput[pos]);
          goto 99
        end;
   for leng := leng+1 to ARGLENG do nm[leng] := ' ';
   parseCmdArg := nm
end; (* parseCmdArg *)

(* processCmd - input, parse, and execute the command *)
procedure processCmd;
var
   i,j: integer;
   cmdnm:CMD;  (* cmdnm is an index to printCmds *)
begin
   readCmd;
   pos:=skipblanks(1);     (* get pos of ")" which begins each command *)
   pos:=skipblanks(pos+1); (* get pos of 1st letter of command name *)
   cmdnm:=parseCmd;
   if (cmdnm = sload) or (cmdnm = load) then
     begin
       infilename:=parseCmdArg;   (* parse filename argument *)

       i := 1;
       while (infilename[i] <> ' ') do
         i := i + 1;
       for j := i to ARGLENG do infilename[j] := #0;  (*Null padding fixes
File Not Found on WSL*)

       Assign(infile,infilename);
       RESET(infile);

       writeln;
       writeln('Current Directory is : ',GetCurrentDir);
```

```
{
   ARGSIZE leng;   // length of argumnet name


   nm[0] = 0;
   leng = 0;
   while (pos < inputleng && userinput[pos] > SPACE)
   {
      if (leng == ARGLENG)
      {
         nm[leng] = 0;
         errmsg(err_arg_len, nm, ARGLENG);
      }
      nm[leng] = userinput[pos];
      leng = leng+1;
      pos = pos+1;
   }

   if (leng == 0)
      errmsg(err_no_name, null_str, null_int);




   nm[leng] = 0;  //null terminate string
} // parseCmdArg

// processCmd - input, parse, and execute the command
void processCmd()
{
   char cwd[PATH_MAX];
   CMD cmdnm;  // cmdnm is an index to printCmds

   readCmdLine();
   pos = 1;              // pos of 1st letter of command name

   cmdnm = parseCmdName();  // parse command name
   if (cmdnm == sload || cmdnm == load)
   {
      parseCmdArg(infilename);   // parse filename argument



      // Load commands cannot be issued inside another file being loaded.
      if (!readfile) //if not already loading a file
      {
         if ((infp = fopen(infilename, "r")) == NULL)
            errmsg(err_open, null_str, null_int);

         if (getcwd(cwd, sizeof(cwd)) != NULL)
            printf("\nCurrent Directory is: %s\n", cwd);
         else
            errmsg(err_cwd, null_str, null_int);
```

```
      writeln(' Loading file : ',infilename);
      writeln;
      readfile:=true;  (* tell nextchar function to read from file *)

      if cmdnm = load then
        echo:=true;
    end;
end;  (* of processCmd *)
```

```
  begin (* readInput *)

    c := ' ';


    dollarflag := false;


    if not readfile then write(PROMPT);


    pos := 0;
    repeat


      pos := pos+1;
      if pos = MAXINPUT
      then begin
             writeln('User input too long');
             goto 99
         end;
      nextchar(c);
      userinput[pos] := c;

      if (pos=1) and (c=')') then   (* if command, execute it*)
        begin
          processCmd;
          if not readfile then write(PROMPT);




          pos:=0
        end
      else (* otherwise read expr or fundef terminated by dollar *)

          if userinput[pos] = dollar then
            dollarflag:=true
          else
            if readfile then
              begin
```

```
          printf(" Loading file : %s\n\n",infilename);

          readfile = true;      // tell nextchar to read from file
          eof = false;
          if (cmdnm == load)
             echo = true;      // remains false for sload (silent load)
       }
       else //error on nested load cmds
          errmsg(err_nested_load, infilename, null_int);
    }
    if (cmdnm == user)
       prUserList();   // display user-defined entries
}  // processCmd

// readInput - read char's into userinput array until dollar sign is input
void readInput()
{
    char c = SPACE;
    char str[2]="";

    dollarflag = false;
    if (!readfile)
    {
       printf(PROMPT);  //display main prompt for new input
       fflush(stdout);
    }
    pos = -1;
    do
    {
       c = nextchar();
       pos = pos+1;
       if (pos == MAXINPUT)
       {
          str[0] = c;     //last char read
          errmsg(err_input_len, str, MAXINPUT);
       }

       userinput[pos] = c;
// parse a command or fundef or expression
       if (pos == 0 && c == RPAREN)  // If it's a cmd (e.g. load or sload)
       {
          processCmd();  //opens file, sets echo
          if (!readfile)
          {
             printf(PROMPT); // redisplay main prompt after a cmd
             fflush(stdout);
          }
          pos = -1;  //restart userinput index
       }
       else //parse fundef or expression
       {
          if (userinput[pos] == DOLLAR)
             dollarflag = true;
          else
```

```
              if eoln(infile) then readDollar
             end
           else (* reading stdin *)
             if eoln then readDollar
    until dollarflag;

    pos:=pos-1;  (* exclude $ from user input *)
    inputleng := pos;
    if readfile and echo then writeln (* echo LF between inputs *)
  end; (* readInput *)




begin (* reader *)

   repeat

     readInput;
     pos := skipblanks(1);


   until pos <= inputleng (* ignore blank lines *)
end; (* reader *)



(* parseName - return (installed) NAME starting at userinput[pos]*)
function parseName: NAME;
var
  nm: NAMESTRING; (* array to accumulate characters *)
  leng: NAMESIZE; (* length of name *)
begin
  nm[1] := #0;
  leng := 0;
  while (pos <= inputleng) and not isDelim(userinput[pos])
  do begin
       if leng = NAMELENG
       then begin
              writeln('Name too long, begins: ', nm);
              goto 99
            end;
       leng := leng+1;
       nm[leng] := userinput[pos];
       tokstring[leng]:=userinput[pos];
       pos := pos+1
    end;
  tokleng:=leng;
  if leng = 0
  then begin
         writeln('Error: expected name, instead read: ',
                userinput[pos]);
         goto 99
     end;
```

```
            if (eoln) readDollar();
        }


    } while (!dollarflag);


    inputleng = pos; // pos of '$' is length of input in 0 to pos-1

    //remove LF and any other chars that follow dollar sign from input buffer
    while (!eoln)
        c = nextchar(); // sets eoln true on LF & returns SPACE
} // readInput

// reader - read char's into userinput; be sure input is not blank
void reader()
{
    do
    {
        readInput();              // read input into userinput array
        pos = skipblanks(0);      // advance to first non-blank
        if (userinput[pos] == DOLLAR) // if it is '$' then
            inputleng = 0;            // it is a blank line
    } while (inputleng == 0); // ignore blank lines
} // reader


NAME install(char *); // forward declaration

// parseName - return (installed) NAME starting at userinput[pos]
NAME parseName()
{
    char nm[NAMELENG+1]; // array to accumulate characters
    NAMESIZE leng; // length of name

    nm[0] = tokstring[0] = 0;
    leng = 0;
    while (pos < inputleng && !isDelim(userinput[pos]))
    {
        if (leng == NAMELENG)
        {
            nm[leng] = 0;
            errmsg(err_name_len, nm, NAMELENG);
        }
        nm[leng] = tokstring[leng] = userinput[pos];
        leng = leng+1;
        pos = pos+1;
    }


    if (leng == 0)
        errmsg(err_no_name2, null_str, null_int);
```

```
  for leng := leng+1 to NAMELENG do nm[leng] := ' ';

  pos := skipblanks(pos); (* skip blanks after name *)
  parseName := install(nm)
end; (* parseName *)
```

```
(* isNumber - check if a number begins at pos                *)
function isNumber (pos: integer): Boolean;

(* isDigits - check if sequence of digits begins at pos        *)
  function isDigits (pos: integer): Boolean;
  begin
    if not (userinput[pos] in ['0'..'9']) then
      isDigits := false
    else
      begin
        isDigits := true;
        while userinput[pos] in ['0'..'9'] do pos := pos + 1;
        if not isDelim(userinput[pos])
        then isDigits := false
      end
  end; (* isDigits *)

begin (* isNumber *)
  isNumber := isDigits(pos)
end; (* isNumber *)

(* parseVal - return number starting at userinput[pos]         *)
function parseVal: NUMBER;

var n: integer;

Begin

  n := 0;
  tokleng:=0;
  while userinput[pos] in ['0'..'9'] do
    begin
      n := 10*n + (ord(userinput[pos]) - ord('0'));
      tokleng:=tokleng+1;
      tokstring[tokleng]:=userinput[pos];
      pos := pos+1
    end;

  pos := skipblanks(pos); (* skip blanks after number *)
  parseVal := n
```

```
   nm[leng] = tokstring[leng] = 0;  //null terminate
   tokleng = leng;
   pos = skipblanks(pos); /* skip blanks after name */
   return install(nm);
} // parseName


// isNumber - check if a number begins at userinput[i]
//          It must be a sequence of digits followed by a delimiter
//          otherwise it will be treated as a name.
//          E.g. 232+ is parsed as the number 232 followed by a plus sign.
//          but 232abc is parsed as a name since the digits are not
//          followed by a delimiter.
BOOLEAN isNumber(short int i)
{



   if (!isdigit(userinput[i]))
      return false;
   else
   {

      while (isdigit(userinput[i])) i = i + 1;
      if (isDelim(userinput[i]))
         return true;
      else
         return false;
   }


} // isNumber

// parseVal - return number starting at userinput[pos]
NUMBER parseVal()
{
   NUMBER n;
   char numString[MAXDIGITS+1]; //digits in value being parsed

   numString[0] = tokstring[0] = 0;
   n = 0;
   tokleng = 0;
   while (isdigit(userinput[pos]) && tokleng < MAXDIGITS)
   {
      n = 10*n + (userinput[pos] - '0');
      numString[tokleng] = tokstring[tokleng] = userinput[pos];
      tokleng = tokleng+1;
      pos = pos+1;
   }
   numString[tokleng] = tokstring[tokleng] = 0; // null terminate

   if (isdigit(userinput[pos]))
      errmsg(err_digits, null_str, MAXDIGITS); // Too many digits

   pos = skipblanks(pos); //skip any blanks after number
   return n;
```

```
end; (* parseVal *)

(*****************************************************************
                    NEW PARSING ROUTINES
 *****************************************************************)

(* writeTokenName - write the specific token name in printnames array
   that corresponds to token symbol t.  If t is generic (i.e. nameidsy,
   funidsy,numsy) then write that generic name *)
procedure writeTokenName(t:token);
var
 i:NAME;
 generic:set of token;
 j:NAMESIZE;
begin
 generic := [nameidsy,numsy,funidsy];
 if t in generic then
(* output generic name *)
   begin
    case t of
      nameidsy:write('nameid');


       numsy:write('number');


      funidsy:write('funid');


      otherwise;
    end;
   end
 else
(* output specific name *)
  begin
    i:=1;
    while (toktable[i] <> t) and (i <= numBuiltins) do
      i:= i+1;
    if i <= numBuiltins then
    (* write the name of the token *)
      begin
        j:=1;
        while (printNames[i][j] <> ' ') and (j <= NAMELENG) do
          begin
            write(printNames[i][j]);
            j:=j+1
          end
      end
    else   (* name not found, write the symbolic name *)
      write(t)
  end
end;  (* of writeTokenName *)

(* writeTokenString - Write out chars of token string. During errors, this
function is used to display invalid string found in the userinput *)
procedure writeTokenString;
```

```
}  //parseVal

//----------------------
// NEW PARSING ROUTINES
//----------------------

// writeTokenName - Display the name corresponding to token symbol t.


void writeTokenName(TOKEN t)
{
   NAME i;




   if (t == nameidsy || t == numsy || t == funidsy)
      // display generic name for user-defined symbols
      switch (t)
      {
         case nameidsy:
            printf("nameid");
            break;
         case numsy:
            printf("number");
            break;
         case funidsy:
            printf("funid");
            break;
         default:
            break;
       }
   else
   {
   // display builtin name
      i = 0;
      while (toktable[i] != t && i < numBuiltins)
         i = i+1;
      if (i < numBuiltins)
         // write the name of the token




         printf("%s", printNames[i]);



      else  // name not found, display token id
         printf("name not found for token %d", t);
   }
}  // of writeTokenName

// writeTokenStr - Display token string. During errors, this function
// is used to display the invalid token found in userinput.
void writeTokenStr()
```

```
var
 i:integer;
begin
 for i:= 1 to tokleng do
   write(tokstring[i]);
 write(' ');
end;


(* displays error messages based on the given error number *)
procedure errmsg(errnum:integer);
begin
  writeln;
  CASE errnum of

    1:begin
       write('Error parsing arglist.  Found ');
       writeTokenString;
       writeln('where ")" or nameid is expected.');
      end;
    2:begin
       write('Error parsing function name.  Found ');
       writeTokenString;
       writeln('funid or nameid is expected.');
      end;
    3:begin
       write('Error parsing exp6.  Found ');
       writeTokenString;
       writeln('where nameid, funid, "(", or a number  is expected.');
      end;
    4:begin
       write('Error parsing expr.  Found ');
       writeTokenString;
       writeln('where one of the following is expected: ');
       writeln('"if", "while", "seq", "print", nameid, funid, number, or
"(" ');
      end;
    otherwise;
  end;
  writeln;
  goto 99
end;  (* of errmsg *)
```

```
{
   printf("%s ", tokstring);
} // writeTokenStr


DD: All error messages in the Pascal version were given an error code and
are now displayed by calling the errmsg() function below.

// errmsg - display error message for given error number and jump to JL99
// in main function
void errmsg(ERROR_NUM errnum, char err_str[], int err_int)
{
   printf("*****");
   switch (errnum)
   {
      case err_arglist:
         printf("Error parsing arglist.  Found ");
         writeTokenStr();
         printf("where \")\" or nameid is expected.");
         break;
      case err_function:
         printf("Error parsing function name.  Found ");
         writeTokenStr();
         printf("where funid or nameid is expected.");
         break;
      case err_exp6:
         printf("Error parsing exp6.  Found ");
         writeTokenStr();
         printf("where nameid, funid, \"(\", or a number is expected.");
         break;
      case err_expr:
         printf("Error parsing expr.  Found ");
         writeTokenStr();
         printf("where one of the following is expected:\n");
         printf("\"if\", \"while\", \"seq\", \"print\", nameid, funid,
number, or \"(\"");
         break;
      case err_cwd:
         perror("getcwd() error");
         break;
      case err_open:
         perror("fopen() error");
         break;
      case err_max_names:
         printf("No more room for names");
         break;
      case err_input_len:
         printf("Input exceeds %d chars. Last char read = %s", err_int,
err_str);
         printf("\nSkipping rest of input and quitting.");
         quittingtime = true;
         if (readfile) fclose(infp);
         break;
      case err_cmd_len:
         printf("Command Name exceeds %d chars, begins: %s", err_int,
err_str);
```

```
            break;
         case err_no_cmd:
            printf("Error: expected Command name, instead read: %c",
userinput[pos]);
            break;
         case err_bad_cmd:
            printf("Unrecognized Command Name, begins: %s", err_str);
            break;
         case err_arg_len:
            printf("Argument name exceeds %d chars, begins: %s", err_int,
err_str);
            break;
         case err_no_name:
            printf("Error: expected name, instead read: %c",
userinput[pos]);
            break;
         case err_name_len:
            printf("Name exceeds %d chars, begins: %s", err_int, err_str);
            break;
         case err_no_name2:
            printf("Error: expected name, instead read: %c",
userinput[pos]);
            break;
         case err_digits:
            printf("parseVal: Max digits allowed in 64 bit signed long
is %d", err_int);
            break;
         case err_no_name3:
            printf("mutate: found ");
            writeTokenStr();
            printf(" where nameid or funid is expected.");
            break;
         case err_mismatch:
            printf("Error in match. Found ");
            writeTokenStr();
            printf(" where ");
            writeTokenName(err_int);
            printf(" is expected.");
            break;
         case err_not_var:
            printf("parseExp1: left hand side of assignment must be a
variable");
            break;
         case err_num_args:
            printf("Wrong number of arguments to ");
            prName(err_int);
            break;
         case err_undef_func:
            printf("Undefined function: ");
            prName(err_int);
            break;
         case err_num_args2:
            printf("Wrong number of arguments to: ");
            prName(err_int);
            break;
         case err_undef_var:
```

```
                                                          printf("Undefined variable: ");
                                                          prName(err_int);
                                                          break;
                                                       case err_undef_op:
                                                          printf("eval: invalid value for op = %d", err_int);
                                                          break;
                                                       case err_nested_load:
                                                          printf("Load commands cannot occur inside a file being
loaded.\n");
                                                          printf("*****");
                                                          printf("Remove the load command for file %s", err_str);
                                                          quittingtime = true;
                                                          fclose(infp);
                                                       default:
                                                          break;
                                                    }
                                                    printf("\n\n");
                                                    longjmp(JL99, errnum);
                                                 }  // errmsg
```

```
(* Identify token that begins at userinput[pos], return its symbol in
global variable toksy and leave pos pointing to first nonblank that
follows. *)
procedure getToken;
var
   nm: NAMESTRING; (* array to accumulate characters *)
   leng: NAMESIZE; (* length of name *)

begin
  if isNumber(pos) then   (* parse a number *)
    begin
      numval := parseVal;
      toksy := numsy
    end

  else if (userinput[pos] = ':') and (userinput[pos+1] = '=') then
   (* parse an assignment *)
    begin
      leng := 2;
      nm[1] := ':';
      nm[2] := '=';

      tokleng := leng;
      tokstring[1] := ':';
      tokstring[2] := '=';

      pos := pos + 2;
      for leng := leng+1 to NAMELENG do nm[leng] := ' ';
      pos := skipblanks(pos);
      tokindex := install(nm);
      toksy := toktable[tokindex]
    end
  else if userinput[pos] in punctop then
(* parse single char punct or operator *)
    begin
```

```
// getToken - get next token in userinput, set toksy, tokstring, tokleng.
//  For names and operators, also set tokindex. For numbers, tokindex does
//  not apply since they are not stored in printNames.
void getToken()
{
   char nm[2]; // array to accumulate characters

   nm[0] = tokstring[0] = 0;

   if (isNumber(pos))  // parse a number
   {
      numval = parseVal(); // set tokstring, tokleng
      toksy = numsy;
   }

   else if (userinput[pos] == ':' && userinput[pos+1] == '=')
   // parse an assignment
   {
      tokleng = 2;
      nm[0] = tokstring[0] = ':';
      nm[1] = tokstring[1] = '=';
      nm[2] = tokstring[2] = 0;




      pos = pos + 2;

      pos = skipblanks(pos);
      tokindex = install(nm); // set toksy
   }

   else if (strchr(punctop, userinput[pos]) != NULL)
   // parse single char punctuation or operator
   {
```

```
     leng := 1;
     nm[1] := userinput[pos];

     tokleng := leng;
     tokstring[1] := userinput[pos];

     pos := pos + 1;
     for leng := leng+1 to NAMELENG do nm[leng] := ' ';
     pos := skipblanks(pos);
     tokindex := install(nm);
     toksy := toktable[tokindex]
    end

  else    (* else parse a name *)
    tokindex := parseName
end; (* getToken *)

(* change nameidsy to funidsy or vice versa *)


procedure mutate(newtype:token);
begin
  if (toksy <> nameidsy) and (toksy <> funidsy) then
    begin
      write('mutate: found ');
      writeTokenString;
      writeln(' where nameid or funid is expected.');
      goto 99
    end
  else
    toktable[tokindex] := newtype
end;   (* of mutate *)

(* match the expected token t and get next one.
Explanation: If the expected token t matches the current one in toksy
then call getToken to return the next token from userinput in toksy *)
procedure match(t:token);
begin
   if toksy = t then
     getToken
   else
     begin
       write('Error in match. Found ');
       writeTokenString;
       write(' where ');
       writeTokenName(t);
       writeln(' is expected.');
       goto 99
     end;
end;  (* of match *)

(* parse parameters of a fundef *)
function parseParams:NAMELIST;
var
   nm:NAME;
   nl:NAMELIST;
```

```
       tokleng = 1;
       nm[0] = tokstring[0] = userinput[pos];
       nm[1] = tokstring[1] = 0;   // null terminate 1 char string



       pos = pos + 1;

       pos = skipblanks(pos);
       tokindex = install(nm);  // set toksy
    }


    else  // else assume it is a name
       tokindex = parseName();  // set toksy, tokstring, tokleng
} // getToken

// mutate - Change type of toksy in toktable to newtype.
// This function is currently used to redefine a variable name (nameidsy)
// as a function name (funidsy)
void mutate(TOKEN newtype)
{
    if (toksy != nameidsy && toksy != funidsy)
       errmsg(err_no_name3, null_str, null_int);




    else
       toktable[tokindex] = toksy = newtype;
} // of mutate

// match - If the expected token t matches the current one in toksy
//         then call getToken() to get the next toksy
//         else print mismatch error
void match(TOKEN t)
{
     if (toksy == t)
        getToken();
     else
        errmsg(err_mismatch, null_str, t);
} // match




// parse parameters of a function definition
NAMELIST parseParams()
{
    NAME nm;
    NAMELIST nl;
```

```
begin
   CASE toksy of

    rparsy:  parseParams := nil;


    nameidsy: begin
              nm:=tokindex;
              match(nameidsy);
              if toksy = comsy then
                begin
                  match(comsy);
                  nl:=parseParams
                end
              else
                nl:=nil;
              parseParams := MkNamelist(nm,nl)
            end;
    otherwise;
        errmsg(1)
   end
end;  (* of parseParams *)



function parseExpr:EXP;forward;

(* parseDef - parse function definition at userinput[pos]       *)

function parseDef:NAME;
var
   fname: NAME;       (* function name *)
   nl: NAMELIST;      (* formal parameters *)
   e: EXP;           (* body *)
begin
   match(funsy);

   mutate(funidsy);
   fname := tokindex;

   CASE toksy of

    nameidsy:match(nameidsy);

    funidsy:match(funidsy);



    otherwise;
      errmsg(2)
   end;

   match(lparsy);
   nl := parseParams;
   match(rparsy);
   match(assignsy);
```

```
   switch (toksy)
   {
      case rparsy:     // end of list, return null
         nl = 0;
         break;
      case nameidsy:
         nm = tokindex;
         match(nameidsy);
         if (toksy == comsy)  // recursively parse remainder of list
         {
            match(comsy);
            nl = parseParams();
         }
         else
            nl = 0;
         nl = mkNamelist(nm, nl);
         break;
      default:
         errmsg(err_arglist, null_str, null_int);
         break;
   }
   return nl;
}  // parseParams

EXP parseExpr(void); //forward declaration

// parseDef - parse function definition at userinput[pos]
// syntax: fun fun_name(arglist):=eL nuf
NAME parseDef()
{
    NAME fname;       // function name
    NAMELIST nl;      // formal parameters
    EXP e;           // body

    match(funsy);    // match "fun" and get next toksy



    switch (toksy)   // match name
    {
       case nameidsy:
         mutate(funidsy); // set type to funidsy & do case funidsy
       case funidsy:
         fname = tokindex; // save name index for use below
         match(funidsy);
         break;
       default:
         errmsg(err_function, null_str, null_int);
         break;
    }
    match(lparsy);
    nl = parseParams();
    match(rparsy);
    match(assignsy);
```

```
   e := parseExpr;
   match(nufsy);
   newDef(fname, nl, e);
   parseDef := fname
end; (* parseDef *)

(* parse arguments of a function call *)
function parseArgs:EXPLIST;
var
  ex:EXP;
  eL:EXPLIST;
begin
  if toksy = rparsy then
    parseArgs := nil
  else
    begin
      ex:=parseExpr;
      if toksy = comsy then
        begin
          match(comsy);
          eL := parseArgs
        end
      else
        eL := nil;
      parseArgs := mkEXPLIST(ex,eL)
    end
end; (* of parseArgs *)

(* parse a function call *)

function parseCall:EXP;
var
  eL:EXPLIST;
  nm:NAME;
begin
  nm:=tokindex;
  match(funidsy);
  match(lparsy);
  eL := parseArgs;
  match(rparsy);
  parseCall := mkAPEXP(nm,eL)
end; (* parseCall *)

(* parse an expression list separated by semicolons *)
function parseEL:EXPLIST;
var
  ex:EXP;
  eL:EXPLIST;
begin
  ex:=parseExpr;
  if toksy = semsy then
    begin
      match(semsy);
      eL := parseEL
    end
  else
```

```
    e = parseExpr();
    match(nufsy);
    newDef(fname, nl, e);
    return fname;
} // parseDef

// parse arguments of a function call
EXPLIST parseArgs()
{
   EXP e;
   EXPLIST eL;

   if (toksy == rparsy)     // RPAREN marks end of arg list
      return 0;
   else
   {
      e = parseExpr();
      if (toksy == comsy)   // recursively parse rest of arg list
      {
         match(comsy);
         eL = parseArgs();
      }
      else
         eL = 0;
      return mkExplist(e,eL);
   }
} // parseArgs

// parse function call
// syntax: f(e1,e2, . . . , en)
EXP parseCall()
{
   EXPLIST eL;
   NAME nm;

   nm = tokindex;
   match(funidsy);
   match(lparsy);
   eL = parseArgs();
   match(rparsy);
   return mkAPEXP(nm,eL);
} /* parseCall */

// parseExplist - parse expression list
EXPLIST parseExplist()
{
   EXP e;
   EXPLIST eL;

   e = parseExpr();
   if (toksy == semsy)
   {
      match(semsy);
      eL = parseExplist();
   }
   else
```

```
   eL := nil;
  parseEL := mkExplist(ex,eL)
end;  (* parseEL *)

(* parse an if expression *)

function parseIf:EXP;
var
  e1,e2,e3:EXP;
  eL:EXPLIST;
  nm:NAME;
begin
  nm := tokindex;
  match(ifsy);
  e1 := parseExpr;
  match(thensy);
  e2 := parseExpr;
  match(elsesy);
  e3 := parseExpr;
  match(fisy);
  eL := mkExplist(e3,nil);
  eL := mkExplist(e2,eL);
  eL := mkExplist(e1,eL);
  parseIf := mkAPEXP(nm,eL)
end; (* parseIf *)

(* parse a while expression *)

function parseWhile:EXP;
var
  e1,e2:EXP;
  eL:EXPLIST;
  nm:NAME;
begin
  nm := tokindex;
  match(whilesy);
  e1 := parseExpr;
  match(dosy);
  e2 := parseExpr;
  match(odsy);
  eL := mkExplist(e2,nil);
  eL := mkExplist(e1,eL);
  parseWhile := mkAPEXP(nm,eL)
end; (* parseWhile *)

(* parse a sequence expression *)
function parseSeq:EXP;
var
  eL:EXPLIST;
  nm:NAME;
begin
  nm := tokindex;
  match(seqsy);
  eL := parseEL;
  match(qessy);
  parseSeq := mkAPEXP(nm,eL)
```

```
      eL = 0;
   return mkExplist(e,eL);
} // parseExplist

// parse if expression
// syntax: if e1 then e2 else e3 fi
EXP parseIf()
{
   EXP e1,e2,e3;
   EXPLIST eL;
   NAME nm;

   nm = tokindex;
   match(ifsy);
   e1 = parseExpr();
   match(thensy);
   e2 = parseExpr();
   match(elsesy);
   e3 = parseExpr();
   match(fisy);
   eL = mkExplist(e3,0);
   eL = mkExplist(e2,eL);
   eL = mkExplist(e1,eL);
   return mkAPEXP(nm,eL);
} // parseIf

// parse while expression
// syntax: while e1 do e2 od
EXP parseWhile()
{
   EXP e1,e2;
   EXPLIST eL;
   NAME nm;

   nm = tokindex;
   match(whilesy);
   e1 = parseExpr();
   match(dosy);
   e2 = parseExpr();
   match(odsy);
   eL = mkExplist(e2,0);
   eL = mkExplist(e1,eL);
   return mkAPEXP(nm,eL);
} // parseWhile

// parse sequence expression
EXP parseSeq()
{
   EXPLIST eL;
   NAME nm;

   nm = tokindex;
   match(seqsy);
   eL = parseExplist();
   match(qessy);
   return mkAPEXP(nm,eL);
```

```
end; (* parseSeq *)

(*
   The following functions (parseExp1 through parseExp6) implement the
   following grammar rules.

   exp1 -→ exp2 [ :=  exp1 ]*
   exp2 -→ [ prtop ] exp3
   exp3 -→ exp4 [ relop exp4 ]*
   exp4 -→ exp5 [ addop exp5 ]*
   exp5 -→ [ addop ] exp6 [ mulop exp6 ]*
   exp6 -→ name | integer | funcall | ( expr )

   The recursive structure of these rules yields the following list from
   lowest to highest precedence:

     :=
     prtop
     relop
     addop
     unary addop, mulop
     variable name, integer, function call, expression in parentheses

   Since the functions call each other recursively, they are implemented
   in reverse order below to avoid forward declarations.
*)

(* parse var name, integer, function call, parenthesized expression *)
function parseExp6:EXP;
var
    ex:EXP;
  varnm:NAME;
   num:NUMBER;
begin
  case toksy of

   nameidsy:begin
            varnm:=tokindex;
            match(nameidsy);
            ex:=mkVAREXP(varnm)
          end;
    numsy:begin
            num:=numval;
            match(numsy);
            ex:=mkVALEXP(num)
          end;
   lparsy:begin
            match(lparsy);
            ex:=parseExpr;
            match(rparsy)
          end;
   funidsy: ex:=parseCall;


  otherwise;
     errmsg(3)
```

```
} // parseSeq

/*
   The following functions (parseExp1 through parseExp6) implement the
   following grammar rules.

   exp1 -→ exp2 [ :=  exp1 ]*
   exp2 -→ [ prtop ] exp3
   exp3 -→ exp4 [ relop exp4 ]*
   exp4 -→ exp5 [ addop exp5 ]*
   exp5 -→ [ addop ] exp6 [ mulop exp6 ]*
   exp6 -→ name | integer | funcall | ( expr )

   The recursive structure of these rules yields the following precedence
   from lowest to highest:

     :=
     prtop
     relop
     addop
     unary addop, mulop
     variable name, integer, function call, expression in parentheses

   Since the functions call each other recursively, they are implemented
   in reverse order below to avoid forward declarations.
*/

// parse variable name, integer, parenthesized expr, function call
EXP parseExp6()
{
    EXP ex;
    NAME varnm;
    NUMBER num;

    switch (toksy)
    {
        case nameidsy:
            varnm = tokindex;
            match(nameidsy);
            ex = mkVAREXP(varnm);
            break;
        case numsy:
            num = numval;
            match(numsy);
            ex = mkVALEXP(num);
            break;
        case lparsy:
            match(lparsy);
            ex = parseExpr();
            match(rparsy);
            break;
        case funidsy:
            ex = parseCall();
            break;
        default:
            errmsg(err_exp6, null_str, null_int);
```

```
  end; (* case *)
  parseExp6 := ex    (* return ptr to an expression *)
end;  (* parseExp6 *)

(* parse unary addop, binary mulop *)
function parseExp5:EXP;
var
  nm:NAME;
  ex,e1,e2:EXP;
  eL:EXPLIST;
  addop_token:token;
  sign:NUMBER;
begin
  addop_token:=dollarsy; (* Initialize so prior value is not reused.
                            E.g. for -10-7$, after negating 10,
                             7 was incorrectly negated. *)

  if toksy in addops then (* unary + or - *)
    begin
      addop_token:=toksy;
      match(toksy)
    end;

  e1:=parseExp6;

  if addop_token = subsy then
  (* for unary minus, make an expr to multiply e1 by -1 *)
    begin
      sign:=-1;
      ex:=mkVALEXP(sign);
      eL:=mkExplist(ex,nil);
      eL:=mkExplist(e1,eL);
      nm:=mulsy_index;
      e1:=mkAPEXP(nm,eL)
    end;

  while toksy in mulops do
    begin
      nm:=tokindex;
      match(toktable[nm]);
      e2:=parseExp6;
      eL:=mkExplist(e2,nil);
      eL:=mkExplist(e1,eL);
      e1:=mkAPEXP(nm,eL)
    end;
  parseExp5:=e1;
end;  (* parseExp5 *)

(* parse binary addop *)
function parseExp4:EXP;
var
  nm:NAME;
  e1,e2:EXP;
  eL:EXPLIST;
begin
```

```
            break;
    }
    return ex;    // return pointer to expression
} // parseExp6

// parse unary addop, binary mulop
EXP parseExp5()
{
    NAME nm;
    EXP ex,e1,e2;
    EXPLIST eL;
    TOKEN addop_token = 0;
    NUMBER sign;




    if (toksy == addsy || toksy == subsy) // unary + or -
    {
        addop_token = toksy;
        match(toksy);
    }

    e1 = parseExp6();

    if (addop_token == subsy)  // unary minus
    {
        // make an expr to multiply e1 by -1
        sign = -1;
        ex = mkVALEXP(sign);
        eL = mkExplist(ex,0);
        eL = mkExplist(e1,eL);
        nm = mulsy_index;
        e1 = mkAPEXP(nm,eL);
    }

    while (toksy == mulsy || toksy == divsy) // binary mulops
    {
        nm = tokindex;
        match(toktable[nm]);
        e2 = parseExp6();
        eL = mkExplist(e2,0);
        eL = mkExplist(e1,eL);
        e1 = mkAPEXP(nm,eL);
    }
    return e1;
} // parseExp5

// parse binary addop
EXP parseExp4()
{
    NAME nm;
    EXP e1,e2;
    EXPLIST eL;
```

```
  e1:=parseExp5;
  while toksy in addops do
    begin
      nm:=tokindex;
      match(toktable[nm]);
      e2:=parseExp5;
      eL:=mkExplist(e2,nil);
      eL:=mkExplist(e1,eL);
      e1:=mkAPEXP(nm,eL)
    end;
  parseExp4:=e1;
end;  (* parseExp4 *)

(* parse binary relop *)
function parseExp3:EXP;
var
  nm:NAME;
  e1,e2:EXP;
  eL:EXPLIST;
begin
  e1:=parseExp4;
  while toksy in relops do
    begin
      nm:=tokindex;
      match(toktable[nm]);
      e2:=parseExp4;
      eL:=mkExplist(e2,nil);
      eL:=mkExplist(e1,eL);
      e1:=mkAPEXP(nm,eL)
    end;
  parseExp3:=e1;
end;  (* parseExp3 *)

(* parse print op *)
function parseExp2:EXP;
var
  eL:EXPLIST;
  ex:EXP;
  nm:NAME;
  printflag:boolean;
begin
  printflag:=false;
  if toksy = printsy then
    begin
      printflag:=true;
      nm:=tokindex;
      match(printsy)
    end;
  ex:=parseExp3;
  if printflag then
    begin
      eL:=mkExplist(ex,nil);
      parseExp2:=mkAPEXP(nm,eL)
    end
  else
    parseExp2:=ex;
```

```
   e1 = parseExp5();
   while (toksy == addsy || toksy == subsy)
   {
      nm = tokindex;
      match(toktable[nm]);
      e2 = parseExp5();
      eL = mkExplist(e2,0);
      eL = mkExplist(e1,eL);
      e1 = mkAPEXP(nm,eL);
   }
   return e1;
} // parseExp4

// parse binary relop
EXP parseExp3()
{
   NAME nm;
   EXP e1,e2;
   EXPLIST eL;

   e1 = parseExp4();
   while (toksy == lssy || toksy == eqsy || toksy == gtsy)
   {
      nm = tokindex;
      match(toktable[nm]);
      e2 = parseExp4();
      eL = mkExplist(e2,0);
      eL = mkExplist(e1,eL);
      e1 = mkAPEXP(nm,eL);
   }
      return e1;
} // parseExp3

// parse print op
EXP parseExp2()
{
   EXPLIST eL;
   EXP ex;
   NAME nm;
   BOOLEAN printflag;

   printflag = false;
   if (toksy == printsy)
   {
      printflag = true;
      nm = tokindex;
      match(printsy);
   }
   ex = parseExp3();
   if (printflag)
   {
      eL = mkExplist(ex,0);
      return mkAPEXP(nm,eL);
   }
   else
      return ex;
```

```
end;  (* parseExp2 *)

(* parse assignment *)
function parseExp1:EXP;
var
  eL:EXPLIST;
  ex,e2:EXP;
  nm:NAME;
begin
  ex:=parseExp2;
  while toksy = assignsy do
  (* build an assignment expression *)
    begin
      nm:=tokindex;
      match(assignsy);
      if ex^.etype = VAREXP then (* l.h.s. must be a variable *)
        begin
          e2:=parseExp1;     (* process r.h.s.*)
          eL:=mkExplist(e2,nil);
          eL:=mkExplist(ex,eL);
          ex:=mkAPEXP(nm,eL)
        end
      else (* illegal l.h.s. *)
        begin
          writeln('parseExp1: left hand side must be a variable');
          goto 99
        end;
    end;  (* of while *)
    parseExp1:=ex
end;  (* parseExp1 *)

(* parse if, while, seq, exp1 *)
function parseExpr;
 var
  ex:EXP;
begin
  case toksy of

      ifsy: ex:=parseIf;


    whilesy: ex:=parseWhile;


     seqsy:  ex:=parseSeq;


     nameidsy,numsy,subsy,funidsy,printsy,lparsy: ex:=parseExp1;









    otherwise;
```

```
} // parseExp2

// parse assign op
EXP parseExp1()
{
   EXPLIST eL;
   EXP ex,e2;
   NAME nm;

   ex = parseExp2();
   while (toksy == assignsy)
   {
      // build an assignment expression
      nm = tokindex;
      match(assignsy);
      if (ex->etype == VAREXP) // lhs must be a variable
      {
         e2 = parseExp1();   // process rhs
         eL = mkExplist(e2,0);
         eL = mkExplist(ex,eL);
         ex = mkAPEXP(nm,eL);
      }
      else  // illegal lhs

         errmsg(err_not_var, null_str, null_int);


   } // while
   return ex;
} // parseExp1

// parse if, while, seq, Exp1
EXP parseExpr()
{
   EXP ex;

   switch (toksy)
   {
      case ifsy:
         ex = parseIf();
         break;
      case whilesy:
         ex = parseWhile();
         break;
      case seqsy:
         ex = parseSeq();
         break;
      case nameidsy:
      case numsy:
      case subsy:
      case funidsy:
      case printsy:
      case lparsy:
         ex = parseExp1();
         break;
      default:
```

```
     errmsg(4)

  end; (* case *)
  parseExpr:=ex;
end; (* parseExpr *)

(*****************************************************************
 *                  ENVIRONMENTS                                 *
 *****************************************************************)

(* emptyEnv - return an environment with no bindings           *)
function emptyEnv: ENV;
begin
   emptyEnv := mkEnv(nil, nil)
end; (* emptyEnv *)

(* bindVar - bind variable nm to value n in environment rho     *)
procedure bindVar (nm: NAME; n: NUMBER; rho: ENV);
begin
   rho^.vars := mkNamelist(nm, rho^.vars);
   rho^.values := mkValuelist(n, rho^.values)
end; (* bindVar *)

(* findVar - look up nm in rho                                  *)
function findVar (nm: NAME; rho: ENV): VALUELIST;
var
   nl: NAMELIST;
   vl: VALUELIST;
   found: Boolean;
begin
   found := false;
   nl := rho^.vars;
   vl := rho^.values;
   while (nl <> nil) and not found do

      if nl^.head = nm
      then found := true
      else begin

             nl := nl^.tail;
             vl := vl^.tail
           end;

   findVar := vl
end; (* findVar *)

(* assign - assign value n to variable nm in rho               *)
procedure assign (nm: NAME; n: NUMBER; rho: ENV);

var varloc: VALUELIST;
begin
   varloc := findVar(nm, rho);
   varloc^.head := n
end; (* assign *)

(* fetch - return number bound to nm in rho                    *)
```

```
          errmsg(err_expr, null_str, null_int);
          break;
    } // case
    return ex;
} /* parseExpr */

//--------------
// ENVIRONMENTS
//--------------

// emptyEnv - return an environment with no bindings
ENV emptyEnv()
{
    return mkEnv(0, 0);
} // emptyEnv

// bindVar - bind variable nm to value n in environment rho
void bindVar (NAME nm, NUMBER n, ENV rho)
{
    rho->vars = mkNamelist(nm, rho->vars);
    rho->values = mkValuelist(n, rho->values);
} // bindVar

// findVar - look up nm in rho
VALUELIST findVar (NAME nm, ENV rho)
{
    NAMELIST nl;
    VALUELIST vl;
    BOOLEAN found;

    found = false;
    nl = rho->vars;
    vl = rho->values;
    while (nl != 0 && !found)
    {
        if (nl->head == nm)
            found = true;
        else
        {
            nl = nl->tail;
            vl = vl->tail;
        }
    }
    return vl;
} // findVar

// assign - assign value n to variable nm in rho
void assign (NAME nm, NUMBER n, ENV rho)
{
    VALUELIST varloc;

    varloc = findVar(nm, rho);
    varloc->head = n;
} // assign

// fetch - return number bound to nm in rho
```

```
function fetch (nm: NAME; rho: ENV): NUMBER;

var vl: VALUELIST;
begin
   vl := findVar(nm, rho);
   fetch := vl^.head
end; (* fetch *)

(* isBound - check if nm is bound in rho                    *)
function isBound (nm: NAME; rho: ENV): Boolean;
begin
   isBound := findVar(nm, rho) <> nil
end; (* isBound *)

(*************************************************************
 *                  NUMBERS                                  *
 *************************************************************)

(* prValue - print number n                                 *)
procedure prValue (n: NUMBER);
begin
   write(n:1)
end; (* prValue *)

(* isTrueVal - return true if n is a true (non-zero) value  *)
function isTrueVal (n: NUMBER): Boolean;
begin
   isTrueVal := n <> 0
end; (* isTrueVal *)

(* applyValueOp - apply VALUEOP op to arguments in VALUELIST vl  *)
function applyValueOp (op: VALUEOP; vl: VALUELIST): NUMBER;

var n, n1, n2: NUMBER;

(* arity - return number of arguments expected by op        *)
   function arity (op: VALUEOP): integer;
   begin
      if op in [ADDOP .. GTOP]
      then arity := 2

      else arity := 1
   end; (* arity *)




begin (* applyValueOp *)



   if arity(op) <> lengthVL(vl)
   then begin
          write('Wrong number of arguments to ');
          prName(ord(op)+1);
          writeln;
```

```
NUMBER fetch (NAME nm, ENV rho)
{
   VALUELIST vl;

   vl = findVar(nm, rho);
   return vl->head;
}  // fetch

// isBound - check if nm is bound in rho
int isBound (NAME nm, ENV rho)
{
   return findVar(nm, rho) != 0;
} // isBound

//---------
// NUMBERS
//---------

// prValue - print number n
void prValue (NUMBER n)
{
   printf("%ld",n);
}

// arity - return number of arguments expected by op
int arity (BUILTINOP op)
{
   if (op >= ADDOP && op <= GTOP)
      return 2;
   else
      return 1;
} // arity

void prName(NAME);  // forward declaration

// applyValueOp - apply operator to arguments in VALUELIST
NUMBER applyValueOp (BUILTINOP op, VALUELIST vl)
{
   NUMBER n, n1, n2;

   if (arity(op) != lengthVL(vl))
      errmsg(err_num_args, null_str, op);
```

```
        goto 99
      end;
  n1 := vl^.head; (* 1st actual *)
  if arity(op) = 2
  then n2 := vl^.tail^.head; (* 2nd actual *)

  case op of

    ADDOP: n := n1+n2;


    SUBOP: n := n1-n2;


    MULOP: n := n1*n2;


    DIVOP: n := n1 div n2;


    EQOP: if n1 = n2 then n := 1 else n := 0;




    LTOP: if n1 < n2 then n := 1 else n := 0;




    GTOP: if n1 > n2 then n := 1 else n := 0;




    PRINTOP:
      begin prValue(n1); writeln; n := n1 end




  end; (* case *)
  applyValueOp := n
end; (* applyValueOp *)


(*****************************************************************
 *                  EVALUATION                                   *
 *****************************************************************)

(* eval - return value of expression e in local environment rho  *)
```

```
   n1 = vl->head;          // 1st actual
   if (arity(op) == 2)
      n2 = vl->tail->head; // 2nd actual

   switch (op)
   {
      case ADDOP:
         n = n1 + n2;
         break;
      case SUBOP:
         n = n1 - n2;
         break;
      case MULOP:
         n = n1 * n2;
         break;
      case DIVOP:
         n = n1 / n2;
         break;
      case EQOP:
         if (n1 == n2)
            n = 1;
         else
            n = 0;
         break;
      case LTOP:
         if (n1 < n2)
            n = 1;
         else
            n = 0;
         break;
      case GTOP:
         if (n1 > n2)
            n = 1;
         else
            n = 0;
         break;
      case PRINTOP:
         prValue(n1);
         printf("\n");
         n = n1;
         break;
      default:  // this case should never occur
         printf("applyValueOp: bad value for op = %d\n", op);
         break;
   } // switch
   return n;
} // applyValueOp


//------------
// EVALUATION
//------------
```

```
function eval (e: EXP; rho: ENV): NUMBER;

var op: BUILTINOP;

(* evalList - evaluate each expression in el                  *)
  function evalList (el: EXPLIST): VALUELIST;
  var
    h: NUMBER;
    t: VALUELIST;
  begin
    if el = nil then evalList := nil

    else begin

           h := eval(el^.head, rho);
           t := evalList(el^.tail);
           evalList := mkValuelist(h, t)
        end
  end; (* evalList *)

(* applyUserFun - look up definition of nm and apply to actuals  *)
  function applyUserFun (nm: NAME; actuals: VALUELIST): NUMBER;
  var
    f: FUNDEF;
    rho: ENV;
  begin
    f := fetchDef(nm);
    if f = nil
    then begin
           write('Undefined function: ');
           prName(nm);
           writeln;
           goto 99
        end;
    with f^ do begin
      if lengthNL(formals) <> lengthVL(actuals)
      then begin
             write('Wrong number of arguments to: ');
             prName(nm);
             writeln;
             goto 99
           end;
      rho := mkEnv(formals, actuals);
      applyUserFun := eval(body, rho)
      end
  end; (* applyUserFun *)

(* applyCtrlOp - apply CONTROLOP op to args in rho             *)
  function applyCtrlOp (op: CONTROLOP;
                        args: EXPLIST): NUMBER;
  var n: NUMBER;
  begin
    with args^ do
      case op of

        IFOP:
```

```
NUMBER eval (EXP, ENV);   // forward declaration



// evalList - evaluate each expression in eL
VALUELIST evalList (EXPLIST eL, ENV rho)
{
   NUMBER h;
   VALUELIST t;

   if (eL == 0)
      return 0;
   else
   {
      h = eval(eL->head, rho);
      t = evalList(eL->tail, rho);
      return mkValuelist(h, t);
   }
} // evalList

// applyUserFun - look up definition of nm and apply to actuals
NUMBER applyUserFun (NAME nm, VALUELIST actuals)
{
   FUNDEF f;
   ENV rho;

   f = fetchDef(nm);
   if (f == 0)
      errmsg(err_undef_func, null_str, nm);









   if (lengthNL(f->formals) != lengthVL(actuals))
      errmsg(err_num_args2, null_str, nm);









   rho = mkEnv(f->formals, actuals);
   return eval(f->body, rho);

} // applyUserFun

// applyCtrlOp - apply CONTROLOP op to args in rho
NUMBER applyCtrlOp (BUILTINOP op, EXPLIST args, ENV rho)
{
   NUMBER n;


   switch (op)
   {
      case IFOP:
```

```
            if isTrueVal(eval(head, rho))
            then applyCtrlOp := eval(tail^.head, rho)

            else applyCtrlOp := eval(tail^.tail^.head, rho);

         WHILEOP:
            begin
               n := eval(head, rho);
               while isTrueVal(n)
               do begin
                    n := eval(tail^.head, rho);
                    n := eval(head, rho)
                  end;
               applyCtrlOp := n
            end;
         ASSIGNOP:
            begin
               n := eval(tail^.head, rho);
               if isBound(head^.varble, rho)
               then assign(head^.varble, n, rho)
               else if isBound(head^.varble, globalEnv)
                   then assign(head^.varble, n, globalEnv)

                   else bindVar(head^.varble, n, globalEnv);
               applyCtrlOp := n
            end;
         SEQOP:
            begin
               while args^.tail <> nil do
                  begin
                    n := eval(args^.head, rho);
                    args := args^.tail
                  end;
               applyCtrlOp := eval(args^.head, rho)
            end



      end (* case and with *)

   end; (* applyCtrlOp *)


begin (* eval *)



   with e^ do
      case etype of

         VALEXP:
           eval := num;

         VAREXP:
           if isBound(varble, rho)
           then eval := fetch(varble, rho)
```

```
            if (eval(args->head, rho))
               n = eval(args->tail->head, rho);
            else
               n = eval(args->tail->tail->head, rho);
            break;
         case WHILEOP:

            n = eval(args->head, rho);
            while (n)
            {
               n = eval(args->tail->head, rho);
               n = eval(args->head, rho);
            }
            break;

         case ASSIGNOP:

            n = eval(args->tail->head, rho);
            if (isBound(args->head->u.varble, rho))
               assign(args->head->u.varble, n, rho);
            else if (isBound(args->head->u.varble, globalEnv))
               assign(args->head->u.varble, n, globalEnv);
            else
               bindVar(args->head->u.varble, n, globalEnv);
            break;

         case SEQOP:

            while (args->tail != 0)
            {
               n = eval(args->head, rho);
               args = args->tail;
            }
            n = eval(args->head, rho);  //value of last statement in seq
            break;
         default:
            printf("applyCtrlOp: bad value for op = %d\n", op);
            break;
      }  // switch
      return n;
} // applyCtrlOp

// eval - return value of expression e in local environment rho
NUMBER eval (EXP e, ENV rho)
{
   BUILTINOP op;
   NUMBER n;

   switch (e->etype)
   {
      case VALEXP:
         n = e->u.num;
         break;
      case VAREXP:
         if (isBound(e->u.varble, rho))
            n = fetch(e->u.varble, rho);
```

```
         else if isBound(varble, globalEnv)
             then eval := fetch(varble, globalEnv)
             else begin
                   write('Undefined variable: ');
                   prName(varble);
                   writeln;
                   goto 99
                  end;
       APEXP:

         if optr > numBuiltins
         then eval := applyUserFun(optr, evalList(args))
         else begin
               op := primOp(optr);
               if op in [IFOP .. SEQOP]
               then eval := applyCtrlOp(op, args)
               else
                  eval:=applyValueOp(op, evalList(args))
             end




     end; (* case and with *)

end; (* eval *)

(*****************************************************************
 *                  READ-EVAL-PRINT LOOP                         *
 *****************************************************************)

begin (* chapter1 main *)


   initParse;
   initNames;



   globalEnv := emptyEnv;
   quittingtime := false;




99:




   while not quittingtime do
     begin
      reader;
```

```
         else if (isBound(e->u.varble, globalEnv))
            n = fetch(e->u.varble, globalEnv);
         else
            errmsg(err_undef_var, null_str, e->u.varble);
         break;



      case APEXP:
         op = e->u.ap.optr;
         if (op > numBuiltins-1)
            n = applyUserFun(op, evalList(e->u.ap.args, rho));
         else
         {
            if (op >= firstControlOp && op <= lastControlOp)
               n = applyCtrlOp(op, e->u.ap.args, rho);
            else if (op >= firstValueOp && op <= lastValueOp)
               n = applyValueOp(op, evalList(e->u.ap.args, rho));
            else
               errmsg(err_undef_op, null_str, op);
         }
         break;
      default:
         printf("Invalid etype = %d", e->etype);
         break;
   } // switch
   return n;
} // eval

//----------------------------
// READ-EVAL-PRINT LOOP (REPL)
//----------------------------

int main (int argc, char **argv)
{
   short int error_no=0;

   initNames();
   initCmds();
   initParse();

   globalEnv = emptyEnv();
   quittingtime = false;

// Set the jump location for longjmp.
// After a parse error, errmsg() displays the error message and does
// a longjmp to here. The program then continues with the REPL below.
   if (setjmp(JL99))
      ;

// repeatedly read, parse and evaluate the input
// until "quit$" is entered

   while (!quittingtime)
   {
      reader();
```

```
    getToken;  (* return the first token from userinput in toksy *)

    if toksy = quitsy then
      quittingtime := true
    else if toksy = funsy then
          begin
            prName(parseDef);
            writeln
          end
        else
          begin
            currentExp := parseExpr;
            prValue(eval(currentExp, emptyEnv));
            writeln
         end
   end (* while *)

end. (* chapter1 *)
```

```
      getToken();

      if (toksy == quitsy)
         quittingtime = true;
      else if (toksy == funsy)
      {
         prName(parseDef());
         printf("\n\n");
      }
      else
      {
         currentExp = parseExpr();
         prValue(eval(currentExp, emptyEnv()));
         printf("\n\n");
      }
   } // while
   exit (EXIT_SUCCESS);
}
```