

# University of Central Florida

## Department of Computer Science

### COP 3402: System Software

### Summer 2018

#### Homework #4 (PL/0 Compiler)

Due Sunday, July 22<sup>nd</sup>, 2018 by 11:59 p.m.

#### **NEW REQUIREMENT:**

**All assignments must compile and run on the Eustis server. Please see course website for details concerning use of Eustis.**

#### **Objective:**

In this assignment, you must extend the functionality of Assignment 3 to include the additional grammatical constructs highlighted in yellow in the grammar below.

#### **Example of a program written in PL/0:**

```
var x, w;  
begin  
    x:= 4;  
    in w;  
    if w > x then  
        w:= w + 1  
    else  
        w:= x;  
    out w  
end.
```

#### **Component Descriptions:**

The compiler must read a program written in PL/0 and generate code for the Virtual Machine (VM) you implemented in HW1. Your compiler must neither parse nor generate code for programming constructs that are not in the grammar described below.

#### **Submission Instructions and rubric:**

1.- Submit via WebCourses:

1. Source code of the PL/0 compiler.
2. A text file with instructions on how to use your program entitled readme.txt.
3. A text file composed of the input file to your Scanner and the output of your Parser to demonstrate a correctly formed PL/0 program. The Parser output should indicate

the program is syntactically correct. Following the statement that the program is syntactically correct, the text file should contain the generated code from your intermediate code generator and the stack output from your Virtual Machine running your code.

4. A text file (or screenshots) composed of the input file to your Scanner and the output of your Parser to demonstrate all possible errors. This may require many runs and the Parser output should indicate which error is being identified.
5. All files should be compressed into a single .zip format.
6. **Late assignments will not be accepted (for this project there is not a two day extension after the due date).**
7. Name your program: hw4compiler.c

2.- Submit in class the next class day following the due date:

1. A hard copy of the User's Guide for the PL/0 compiler.

The User's Guide should assume that the user has no experience whatsoever with the compiler and the PL/0 language and very little experience with the platform on which the compiler is run. At the very least, the User's Guide should cover:

1. How to compile and run the PL/0 compiler.
2. How to use the PL/0 compiler once it is running.
3. How to use the PL/0 language.
  - a. E.g. how to use an "if" statement, how to assign a value to a variable, etc.
  - b. Examples of PL/0 code are very helpful.

### Rubric:

Deduction	Description
-100	Does not compile on Eustis.
-100	Does not accept input filename from command line.
-100	<b>If the compiler follows a different grammar.</b>
-100	<b>Submitting HW3 again without implementing procedures and if-then-else.</b>
-15	Does not handle file I/O or resource errors gracefully.
-15	Crashes handling statements (-15 for each statement that is not handled).
-10	Crashes handling directive. (-10 for per directive)



## Appendix A:

### Traces of Execution:

Example 1, if the input is:

```
var x, y;  
begin  
  x := y + 56  
end.
```

The output should look like:

1.- A print out of the token (internal representation) file:

```
29 2 x 17 2 y 18 21 2 x 20 2 y 4 3 56 18 22 19
```

And it's symbolic representation:

```
varsym identsym x commasy identsym y semicolon beginsym identsym x  
  becomessym identsym y plussym numbersym 56 semicolonsym endsym  
  periodsym
```

2.- Print out the message “ No errors, program is syntactically correct”

3.- Print out the generated code

4.- Run the program on the VM virtual machine (HW1)

Example 2, if the input is:

```
var x, y;  
begin  
  x := y + 56  
end           ← ( notice period expected after the “end” reserved word)
```

The output should look like:

1.- A print out of the token (internal representation) file:

```
29 2 1 17 2 2 18 21 2 1 20 2 2 4 3 56 18 22
```

And its symbolic representation:

```
varsym identsym x commasym identsym y semicolon beginsym identsym x becomessym  
identsym y plussym numbersym 56 semicolonsym endsym
```

2.- Print the message “Error number xxx, period expected”

```
var x, y;  
begin  
  x := y + 56  
end  
  ***** Error number xxx, period expected
```

Example 3: Use this example (recursive program) to test your compiler:

```
var f, n;  
procedure fact;  
var ans1;  
begin  
  ans1:=n;  
  n:= n-1;  
  if n = 0 then f := 1;  
  if n > 0 then call fact;  
  f:=f*ans1;  
end;
```

```
begin  
n:=3;  
call fact;  
write f  
end.
```

Example 4: Use this example (nested procedures program) to test your compiler:

```
int x,y,z,v,w;
procedure a;
  int x,y,u,v;
  procedure b;
    int y,z,v;
    procedure c;
      int y,z;
      begin
        z:=1;
        x:=y+z+w
      end;
    begin
      y:=x+u+w;
      call c
    end;
  begin
    z:=2;
    u:=z+w;
    call b
  end;
begin
  x:=1; y:=2; z:=3; v:=4; w:=5;
  x:=v+w;
  write z;
  call a;
end.
```

## Appendix B:

### EBNF of PL/0:

program ::= block "." .  
block ::= const-declaration var-declaration **procedure-declaration** statement.  
constdeclaration ::= [ "**const**" ident "=" number { "," ident "=" number } ";" ].  
var-declaration ::= [ "**var**" ident { "," ident } ";" ].  
**procedure-declaration** ::= { "**procedure**" ident ";" block ";" }  
statement ::= [ ident ":" expression  
                  | "**call**" ident  
                  | "**begin**" statement { ";" statement } "**end**"  
                  | "**if**" condition "**then**" statement [**else** statement]  
                  | "**while**" condition "**do**" statement  
                  | "**read**" ident  
                  | "**write**" expression  
                  | **e** ] .  
condition ::= "**odd**" expression  
                  | expression rel-op expression.  
rel-op ::= "=" | "<" | "<=" | ">" | ">=" .  
expression ::= [ "+" | "-" ] term { ("+" | "-") term } .  
term ::= factor { ("\*" | "/" ) factor } .  
factor ::= ident | number | "(" expression ")" .  
number ::= digit { digit } .  
ident ::= letter { letter | digit } .  
digit ::= "0" | "1" | "2" | "3" | "4" | "5" | "6" | "7" | "8" | "9" .  
letter ::= "a" | "b" | ... | "y" | "z" | "A" | "B" | ... | "Y" | "Z" .

Based on Wirth's definition for EBNF we have the following rule:

[ ] means an optional item.

{ } means repeat 0 or more times.

Terminal symbols are enclosed in quote marks.

A period is used to indicate the end of the definition of a syntactic class.

## Appendix C:

### Error messages for the tiny PL/0 Parser:

1. Use = instead of :=.
2. = must be followed by a number.
3. Identifier must be followed by =.
4. **const**, **int**, **procedure** must be followed by identifier.
5. Semicolon or comma missing.
6. Incorrect symbol after procedure declaration.
7. Statement expected.
8. Incorrect symbol after statement part in block.
9. Period expected.
10. Semicolon between statements missing.
11. Undeclared identifier.
12. Assignment to constant or procedure is not allowed.
13. Assignment operator expected.
14. **call** must be followed by an identifier.
15. Call of a constant or variable is meaningless.
16. **then** expected.
17. Semicolon or **end** expected.
18. **do** expected.
19. Incorrect symbol following statement.
20. Relational operator expected.
21. Expression must not contain a procedure identifier.
22. Right parenthesis missing.
23. The preceding factor cannot begin with this symbol.
24. An expression cannot begin with this symbol.
25. This number is too large.
26. Identifier too long.
27. Invalid symbol.

Note:

1. Identifiers: Maximum 11 characters.
2. Numbers: Maximum 5 digits.
3. Invalid symbols are not accepted ( or example % does not belong to PL/0 grammar).
4. Comments and invisible characters must be ignored and not tokenized.

**Note: Not all of these error messages may be used, and you may choose to create some error messages of your own to more accurately represent certain situations.**





## Appendix D:

### Recursive Descent Parser for a PL/0 like programming language in pseudo code:

As follows you will find the pseudo code for a PL/0 like parser. This pseudo code will help you out to develop your parser and intermediate code generator for tiny PL/0:

```
procedure PROGRAM;
begin
  GET(TOKEN);
  BLOCK;
  if TOKEN != "periodsym" then ERROR
end;

procedure BLOCK;
begin
  if TOKEN = "constsym" then begin
    repeat
      GET(TOKEN);
      if TOKEN != "identsym" then ERROR;
      GET(TOKEN);
      if TOKEN != "eqsym" then ERROR;
      GET(TOKEN);
      if TOKEN != NUMBER then ERROR;
      GET(TOKEN)
    until TOKEN != "commasym";
    if TOKEN != "semicolomsym" then ERROR;
    GET(TOKEN)
  end;
  if TOKEN = "var" then begin
    repeat
      GET(TOKEN);
      if TOKEN != "identsym" then ERROR;
      GET(TOKEN)
    until TOKEN != "commasym";
    if TOKEN != "semicolomsym" then ERROR;
    GET(TOKEN)
  end;
  while TOKEN = "procsym" do begin
    GET(TOKEN);
    if TOKEN != "identsym" then ERROR;
```

```

    GET(TOKEN);
    if TOKEN != "semicolon" then ERROR;
    GET(TOKEN);
    BLOCK;
    if TOKEN != "semicolon" then ERROR;
    GET(TOKEN);
end;
STATEMENT
end;

```

```

procedure STATEMENT;
begin
    if TOKEN = "ident" then begin
        GET(TOKEN);
        if TOKEN != "become" then ERROR;
        GET(TOKEN);
        EXPRESSION
    end
    else if TOKEN = "call" then begin
        GET(TOKEN);
        if TOKEN != "ident" then ERROR;
        GET(TOKEN);
    end
    else if TOKEN = "begin" then begin
        GET(TOKEN);
        STATEMENT;
        while TOKEN = "semicolon" do begin
            GET(TOKEN);
            STATEMENT
        end;
        if TOKEN != "end" then ERROR;

        GET(TOKEN);
    end
    else if TOKEN = "if" then begin
        GET(TOKEN);
        CONDITION;
        if TOKEN != "then" then ERROR;
        GET(TOKEN);
        STATEMENT
    end
    else if TOKEN = "while" then begin
        GET(TOKEN);
        CONDITION;
        if TOKEN != "do" then ERROR;

```

```

        GET(TOKEN);
        STATEMENT
    end
end;

procedure CONDITION;
begin
    if TOKEN = "oddsym" then begin
        GET(TOKEN);
        EXPRESSION
    else begin
        EXPRESSION;
        if TOKEN != RELATION then ERROR;
        GET(TOKEN);
        EXPRESSION
    end
end;

procedure EXPRESSION;
begin
    if TOKEN = "plussym" or "minussym" then GET(TOKEN);
    TERM;
    while TOKEN = "plussym" or "slashsym" do begin
        GET(TOKEN);
        TERM
    end
end;

procedure TERM;
begin
    FACTOR;
    while TOKEN = "multsym" or "slashsym" do begin
        GET(TOKEN);
        FACTOR
    end
end;

procedure FACTOR;
begin
    if TOKEN = "identsym" then
        GET(TOKEN)
    else if TOKEN = NUMBER then
        GET(TOKEN)
    else if TOKEN = "(" then begin
        GET(TOKEN);

```

```
    EXPRESSION;  
    if TOKEN != ")" then ERROR;  
    GET(TOKEN)  
end  
else ERROR  
end;
```

## Appendix E:

### Symbol Table

Recommended data structure for the symbol.

```
typedef struct
{
    int kind;           // const = 1, var = 2, proc = 3
    char name[10];      // name up to 11 chars
    int val;            // number (ASCII value)
    int level;          // L level
    int addr;           // M address
    int mark;           // to indicate that code has been generated already for a block.

} symbol;
```

```
symbol_table[MAX_SYMBOL_TABLE_SIZE];
```

For constants, you must store kind, name and value.

For variables, you must store kind, name, L and M.

For procedures, you must store kind, name, L and M.