COVER PAGE

CS323 Programming Assignments

Fill out all entries 1 - 7.   If not, there will be deductions!

Check one

1. Names [1. Liren Yin CPSC323-02], (4pm class [ ] or 5:30pm class [X])

[2.Yafei Mo CPSC323-04], (4pm class [ ] or 5:30pm class [X])

2. Assignment Number [3]

3. Due Dates **Softcopy** [Monday 5/7/2018 11:59PM]
Hardcopy [Tuesday 5/8/2018 8:15PM]

4. Turn-In Dates **Softcopy** [Thursday 5/3/2018 10:00AM], **Hardcopy** [Tuesday 5/8/2018 5:15PM]

5. Executable FileName [CPSC323_HW3]
(**A file that can be executed without compilation by the instructor**)

6. LabRoom [CS101]
(Execute your program in a lab in the CS building before submission)

7. Operating System [MacOS Sierra 10.12.6]

To be filled out by the Instructor:

GRADE:

COMMENTS:

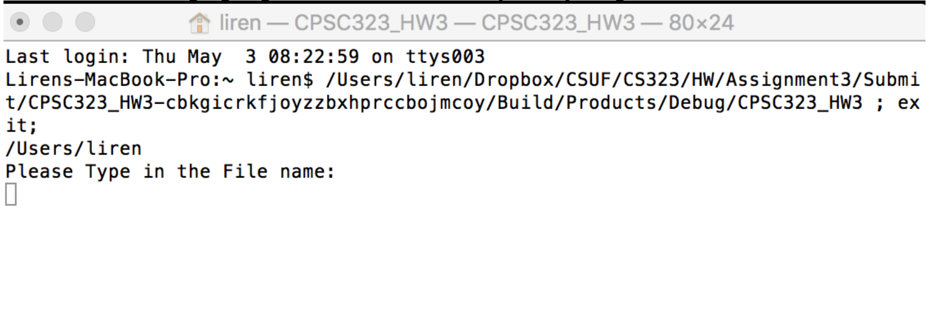
1. Problem Statement

We are building a customize compiler Rat18S with our own defined programming language. At this stage, we are going to design a semantic analyzer for this compiler. Output of the program consists of symbol table and assembly code.

2. How to use your program

1. *The environment for running this program will be macOS High Sierra (V10.12.6).*
2. *Open the folder **CPSC323_HW3-cbkgicrkfjoyzzbxhprccbojmcoy/Build/Products/Debug***
3. *Open file **CPSC323_HW3***

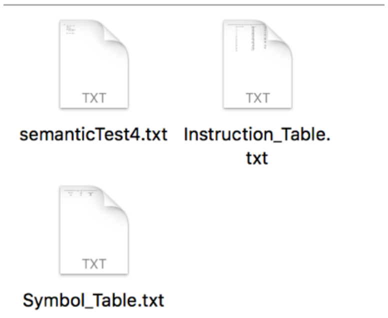
A console will pop up, and there's a default file path on the screen

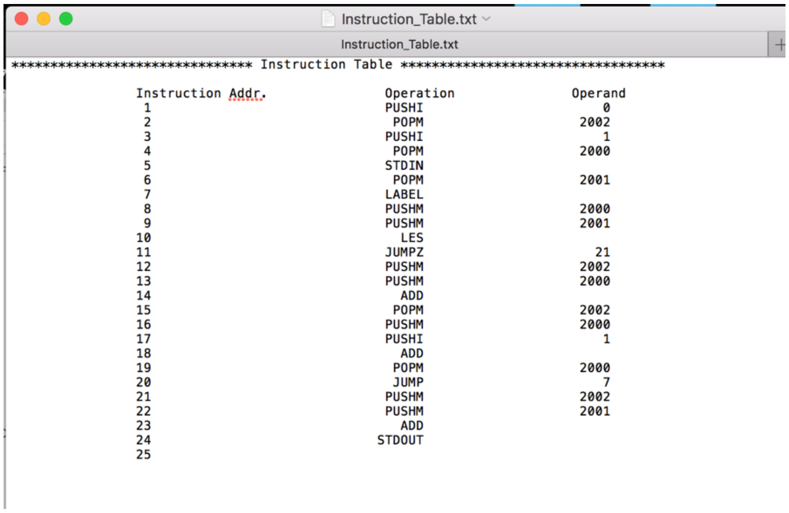


```
Last login: Thu May  3 08:22:59 on ttys003
Lirens-MacBook-Pro:~ liren$ /Users/liren/Dropbox/CSUF/CS323/HW/Assignment3/Submi
t/CPSC323_HW3-cbkgicrkfjoyzzbxhprccbojmcoy/Build/Products/Debug/CPSC323_HW3 ; ex
it;
/Users/liren
Please Type in the File name:
```

In this case, the default file path is /Users/liren

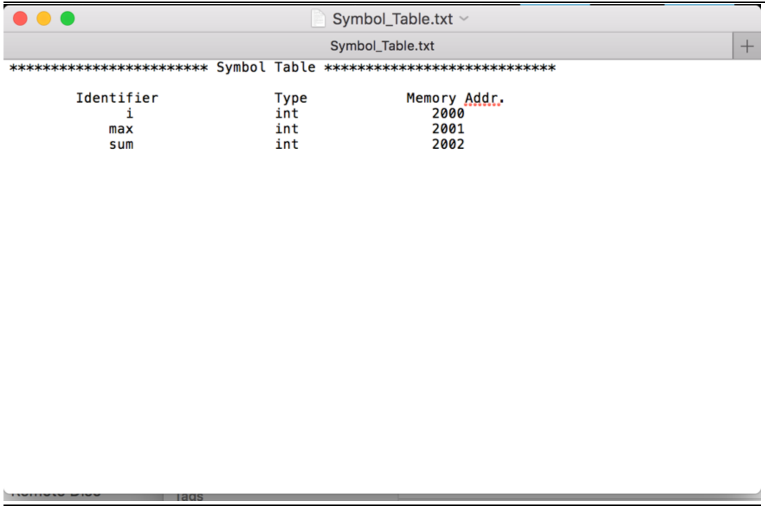
4. *Copy the source code file expected to be dealt with.*
5. *Go to default path (/Users/liren in this case), paste the source code you would like to parse here.*
6. *In the console, type in the file name you would like to parse (Ex. SemanticTest4.txt)*
7. *The outputs of lexical analysis, syntax analysis, list of identifiers, symbol table and instruction table will show on the console screen. In addition, the program will generate two files. "Instruction_Table.txt" contains assembly codes and "Symbol_Table.txt" contains all identifiers with corresponding types and memory addresses.*





```
******************************* Instruction Table *********************************

                Instruction Addr.                Operation              Operand
                 1                                PUSHI                     0
                 2                                 POPM                  2002
                 3                                PUSHI                     1
                 4                                 POPM                  2000
                 5                                STDIN
                 6                                 POPM                  2001
                 7                                LABEL
                 8                                PUSHM                  2000
                 9                                PUSHM                  2001
                10                                  LES
                11                                JUMPZ                    21
                12                                PUSHM                  2002
                13                                PUSHM                  2000
                14                                  ADD
                15                                 POPM                  2002
                16                                PUSHM                  2000
                17                                PUSHI                     1
                18                                  ADD
                19                                 POPM                  2000
                20                                 JUMP                     7
                21                                PUSHM                  2002
                22                                PUSHM                  2001
                23                                  ADD
                24                               STDOUT
                25
```



```
************************* Symbol Table *****************************

        Identifier              Type            Memory Addr.
            i                   int                2000
           max                  int                2001
           sum                  int                2002
```

3. Design of your program

Predictive recursive descent parser is used in this homework design, at the mean time of producing parsing tree, assembly code is produced during the recursive functions are called when certain production rules are matched.

4. Any Limitation

None

5. Any shortcomings

It's not working under Microsoft Windows Enviornment.

Test Cases:

semanticTest1.txt

```
%%
   int x, a, c, d, e, b, i, max, low, high, step;

   while (i < max) i = i + 1;
   x = a + b * c/d-e;
   if (a < b) a = c;
   else a = b + c;
   endif

   get(low, high, step);
   a = put(low - high * step);
   c = a * d - e;
   while (i < 10) {
     a = c + 1;
     i = i + 1;
   }
```

Instruction_Table.txt

```
*********************** Symbol Table ***************************

     Identifier             Type          Memory Addr.
             x                int               2000
             a                int               2001
             c                int               2002
             d                int               2003
             e                int               2004
             b                int               2005
             i                int               2006
           max                int               2007
           low                int               2008
```

Symbol_Table.txt

```
************************ Instruction Table ***************************

       Instruction Addr.            Operation            Operand
                1                          LABEL
                2                          PUSHM                    2006
                3                          PUSHM                    2007
                4                            LES
                5                          JUMPZ                      11
                6                          PUSHM                    2006
                7                          PUSHI                       1
                8                            ADD
                9                           POPM                    2006
               10                           JUMP                       1
               11                          PUSHM                    2001
```

```
12                             PUSHM                     2005
13                             PUSHM                     2002
14                               MUL
15                             PUSHM                     2003
16                               DIV
17                               ADD
18                             PUSHM                     2004
19                               SUB
20                              POPM                     2000
21                             PUSHM                     2001
22                             PUSHM                     2005
23                               LES
24                             JUMPZ                       27
25                             PUSHM                     2002
26                              POPM                     2001
27                             PUSHM                     2005
28                             PUSHM                     2002
29                               ADD
30                              POPM                     2001
31                             STDIN
32                              POPM                     2008
33                             STDIN
34                              POPM                     2009
35                             STDIN
36                              POPM                     2010
37                             PUSHM                     2008
38                             PUSHM                     2009
39                             PUSHM                     2010
40                               MUL
41                               SUB
42                            STDOUT
43                             PUSHM                     2001
44                             PUSHM                     2003
45                               MUL
46                             PUSHM                     2004
47                               SUB
48                              POPM                     2002
49                             LABEL
50                             PUSHM                     2006
51                             PUSHI                       10
52                               LES
53                             JUMPZ                       63
54                             PUSHM                     2002
55                             PUSHI                        1
56                               ADD
57                              POPM                     2001
58                             PUSHM                     2006
59                             PUSHI                        1
60                               ADD
61                              POPM                     2006
62                              JUMP                       49
63
```

semanticTest2.txt

```
%%
   int a, b, c;
   if (a < b) a = c; endif
```

Instruction_Table.txt

```
*********************** Symbol Table ***************************
```

```
      Identifier              Type           Memory Addr.
              a                 int                2000
              b                 int                2001
              c                 int                2002
```

Symbol_Table.txt

```
************************* Instruction Table ****************************

        Instruction Addr.             Operation             Operand
                 1                              PUSHM                     2000
                 2                              PUSHM                     2001
                 3                                LES
                 4                              JUMPZ                        7
                 5                              PUSHM                     2002
                 6                               POPM                     2000
                 7
```

semanticTest3.txt

```
%%
   int i, max, sum;
   boolean hello;
   sum = 0;
   i = 1;
   get (max);
   while (i < max) {
      sum = sum + i;
      i = i + 1;
   }
   put (sum + max);

   hello = true;
   if (hello == true) {
     sum = sum + 3;
   }
   endif

   if (hello == false) {
     sum = 0;
     max = 0;
   }
   endif
```

Instruction_Table.txt

```
************************ Symbol Table ****************************

      Identifier              Type           Memory Addr.
              i             boolean                2000
            max             boolean                2001
            sum             boolean                2002
          hello             boolean                2003
```

Symbol_Table.txt

```
************************* Instruction Table ****************************

       Instruction Addr.             Operation              Operand
                 1                   PUSHI                      0
                 2                   POPM                    2002
                 3                   PUSHI                      1
                 4                    POPM                   2000
                 5                   STDIN
                 6                    POPM                   2001
                 7                   LABEL
                 8                   PUSHM                   2000
                 9                   PUSHM                   2001
                10                     LES
                11                   JUMPZ                     21
                12                   PUSHM                   2002
                13                   PUSHM                   2000
                14                     ADD
                15                    POPM                   2002
                16                   PUSHM                   2000
                17                   PUSHI                      1
                18                     ADD
                19                    POPM                   2000
                20                    JUMP                      7
                21                   PUSHM                   2002
                22                   PUSHM                   2001
                23                     ADD
                24                  STDOUT
                25                    POPM                   2003
                26                   PUSHM                   2003
                27                     EQU
                28                    JMPZ                     33
                29                   PUSHM                   2002
                30                   PUSHI                      3
                31                     ADD
                32                    POPM                   2002
                33                   PUSHM                   2003
                34                     EQU
                35                    JMPZ                     40
                36                   PUSHI                      0
                37                    POPM                   2002
                38                   PUSHI                      0
                39                    POPM                   2001
                40
```

Source Code:

```
//
//  main.cpp
//  CPSC323_HW3
//
//  Created by Liren on 4/20/18.
//  Copyright © 2018 Liren. All rights reserved.
//

//main.cpp
#include <iostream>
#include <fstream>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <iomanip>
#include "LexAnalysis.h"
#include "SynAnalysis.h"


int main()
{
    bool tokenError = false;
    system("pwd");
    NormalNode* SyntaxPartHead;
    NormalNode* SemanticPartHead;
    //Lexical Analysis Part
    initKeyMapping();
    initOperMapping();
    initLimitMapping();
    initNode();
    scanner();
    BraMappingError();
    SyntaxPartHead = printNodeLink();
    SemanticPartHead = SyntaxPartHead;
//    printErrorLink(tokenError);
//    if (tokenError) {
//        std::cout << "Since Token Error exists, Syntax Analysis will not proceed.\n";
//        return 0;
//    }
    printIdentLink();

    //Syntax Analysis Part
    analysis(*SyntaxPartHead);
}

//
//  LexAnalysis.h
#ifndef LexAnalysis_h
#define LexAnalysis_h

//Keywords
#define AUTO 1
#define BREAK 2
#define CASE 3
#define CHAR 4
#define CONST 5
#define CONTINUE 6
#define DEFAULT 7
#define DO 8
#define DOUBLE 9
#define ELSE 10

#define FLOAT 13
#define FOR 14
#define GOTO 15
#define IF 16
#define INT 17
#define LONG 18
#define REGISTER 19
#define RETURN 20
#define SHORT 21
#define SIGNED 22
#define SIZEOF 23
#define STATIC 24
#define STRUCT 25
#define SWITCH 26
#define TYPEDEF 27
#define UNION 28
#define UNSIGNED 29
#define VOID 30
#define VOLATILE 31
#define WHILE 32
```

```
#define REAL 33

#define PUT 34
#define GET 35
#define FUNCTION 36
#define BOOLEAN 37
#define ENDIF 38
#define TRUE_VALUE 11
#define FALSE_VALUE 12
#define KEY_DESC "Keyword"

//Identifiers
#define IDENTIFER 40
#define IDENTIFER_DESC "Identifier"

//Constant
#define INT_VAL 51 //int constant
#define MACRO_VAL 55 //macro constant
#define REAL_VAL 56 // Real Numbers
#define REAL_DESC "real"
#define INT_DESC "int"

//Operators
#define MUL 65 // *
#define DIV 66// /

#define ADD 68 // +
#define SUB 69 // -
#define LES_THAN 70 // <
#define GRT_THAN 71 // >
#define ASG 72 // =
#define SELF_ADD 74 // ++
#define SELF_SUB 75 // --
#define LEFT_MOVE 76 // <<
#define RIGHT_MOVE 77 // >>
#define LES_EQUAL 78 // =>
#define GRT_EQUAL 79 // =<
#define EQUAL 80 // ==
#define COMPLETE_BYTE_XOR 88 // ^=
#define PERCENTPERCENT 91 //%%
#define BYTE_OR 92 // |

#define OPE_DESC "Operator"

//Seperators
#define LEFT_BRA 100 // (
#define RIGHT_BRA 101 // )
#define LEFT_INDEX 102 // [
#define RIGHT_INDEX 103 // ]
#define L_BOUNDER 104 //  {
#define R_BOUNDER 105 // }
#define POINTER 106 // .
#define JING 107 // #
#define UNDER_LINE 108 // _
#define COMMA 109 // ,
#define SEMI 110 // ;
#define COLON 81 // :
#define SIN_QUE 111 // '
#define DOU_QUE 112 // "

#define CLE_OPE_DESC "Seperator"

#define NOTE1 120 // "!!"comment
#define NOTE_DESC "comment"


#define HEADER 130 //header
#define HEADER_DESC "header"

//Error Types
#define REAL_ERROR "real type error"
#define REAL_ERROR_NUM 1
#define DOUBLE_ERROR "double type error"
#define DOUBLE_ERROR_NUM 2
#define NOTE_ERROR "comment format error"
#define NOTE_ERROR_NUM 3
#define STRING_ERROR "String constant error"
#define STRING_ERROR_NUM 4
#define CHARCONST_ERROR "Char constant error"
#define CHARCONST_ERROR_NUM 5
#define CHAR_ERROR "Invalid Char"
#define CHAR_ERROR_NUM 6
#define LEFT_BRA_ERROR "'('not matching"
#define LEFT_BRA_ERROR_NUM 7
#define RIGHT_BRA_ERROR "')'not matching"
```

```
#define RIGHT_BRA_ERROR_NUM 8
#define LEFT_INDEX_ERROR "'['not matching"
#define LEFT_INDEX_ERROR_NUM 9
#define RIGHT_INDEX_ERROR "']'not matching"
#define RIGHT_INDEX_ERROR_NUM 10
#define L_BOUNDER_ERROR "'{'not matching"
#define L_BOUNDER_ERROR_NUM 11
#define R_BOUNDER_ERROR "'}'not matching"
#define R_BOUNDER_ERROR_NUM 12
#define IDENTIFIER_ERROR "Identifier Error" //Invalid identifier
#define IDENTIFIER_ERROR_NUM  13

#define _NULL "null"

#define DESCRIBE 4000
#define TYPE 4001
#define STRING 4002
#define DIGIT 4003

struct NormalNode
{
    char content[30];
    char describe[30];
    int type;
    int addr;
    int line;
    NormalNode * next;
    NormalNode * prev;
};

void initKeyMapping();
void initOperMapping();
void initLimitMapping();

void initNode();
void createNewNode(char * content,char *descirbe,int type,int addr,int line);
void createNewError(char * content,char *descirbe,int type,int line);
int createNewIden(char * content,char *descirbe,int type,int addr,int line);
NormalNode* printNodeLink();
void printErrorLink(bool &TokenError);
void printIdentLink();
int mystrlen(char * word);
void preProcess(char * word,int line);
void close();
int seekKey(char * word);
void scanner();
void BraMappingError();

#endif /* LexAnalysis_h */


//LexAnalysis.cpp
#include <iostream>
#include <fstream>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <vector>
#include <iomanip>
#include "LexAnalysis.h"

using namespace std;

int leftSmall = 0;//(
int rightSmall = 0;//)
int leftMiddle = 0;//[
int rightMiddle = 0;//]
int leftBig = 0;//{
int rightBig = 0;//}
int lineBra[6][1000] = {0};
int static_iden_number = 0;

NormalNode * normalHead;
NormalNode * normalTail;

struct ErrorNode
{
    char content[30];
    char describe[30];
    int type;
    int line;
    ErrorNode * next;
};

ErrorNode * errorHead;
```

```
struct IdentiferNode
{
    char content[30];
    char describe[30];
    int type;
    int addr;
    int line;
    IdentiferNode * next;
    IdentiferNode * prev;
};
IdentiferNode * idenHead;
IdentiferNode * idenTail;

vector<pair<const char *,int> > keyMap;
vector<pair<const char *,int> > operMap;
vector<pair<const char *,int> > limitMap;

void initKeyMapping()
{
    keyMap.clear();
    keyMap.push_back(make_pair("else",ELSE));
    keyMap.push_back(make_pair("true",TRUE_VALUE));
    keyMap.push_back(make_pair("false",FALSE_VALUE));
    keyMap.push_back(make_pair("if",IF));
    keyMap.push_back(make_pair("int",INT));
    keyMap.push_back(make_pair("real",REAL));
    keyMap.push_back(make_pair("long",LONG));
    keyMap.push_back(make_pair("register",REGISTER));
    keyMap.push_back(make_pair("return",RETURN));
    keyMap.push_back(make_pair("while",WHILE));
    keyMap.push_back(make_pair("put",PUT));
    keyMap.push_back(make_pair("get",GET));
    keyMap.push_back(make_pair("function",FUNCTION));
    keyMap.push_back(make_pair("boolean",BOOLEAN));
    keyMap.push_back(make_pair("endif",ENDIF));
keyMap.push_back(make_pair("id",IDENTIFER));
}
void initOperMapping()
{
    operMap.clear();
    operMap.push_back(make_pair("*",MUL));
    operMap.push_back(make_pair("/",DIV));
    operMap.push_back(make_pair("+",ADD));
    operMap.push_back(make_pair("-",SUB));
    operMap.push_back(make_pair("<",LES_THAN));
    operMap.push_back(make_pair(">",GRT_THAN));
    operMap.push_back(make_pair("=",ASG));
    operMap.push_back(make_pair("=<",LES_EQUAL));
    operMap.push_back(make_pair("=>",GRT_EQUAL));
    operMap.push_back(make_pair("==",EQUAL));
    operMap.push_back(make_pair(":",COLON));
    operMap.push_back(make_pair("||",OR));
    operMap.push_back(make_pair("^=",COMPLETE_BYTE_XOR));
    operMap.push_back(make_pair("%%",PERCENTPERCENT));
}
void initLimitMapping()
{
    limitMap.clear();
    limitMap.push_back(make_pair("(",LEFT_BRA));
    limitMap.push_back(make_pair(")",RIGHT_BRA));
    limitMap.push_back(make_pair("[",LEFT_INDEX));
    limitMap.push_back(make_pair("]",RIGHT_INDEX));
    limitMap.push_back(make_pair("{",L_BOUNDER));
    limitMap.push_back(make_pair("}",R_BOUNDER));
    limitMap.push_back(make_pair(".",POINTER));
    limitMap.push_back(make_pair(",",COMMA));
    limitMap.push_back(make_pair(";",SEMI));
    limitMap.push_back(make_pair("'",SIN_QUE));
}
void initNode()
{
    normalHead = new NormalNode();
    normalTail = new NormalNode();
    strcpy(normalHead->content,"");
    strcpy(normalHead->describe,"");
    normalHead->type = -1;
    normalHead->addr = -1;
    normalHead->line = -1;
    normalHead->next = NULL;
    normalHead->prev = NULL;

    normalTail->type = -1;
    normalTail->addr = -1;
    normalTail->line = -1;
    normalTail->next = NULL;
    normalTail->prev = NULL;

    errorHead = new ErrorNode();
    strcpy(errorHead->content,"");
    strcpy(errorHead->describe,"");
    errorHead->line = -1;
    errorHead->next = NULL;

    idenHead = new IdentiferNode();
    idenTail = new IdentiferNode();
    strcpy(idenHead->content,"");
    strcpy(idenHead->describe,"");
    idenHead->type = -1;
    idenHead->addr = -1;
    idenHead->line = -1;
    idenHead->next = NULL;
    idenHead->prev = NULL;

    idenTail->type = -1;
    idenTail->addr = -1;
    idenTail->line = -1;
    idenTail->next = NULL;
    idenTail->prev = NULL;
}

void createNewNode(char * content,char *descirbe,int type,int addr,int line)
{
    NormalNode * p = normalHead;
    NormalNode * temp = new NormalNode();

    while(p->next != NULL)
    {
        p = p->next;
    }

    strcpy(temp->content,content);
    strcpy(temp->describe,descirbe);
    temp->type = type;
    temp->addr = addr;
    temp->line = line;
    temp->next = NULL;
    p->next = temp;
    temp->prev = p;
    normalTail = temp;
}
void createNewError(char * content,char *descirbe,int type,int line)
{
    ErrorNode * p = errorHead;
    ErrorNode * temp = new ErrorNode();

    strcpy(temp->content,content);
    strcpy(temp->describe,descirbe);
    temp->type = type;
    temp->line = line;
    temp->next = NULL;
    while(p->next!=NULL)
    {
        p = p->next;
    }
    p->next = temp;
}

int createNewIden(char * content,char *descirbe,int type,int addr,int line)
{
    IdentiferNode * p = idenHead;
    IdentiferNode * temp = new IdentiferNode();
    int flag = 0;
    int addr_temp = -2;
    while(p->next!=NULL)
    {
        if(strcmp(content,p->next->content) == 0)
        {
            flag = 1;
            addr_temp = p->next->addr;
        }
        p = p->next;
    }
    if(flag == 0)
    {
        addr_temp = ++static_iden_number;
    }
    strcpy(temp->content,content);
    strcpy(temp->describe,descirbe);
    temp->type = type;
    temp->addr = addr_temp;
    temp->line = line;
    temp->next = NULL;
    p->next = temp;
    temp->prev = p;
    idenTail = temp;
    return addr_temp;
}

NormalNode* printNodeLink()
{
    NormalNode * p = normalHead;
    NormalNode * SyntaxPartHead = normalHead;
    p = p->next;
    cout<<"************************************Lexical Analysis Table******************************"<<endl<<endl;
    cout<<setw(30)<<"Lexeme"<<setw(10)<<"\t\tToken"<<"\t\t\t"<<"Line"<<endl;
    while(p!=NULL)
    {
        if(p->type == IDENTIFER)
        {
            cout<<setw(30)<<p->content<<"\t\t"<<setw(10)<<p->describe<<"\t\t\t"<<p->line<<endl;
        }
        else
        {
            cout<<setw(30)<<p->content << "\t\t"<<setw(10) << p->describe<<"\t\t\t"<<p->line<<endl;
        }
        p = p->next;
    }
    cout<<endl<<endl;
    return SyntaxPartHead;
}

void printErrorLink(bool &TokenError)
{
    ErrorNode * p = errorHead;
    if (p->next != NULL) {
        TokenError = true;
    }
    else TokenError = false;
    p = p->next;
    cout<<"************************************Error Table******************************"<<endl<<endl;
    cout<<setw(10)<<"Lexeme"<<setw(30)<<"\t\t\t\t\tToken"<<"\t\t\t"<<"Line"<<endl;
    while(p!=NULL)
    {
        cout<<setw(10)<<p->content<< "\t\t\t\t\t\t" <<setw(30)<< p->describe<<"\t\t\t"<<p->line<<endl;
        p = p->next;
    }
    cout<<endl<<endl;
}

void printIdentLink()
{
    IdentiferNode * p = idenHead;
    p = p->next;
    cout<<"************************************Identifiers Table******************************"<<endl<<endl;
    cout<<setw(30)<<"Lexeme"<<setw(10)<<"\tToken"<<"\t\t"<<"Address"<<"  \t\t"<<"Line"<<endl;
    while(p!=NULL)
    {
        cout<<setw(30)<<p->content << "\t\t" <<setw(10)<<p->describe<<"\t\t"<<p->addr<<"\t\t\t"<<p->line<<endl;
        p = p->next;
    }
    cout<<endl<<endl;
}
int mystrlen(char * word)
{
    if(*word == '\0')
    {
        return 0;
    }
    else
    {
        return 1+mystrlen(word+1);
    }
}

void preProcess(char * word,int line)
{
    const char * include_temp = "include";
    const char * define_temp = "define";
    char * p_include,*p_define;
    int flag = 0;
    p_include = strstr(word,include_temp);
    if(p_include!=NULL)
    {
        flag = 1;
        int i;
        for(i=7;;)
        {
            if(*(p_include+i) == ' ' || *(p_include+i) == '\t')
            {
                i++;
            }
            else
            {
                break;
            }
        }
        createNewNode(p_include+i,HEADER_DESC,HEADER,-1,line);
    }
    else
    {
        p_define = strstr(word,define_temp);
        if(p_define!=NULL)
        {
            flag = 1;
            int i;
            for(i=7;;)
            {
                if(*(p_define+i) == ' ' || *(p_define+i) == '\t')
                {
                    i++;
                }
                else
                {
                    break;
                }
            }
            createNewNode(p_define+i,CONSTANT_DESC,MACRO_VAL,-1,line);
        }
    }
    if(flag == 0)
    {

    }
}

void close()
{
    //delete idenHead;
    //delete errorHead;
    //delete normalHead;
}

int seekKey(char * word)
{
    for(int i=0; i<keyMap.size(); i++)
    {
        if(strcmp(word,keyMap[i].first) == 0)
        {
            return i+1;
        }
    }
    return IDENTIFER;
}

void scanner()
{
    char filename[30];
    char ch;
    char array[30];
    char * word;
    int i;
    int line = 1;


    FILE * infile;
    printf("Please Type in the File name:\n");
    scanf("%s",filename);
    infile = fopen(filename,"r");
    while(!infile)
    {
        printf("Fail to open file！\n");
        return;
    }
    ch = fgetc(infile);
BIGLOOP: while(ch!=EOF)
{

    i = 0;
    //Identifiers should begin with letter, can end with '$'
    if((ch>='A' && ch<='Z') || (ch>='a' && ch<='z')) {
        array[i++] = ch;
        ch = fgetc(infile);

        while((ch>='A' && ch<='Z')||(ch>='a' && ch<='z')||(ch>='0' && ch<='9') || ch == '$') {

            //if the second place of a variable is '$'
            if (ch == '$') {
                array[i++] = ch;
                ch = fgetc(infile);
                //if there's more letters or numbers or '$' after '$', which the variable does not end with '$' but
contains '$'
                if ((ch>='A' && ch<='Z')||(ch>='a' && ch<='z')||(ch>='0' && ch<='9') || ch == '$' || ch == '@'
                    || ch == '#' || ch == '?' || ch == '_') {
                    while ((ch>='A' && ch<='Z')||(ch>='a' && ch<='z')||(ch>='0' && ch<='9') || ch == '$' || ch == '@'
                           || ch == '#' || ch == '?' || ch == '_') {
                        array[i++] = ch;
                        ch = fgetc(infile);
                    }
                    fseek(infile,-1L,SEEK_CUR);//go back one place
                    word = new char[i+1];
                    memcpy(word,array,i);
                    word[i] = '\0';
                    createNewError(word,IDENTIFIER_ERROR,IDENTIFIER_ERROR_NUM,line);
                    ch = fgetc(infile);
                    goto BIGLOOP;
                }
                //Variable ends with '$', then create a new lexeme
                else {
                    word = new char[i+1];
                    memcpy(word,array,i);
                    word[i] = '\0';
                    int seekTemp = seekKey(word);
                    if(seekTemp!=IDENTIFER) {
                        createNewNode(word,KEY_DESC,seekTemp,-1,line);
                    }
                    else {
                        int addr_tmp = createNewIden(word,IDENTIFER_DESC,seekTemp,-1,line);
                        createNewNode(word,IDENTIFER_DESC,seekTemp,addr_tmp,line);
                    }
                    fseek(infile,-1L,SEEK_CUR);//go back one place
                    ch = fgetc(infile);
                    goto BIGLOOP;
                }
            }
            array[i++] = ch;
            ch = fgetc(infile);
        }
        word = new char[i+1];
        memcpy(word,array,i);
        word[i] = '\0';
        int seekTemp = seekKey(word);
        if (array[i - 1] >='0' && array[i - 1]<='9') {
            createNewError(word,IDENTIFIER_ERROR,IDENTIFIER_ERROR_NUM,line);
            ch = fgetc(infile);
            goto BIGLOOP;
        }
        else if(seekTemp!=IDENTIFER) {
            createNewNode(word,KEY_DESC,seekTemp,-1,line);
        }
        else {
            int addr_tmp = createNewIden(word,IDENTIFER_DESC,seekTemp,-1,line);
            createNewNode(word,IDENTIFER_DESC,seekTemp,addr_tmp,line);
        }
        fseek(infile,-1L,SEEK_CUR);//go back one place
    }

    //if a variable starts with '$', the entire variable is
    else if (ch == '$' || ch == '_') {
        array[i++] = ch;
        ch = fgetc(infile);
        if ((ch>='A' && ch<='Z')||(ch>='a' && ch<='z')||(ch>='0' && ch<='9') || ch == '$' || ch == '@'
            || ch == '#' || ch == '?' || ch == '_') {
            while ((ch>='A' && ch<='Z')||(ch>='a' && ch<='z')||(ch>='0' && ch<='9') || ch == '$' || ch == '@'
                   || ch == '#' || ch == '?' || ch == '_') {
                array[i++] = ch;
                ch = fgetc(infile);
            }
            fseek(infile,-1L,SEEK_CUR);//go back one place
            word = new char[i+1];
            memcpy(word,array,i);
            word[i] = '\0';
            createNewError(word,IDENTIFIER_ERROR,IDENTIFIER_ERROR_NUM,line);
            ch = fgetc(infile);
            goto BIGLOOP;
        }
    }
    //Start with number
    else if(ch >='0' && ch<='9')
    {
        int flag = 0;
        int flag2 = 0;
        //deal with int
        while(ch >='0' && ch<='9')
        {
            array[i++] = ch;
            ch = fgetc(infile);
        }
        //deal with float which is the same as real
        if(ch == '.')
        {
            flag2 = 1;
            array[i++] = ch;
            ch = fgetc(infile);
            if(ch>='0' && ch<='9')
            {
                while(ch>='0' && ch<='9')
                {
                    array[i++] = ch;
                    ch = fgetc(infile);
                }
            }
            else
            {
                flag = 1;
            }
        }
        word = new char[i+1];
        memcpy(word,array,i);
        word[i] = '\0';
        if(flag == 1)
        {
            createNewError(word,REAL_ERROR,REAL_ERROR_NUM,line);
        }
        else if(flag == 2)
        {
            createNewError(word,REAL_ERROR,REAL_ERROR_NUM,line);
        }
        else
        {
            if(flag2 == 0)
            {
                createNewNode(word,INT_DESC,INT_VAL,-1,line);
            }
            else
            {
                createNewNode(word,REAL_DESC,REAL_VAL,-1,line);
            }
        }
        fseek(infile,-1L,SEEK_CUR);
    }

//    //start with "/"
//    else if(ch == '/')
//    {
//        ch = fgetc(infile);
//        createNewNode("/",OPE_DESC,DIV,-1,line);
//    }

    else if(ch == ' ' || ch == '\t' || ch == '\r' || ch == '\n')
    {
        if(ch == '\n')
        {
            line++;
        }
    }
    else
    {
        if(ch == EOF)
        {
            return;
        }
        else if(ch == '-')
        {
            array[i++] = ch;
            ch = fgetc(infile);
            createNewNode("-",OPE_DESC,SUB,-1,line);
            fseek(infile,-1L,SEEK_CUR);
        }
        else if (ch == '/') {
```

```
        ch = fgetc(infile);
        createNewNode("/", OPE_DESC, DIV, -1, line);
        fseek(infile, -1L, SEEK_CUR);
    }
    else if(ch == '+')
    {
        ch = fgetc(infile);
        createNewNode("+",OPE_DESC,ADD,-1,line);
        fseek(infile,-1L,SEEK_CUR);
    }

    else if(ch == '*')
    {
        ch = fgetc(infile);
        createNewNode("*",OPE_DESC,MUL,-1,line);
        fseek(infile,-1L,SEEK_CUR);
    }

    else if(ch == '^')
    {
        ch = fgetc(infile);
        if(ch == '=')
        {
            createNewNode("^=",OPE_DESC,COMPLETE_BYTE_XOR,-1,line);
        }
    }
    //deal with %%
    else if(ch == '%')
    {
        ch = fgetc(infile);
        if(ch == '%')
        {
            createNewNode("%%",CLE_OPE_DESC,PERCENTPERCENT,-1,line);
        }
    }

    //deal with comments
    else if (ch == '!') {
        ch = fgetc(infile);
        while (1) {
            if (ch == '\n') {
                line++;
            }
            ch = fgetc(infile);
            if (ch == EOF) {
                createNewError(NULL, NOTE_ERROR, NOTE_ERROR_NUM, line);
                return ;
            }
            if (ch == '!') {
                break;
            }
        }
    }
    //Deal with "<"
    else if(ch == '<')
    {
        ch = fgetc(infile);
        createNewNode("<",OPE_DESC,LES_THAN,-1,line);
        fseek(infile,-1L,SEEK_CUR);
    }
    //Deal with ">"
    else if(ch == '>')
    {
        ch = fgetc(infile);
        createNewNode(">",OPE_DESC,GRT_THAN,-1,line);
        fseek(infile,-1L,SEEK_CUR);
    }
    else if(ch == '=')
    {
        ch = fgetc(infile);
        if(ch == '=')
        {
            createNewNode("==",OPE_DESC,EQUAL,-1,line);
        }
        else if (ch == '>') {
            createNewNode("=>",OPE_DESC,GRT_EQUAL,-1,line);
        }
        else if (ch == '<') {
            createNewNode("=<",OPE_DESC,LES_EQUAL,-1,line);
        }
        else
        {
            createNewNode("=",OPE_DESC,ASG,-1,line);
            fseek(infile,-1L,SEEK_CUR);
        }
        }

        else if(ch == '(')
        {
            leftSmall++;
            lineBra[0][leftSmall] = line;
            createNewNode("(",CLE_OPE_DESC,LEFT_BRA,-1,line);
        }
        else if(ch == ')')
        {
            rightSmall++;
            lineBra[1][rightSmall] = line;
            createNewNode(")",CLE_OPE_DESC,RIGHT_BRA,-1,line);
        }
        else if(ch == '[')
        {
            leftMiddle++;
            lineBra[2][leftMiddle] = line;
            createNewNode("[",CLE_OPE_DESC,LEFT_INDEX,-1,line);
        }
        else if(ch == ']')
        {
            rightMiddle++;
            lineBra[3][rightMiddle] = line;
            createNewNode("]",CLE_OPE_DESC,RIGHT_INDEX,-1,line);
        }
        else if(ch == '{')
        {
            leftBig++;
            lineBra[4][leftBig] = line;
            createNewNode("{",CLE_OPE_DESC,L_BOUNDER,-1,line);
        }
        else if(ch == '}')
        {
            rightBig++;
            lineBra[5][rightBig] = line;
            createNewNode("}",CLE_OPE_DESC,R_BOUNDER,-1,line);
        }
        else if(ch == '.')
        {
            createNewNode(".",CLE_OPE_DESC,POINTER,-1,line);
        }
        else if(ch == ',')
        {
            createNewNode(",",CLE_OPE_DESC,COMMA,-1,line);
        }
        else if (ch == ':') {
            createNewNode(":",CLE_OPE_DESC,COLON,-1,line);
        }
        else if(ch == ';')
        {
            createNewNode(";",CLE_OPE_DESC,SEMI,-1,line);
        }
        else
        {
            char temp[2];
            temp[0] = ch;
            temp[1] = '\0';
            createNewError(temp,CHAR_ERROR,CHAR_ERROR_NUM,line);
        }
    }
    ch = fgetc(infile);
}
}
void BraMappingError()
{
    if(leftSmall != rightSmall)
    {
        int i = (leftSmall>rightSmall) ? (leftSmall-rightSmall) : (rightSmall - leftSmall);
        bool  flag = (leftSmall>rightSmall) ? true : false;
        if(flag)
        {
            while(i--)
            {
                createNewError(_NULL,LEFT_BRA_ERROR,LEFT_BRA_ERROR_NUM,lineBra[0][i+1]);
            }
        }
        else
        {
            while(i--)
            {
                createNewError(_NULL,RIGHT_BRA_ERROR,RIGHT_BRA_ERROR_NUM,lineBra[1][i+1]);
            }
        }
    }
    if(leftMiddle != rightMiddle)
    {
        int i = (leftMiddle>rightMiddle) ? (leftMiddle-rightMiddle) : (rightMiddle - leftMiddle);
        bool flag = (leftMiddle>rightMiddle) ? true : false;
        if(flag)
        {
            while(i--)
            {
                createNewError(_NULL,LEFT_INDEX_ERROR,LEFT_INDEX_ERROR_NUM,lineBra[2][i+1]);
            }
        }
        else
        {
            while(i--)
            {
                createNewError(_NULL,RIGHT_INDEX_ERROR,RIGHT_INDEX_ERROR_NUM,lineBra[3][i+1]);
            }
        }
    }
    if(leftBig != rightBig)
    {
        int i = (leftBig>rightBig) ? (leftBig-rightBig) : (rightBig - leftSmall);
        bool flag = (leftBig>rightBig) ? true : false;
        if(flag)
        {
            while(i--)
            {
                createNewError(_NULL,L_BOUNDER_ERROR,L_BOUNDER_ERROR_NUM,lineBra[4][i+1]);
            }
        }
        else
        {
            while(i--)
            {
                createNewError(_NULL,R_BOUNDER_ERROR,R_BOUNDER_ERROR_NUM,lineBra[5][i+1]);
            }
        }
    }
}
```

```
//
//  SynAnalysis.h
//  CPSC323_HW3
//
//  Created by Liren on 4/21/18.
//  Copyright © 2018 Liren. All rights reserved.
//

#ifndef SynAnalysis_h
#define SynAnalysis_h

bool Rat18S(NormalNode&);
bool OptFunctionDefinitions(NormalNode&);
bool FunctionDefinitions(NormalNode&);
bool Function(NormalNode&);
bool OptParameterList(NormalNode&);
bool ParameterList(NormalNode&);
bool Parameter(NormalNode&);
bool Qualifier(NormalNode&);
bool Body(NormalNode&);
bool OptDeclarationList(NormalNode&);
bool DeclarationList(NormalNode&);
bool Declaration(NormalNode&);
bool IDs(NormalNode&);
bool StatementList(NormalNode&);
bool Statement(NormalNode&);
bool Compound(NormalNode&);
bool Assign(NormalNode&);
bool If(NormalNode&);
bool Return(NormalNode&);
bool Print(NormalNode&);
bool Scan(NormalNode&);
bool While(NormalNode&);
bool Condition(NormalNode&);
bool Relop(NormalNode&);
bool Expression(NormalNode&);
bool Term(NormalNode&);
bool Factor(NormalNode&);
bool Primary(NormalNode&);
bool Identifier(NormalNode&);
bool Real(NormalNode&);
bool Integer(NormalNode&);
bool Empty(NormalNode&);
bool ExpressionP(NormalNode&);
bool TermP(NormalNode&);
bool FunctionDefinitionsP(NormalNode&);
bool ParameterListP(NormalNode&);
bool DeclarationListP(NormalNode&);
bool IDsP(NormalNode&);
bool StatementListP(NormalNode&);
bool IfP(NormalNode&);
bool ReturnP(NormalNode&);
bool PrimaryP(NormalNode&);


void analysis(NormalNode&);


#endif /* SynAnalysis_h */


//
//  SynAnalysis.cpp
//  CPSC323_HW3
//
//  Created by Liren on 4/21/18.
//  Copyright © 2018 Liren. All rights reserved.
//
#include <iostream>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fstream>
#include <vector>
#include <string>
#include <stack>
#include <iomanip>
#include "LexAnalysis.h"
#include "SynAnalysis.h"
using namespace std;

extern NormalNode * normalHead;//First node
extern NormalNode * normalTail;//Last node
extern vector<pair<const char *,int> > keyMap;
extern vector<pair<const char *,int> > operMap;
extern vector<pair<const char *,int> > limitMap;
vector<pair<const char *,int> > specialMap;//special symbol in grammar (-> | EPSILON $)
fstream resultfile;

string SYMBOL_TYPE = "";

stack<int> jumpStack;

struct Instruction_Table {
    int inst_address_;
    string op_;
    string oprnd_;
};

struct Symbol_Table {
    string symbol_;
    string type_;
    int address_;
};

int instr_address = 1;
int symbol_table_num = 1;
int curr_Symbol_addr = 2000;
Instruction_Table* Inst_table = new Instruction_Table[500]();
int Inst_table_size = 0;
Symbol_Table* Sym_table = new Symbol_Table[100]();
int Sym_table_size = 1;

void gen_instr(string op, string oprnd) {
    Inst_table[instr_address].inst_address_ = instr_address;
    Inst_table[instr_address].op_ = op;
    Inst_table[instr_address].oprnd_ = oprnd;
    instr_address++;
}

int get_address(NormalNode node) {
    return Sym_table[node.addr].address_;
}


void back_patch(int instr_address) {
    int addr = 0;
    addr = jumpStack.top();
    jumpStack.pop();
    Inst_table[addr].oprnd_ = to_string(instr_address);
}

bool Rat18S(NormalNode& p) {
    NormalNode iterator = p;
    if (!OptFunctionDefinitions(iterator)) return false;
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;
    string str(iterator.content);
    if (str.compare("%%") != 0) {
        cout << "Syntax Error: " << "Line " << p.line << " , %% not matched." << endl;
        return false;
    }

    if (iterator.next == NULL) {
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;
    if (!OptDeclarationList(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;
    if (!StatementList(iterator)) {
        return false;
    }
    p = iterator;
    cout << "Line " << p.line << " , <Rat18S> matched." << endl;
    return true;
}

bool OptFunctionDefinitions(NormalNode& p) {
    NormalNode iterator = p;
    if (FunctionDefinitions(iterator)) {
        cout << "Line " << p.line << " , <OptFunctionDefinitions> -> <OptFunctionDefinitions> is match." << endl;
        p = iterator;
        return true;
    }
    else {
        cout << "Line " << p.line << " , <OptFunctionDefinitions> -> <Empty>" << endl;
        p = *p.prev;
        return true;
    }
}

bool FunctionDefinitions(NormalNode& p) {
    NormalNode iterator = p;
    if (!Function(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!FunctionDefinitionsP(iterator)) {
        return false;
    }
    cout << "Line " << p.line << " , <FunctionDefinitions> -> <Function><FunctionDefinitionsP> is match." << endl;
    p = iterator;
    return true;
}

bool Function(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("function") != 0) {
        return false;
    }
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Identifier(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare("[") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!OptParameterList(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str3(p.content);
    if (str3.compare("]") != 0) {
        cout << "Syntax Error: " << "Line " << p.line << " , seperator \"]\" not matched." << endl;
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!OptDeclarationList(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Body(iterator)) {
        return false;
    }
    cout << "Line " << p.line << " , <Function> -> function <Identifier> [ <OptParameterList> ] <OptDeclarationList>
<Body> matched "<< endl;
    p = iterator;
    return true;
}


bool OptParameterList(NormalNode& p) {
    NormalNode iterator = p;
    if (ParameterList(iterator)) {
        cout << "Line " << p.line << " , <OptParameterList> -> <ParameterList> matched." << endl;
        p = iterator;
        return true;
    }
    else {
        cout << "Line " << p.line << " , <OptParameterList> -> <Empty>" << endl;
        p = *p.prev;
        return true;
    }
}


bool ParameterList(NormalNode& p) {
    NormalNode iterator = p;
    if (!Parameter(iterator)) {
        cout << "Syntax Error: " << "Line " << p.line << " , <Parameter> not matched." << endl;
        return false;
    }

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!ParameterListP(iterator)) {
        cout << "Syntax Error: " << "Line " << p.line << " , <ParameterListP> not matched." << endl;
        return false;
    }

    cout << "Line " << p.line << " , <ParameterList> -> <Parameter> <ParameterListP> matched." << endl;
    p = iterator;
    return true;
}

bool Parameter(NormalNode& p) {
    NormalNode iterator = p;
    if (!IDs(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str(p.content);
    if (str.compare(":") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Qualifier(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <Parameter> -> <IDs> : <Qualifier> matched." << endl;
    p = iterator;
    return true;
}


bool Qualifier(NormalNode& p) {
    string str(p.content);
    if (str.compare("int") == 0) {
        cout << "Line " << p.line << " , <Qualifier> -> int  matched." << endl;
        return true;
    }
    else if (str.compare("boolean") == 0) {
        cout << "Line " << p.line << " , <Qualifier> -> boolean  matched." << endl;
        return true;
    }
    else if (str.compare("real") == 0) {
        cout << "Line " << p.line << " , <Qualifier> -> real  matched." << endl;
        return true;
    }
    else {
        return false;
    }
}


bool Body(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("{") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!StatementList(iterator)) {
        return false;
    }

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;


    string str2(p.content);
    if (str2.compare("}") != 0) {
        cout << "Syntax Error: " << "Line " << p.line << " , seperator \"}\" not matched." << endl;
        return false;
    }

    cout << "Line " << p.line << " , <Body> -> { <StatementList> } matched." << endl;
    p = iterator;
    return true;
}

bool OptDeclarationList(NormalNode& p) {
    NormalNode iterator = p;
    if (DeclarationList(iterator)) {
        cout << "Line " << p.line << " , <OptDeclarationList> -> <DeclarationList> matched." << endl;
        p = iterator;
        return true;
    }
    else {
        cout << "Line " << p.line << " , <OptDeclarationList> -> <Empty>." << endl;
        p = *p.prev;
        return true;
    }
}

bool DeclarationList(NormalNode& p) {
    NormalNode iterator = p;
    if (!Declaration(iterator)) {
        return false;
    }

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str(p.content);
    if (str.compare(";") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!DeclarationListP(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <DeclarationList> -> <Declaration> ; <DeclarationListP> matched." << endl;
    p = iterator;
    return true;
}


bool Declaration(NormalNode& p) {
    NormalNode iterator = p;
    string str(iterator.content);
    if (str.compare("int") == 0) {
        SYMBOL_TYPE = "int";
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;


        NormalNode declarationStart = p;
        if (!IDs(iterator)) {
            return false;
        }
        else {
            NormalNode declarationEnd = iterator;
            while (declarationStart.next != declarationEnd.next) {
                string declarationStartString(declarationStart.describe);
                if (declarationStartString.compare("Identifier") == 0) {
                    //check duplicate declaration
                    if (Sym_table[declarationStart.addr].address_ != 0) {
                        cout << "Syntax Error: \"" << declarationStart.content << "\" is already defined." << endl;
                        return false;
                    }
                    //create declared variables in symbol table
                    string declarationStartContent(declarationStart.content);
                    Sym_table[declarationStart.addr].type_ = SYMBOL_TYPE;
                    Sym_table[declarationStart.addr].address_ = declarationStart.addr - 1 + 2000;
                    Sym_table[declarationStart.addr].symbol_ = declarationStartContent;
                }
                declarationStart = *declarationStart.next;
            }
            string declarationStartString(declarationStart.describe);
            if (declarationStartString.compare("Identifier") == 0) {
                //check duplicate declaration
                if (Sym_table[declarationStart.addr].address_ != 0) {
                    cout << "Syntax Error: \"" << declarationStart.content << "\" is already defined." << endl;
                    return false;
                }
                string declarationStartContent(declarationStart.content);
                Sym_table[declarationStart.addr].type_ = SYMBOL_TYPE;
                Sym_table[declarationStart.addr].address_ = declarationStart.addr - 1 + 2000;
                Sym_table[declarationStart.addr].symbol_ = declarationStartContent;
            }
            cout << "Line " << p.line << " , <Declaration> -> int <IDs> matched." << endl;
            p = iterator;
            return true;
        }
    }
    else if (str.compare("boolean") == 0) {
        SYMBOL_TYPE = "boolean";
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!IDs(iterator)) {
            return false;
        }
        else {
            cout << "Line " << p.line << " , <Declaration> -> boolean <IDs> matched." << endl;
            p = iterator;
            return true;
        }
    }
    else if (str.compare("real") == 0) {
        cout << "No \"real\" type variable is allowed in simplified Rat18S compiler." << endl;
        return false;
        SYMBOL_TYPE = "real";
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!IDs(iterator)) {
            return false;
        }
        else {
            cout << "Line " << p.line << " , <Declaration> -> real <IDs> matched." << endl;
            p = iterator;
            return true;
        }
    }
    else {
        //cout << "Syntax Error: " << "Line " << p.line << " , <Declaration> not matched." << endl;
        return false;
    }

}

bool IDs(NormalNode& p) {
    NormalNode iterator = p;
    if (!Identifier(iterator)) {
        return false;
    }

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!IDsP(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <IDs> -> <Identifier> <IDsP> matched." << endl;
    p = iterator;
    return true;
}

bool StatementList(NormalNode& p) {
    NormalNode iterator = p;
    if (!Statement(iterator)) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!StatementListP(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <StatementList> -> <Statement> <StatementListP> matched." << endl;
    p = iterator;
    return true;
}

bool Statement(NormalNode& p) {
    NormalNode iterator = p;
    if (Compound(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <Compound> matched." << endl;
        p = iterator;
        return true;
    }
    else if (Assign(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <Assign> matched." << endl;
        p = iterator;
        return true;
    }
    else if (If(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <If> matched." << endl;
        p = iterator;
        return true;
    }
    else if (Return(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <Return> matched." << endl;
        p = iterator;
        return true;
    }
    else if (Print(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <Print> matched." << endl;
        p = iterator;
        return true;
    }
    else if (Scan(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <Scan> matched." << endl;
        p = iterator;
        return true;
    }
    else if (While(iterator)) {
        cout << "Line " << p.line << " , <Statement> -> <While> matched." << endl;
        p = iterator;
        return true;
    }
    else {
        //cout << "Syntax Error: " << "Line " << p.line << " , <Statement> not matched." << endl;
        return false;
    }
}

bool Compound(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("{") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!StatementList(iterator)) {
        return false;
    }

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;


    string str2(p.content);
    if (str2.compare("}") != 0) {
        return false;
    }

    cout << "Line " << p.line << " , <Compound> -> { <StatementList> } matched." << endl;
    p = iterator;
    return true;
}


bool Assign(NormalNode& p) {
    NormalNode iterator = p;
    if (!Identifier(iterator)) {
        return false;
    }

    NormalNode save = iterator;
    string pContent(save.content);
    string pDescribe(save.describe);

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str(p.content);
    if (str.compare("=") != 0) {
        cout << "Line: " << p.line << "Syntax Error: " << "= expected" << endl;
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;



    if (!Expression(iterator)) {
        return false;
    }

    string saveContent(save.content);
    Sym_table[save.addr].type_ = SYMBOL_TYPE;
    Sym_table[save.addr].address_ = save.addr - 1 + 2000;
    Sym_table[save.addr].symbol_ = saveContent;
    gen_instr("POPM", to_string(get_address(save)));
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare(";") != 0) {
        return false;
    }

    cout << "Line " << p.line << " , <Assign> -> <Identifier> = <Expression> ; matched." << endl;
    p = iterator;
    return true;
}


bool If(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("if") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare("(") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Condition(iterator)) {
        return false;
    }
    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;


    string str3(p.content);
    if (str3.compare(")") != 0) {
        cout << "Line: " << p.line << " Syntax Error: " << ") expected." << endl;
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Statement(iterator)) {
        return false;
    }

    back_patch(instr_address);

    p = iterator;
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!IfP(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <If> -> if ( <Condition> ) <Statement> <IfP> matched." << endl;
    p = iterator;
    return true;
}

bool Return(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("return") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!ReturnP(iterator)) {
        return false;
    }

    cout << "Line " << p.line << " , <Return> -> return <ReturnP> matched." << endl;
    p = iterator;
    return true;
}

bool Print(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("put") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare("(") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

//
//    NormalNode printIDstart = iterator;

    if (!Expression(iterator)) {
        return false;
    }
    gen_instr("STDOUT", " ");

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str3(p.content);
    if (str3.compare(")") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str4(p.content);
    if (str4.compare(";") != 0) {
        return false;
    }
    cout << "Line " << p.line << " , <Print> -> put ( <Expression> ) ; matched." << endl;
    p = iterator;
    return true;
}

bool Scan(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("get") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare("(") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    NormalNode scanIDstart = p;

    if (!IDs(iterator)) {
        return false;
    }

    NormalNode scanIDend = iterator;
    while (scanIDstart.next != scanIDend.next) {
        string scanIDstartString(scanIDstart.describe);
        if (scanIDstartString.compare("Identifier") == 0) {
            gen_instr("STDIN", " ");
            gen_instr("POPM", to_string(get_address(scanIDstart)));
        }
        else if (scanIDstartString.compare("int") == 0) {
            gen_instr("STDIN", " ");
            gen_instr("POPM", to_string(get_address(scanIDstart)));
        }
        scanIDstart = *scanIDstart.next;
    }
    string scanIDstartString(scanIDstart.describe);
    if (scanIDstartString.compare("Identifier") == 0) {
        gen_instr("STDIN", " ");
        gen_instr("POPM", to_string(get_address(scanIDstart)));
    }
    else if (scanIDstartString.compare("int") == 0) {
        gen_instr("STDIN", " ");
        gen_instr("POPM", to_string(get_address(scanIDstart)));
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str3(p.content);
    if (str3.compare(")") != 0) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str4(p.content);
    if (str4.compare(";") != 0) {
        return false;
    }
    cout << "Line " << p.line << " , <Scan> -> get ( <IDs> ) ; matched." << endl;
    p = iterator;
    return true;
}

bool While(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("while") != 0) {
        cout << "Line: " << p.line << " Syntax Error: " << "while expected" << endl;
        return false;
    }
    int addr = instr_address;
    gen_instr("LABEL", " ");

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str2(p.content);
    if (str2.compare("(") != 0) {
        cout << "Line: " << p.line << " Syntax Error: " << "( expected" << endl;
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Condition(iterator)) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    string str3(p.content);
    if (str3.compare(")") != 0) {
        cout << "Line: " << p.line << " Syntax Error: " << ") expected" << endl;
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Statement(iterator)) {
        return false;
    }

    gen_instr("JUMP", to_string(addr));
    back_patch(instr_address);

    cout << "Line " << p.line << " , <While> -> while ( <Condition> ) <Statement> matched." << endl;
    p = iterator;
    return true;
}

bool Condition(NormalNode& p) {
    NormalNode iterator = p;
    if (!Expression(iterator)) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;


    if (!Relop(iterator)) {
        return false;
    }
    NormalNode op = iterator;
    string opstring(op.content);
    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!Expression(iterator)) {
        return false;
    }

    if (opstring.compare("<") == 0) {
        gen_instr("LES", " ");
        jumpStack.push(instr_address);
        gen_instr("JUMPZ", " ");
    }
    else if (opstring.compare(">") == 0) {
        gen_instr("GRT", " ");
        jumpStack.push(instr_address);
        gen_instr("JUMPZ", " ");
    }
    else if (opstring.compare("==") == 0) {
        gen_instr("EQU", " ");
        jumpStack.push(instr_address);
        gen_instr("JMPZ", " ");
    }
    else if (opstring.compare("^=") == 0) {
        gen_instr("NEQ", " ");
        jumpStack.push(instr_address);
        gen_instr("JUMPZ", " ");
    }
    else if (opstring.compare("=>") == 0) {
        gen_instr("GEQ", " ");
        jumpStack.push(instr_address);
        gen_instr("JUMPZ", " ");
    }
    else if (opstring.compare("=<") == 0) {
        gen_instr("LEQ", " ");
        jumpStack.push(instr_address);
        gen_instr("JUMPZ", " ");
    }
    cout << "Line " << p.line << " , <Condition> -> <Expression> <Relop> <Expression> matched." << endl;
    p = iterator;
    return true;
}

bool Relop(NormalNode& p) {
    string str(p.content);
    if (str.compare("==") == 0) {
        cout << "Line " << p.line << " , <Relop> -> == matched." << endl;
        return true;
    }
    else if (str.compare("^=") == 0) {
        cout << "Line " << p.line << " , <Relop> -> ^= matched." << endl;
        return true;
    }
    else if (str.compare("<") == 0) {
        cout << "Line " << p.line << " , <Relop> -> < matched." << endl;
        return true;
    }
    else if (str.compare(">") == 0) {
        cout << "Line " << p.line << " , <Relop> -> > matched." << endl;
        return true;
    }
    else if (str.compare("=>") == 0) {
        cout << "Line " << p.line << " , <Relop> -> => matched." << endl;
        return true;
    }
    else if (str.compare("=<") == 0) {
        cout << "Line " << p.line << " , <Relop> -> =< matched." << endl;
        return true;
    }
    else {
        cout << "Line: " << p.line << " Syntax Error: " << "==, < , >, =>, =< or ^= token is expcted. " << endl;
        return false;
    }
}

bool Expression(NormalNode& p) {
    NormalNode iterator = p;
    if (!Term(iterator)) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;

    if (!ExpressionP(iterator)) {
        return false;
    }
    cout << "Line " << p.line << " , <Expression> -> <Term> <ExpressionP> matched." << endl;
    p = iterator;
    return true;
}

bool Term(NormalNode& p) {
    NormalNode iterator = p;
    if (!Factor(iterator)) {
        return false;
    }

    if (iterator.next == NULL) {
        p = iterator;
        cout << "EOF: " << "Line " << p.line << "." << endl;
        return true;
    }
    p = *iterator.next;
    iterator = p;


    if (!TermP(iterator)) {
        return false;
    }
    cout << "Line " << p.line << " , <Term> -> <Factor> <TermP> matched." << endl;
    p = iterator;
    return true;
}

bool Factor(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("-") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;
        if (!Primary(iterator)) {
            return false;
        }
        else {
            cout << "Line " << p.line << " , <Factor> -> - <Primary> matched." << endl;
            p = iterator;
            return true;
        }
    }
    if (Primary(iterator)) {
        cout << "Line " << p.line << " , <Factor> -> <Primary> matched." << endl;
        p = iterator;
        return true;
    }
    cout << "Line: " << p.line << " Syntax Error: id expected" << endl;
    return false;
}

bool Primary(NormalNode& p) {
    NormalNode iterator = p;
    string str(iterator.content);
    if (Identifier(iterator)) {
        if (Sym_table[iterator.addr].address_ == 0) {
            cout << "Error: " << iterator.content << " is not declared." << endl;
            return false;
        }
        else {
            gen_instr("PUSHM", to_string(get_address(p)));
        }

        //gen_instr("PUSHM", to_string(get_address(p)));

        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (PrimaryP(iterator)) {
            cout << "Line " << p.line << " , <Primary> -> <Identifier> <PrimaryP> matched." << endl;
            p = iterator;
            return true;
        }
        else {
            return false;
        }
    }
    else if (Integer(iterator)) {
        cout << "Line " << p.line << " , <Primary> -> <Integer> matched." << endl;
        p = iterator;
        return true;
    }
    else if (str.compare("(") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!Expression(iterator)) {
            return false;
        }

        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        string str2(iterator.content);
        if (str2.compare(")") != 0) {
            return false;
        }
        cout << "Line " << p.line << " , <Primary> -> ( <Expression> ) matched." << endl;
        p = iterator;
        return true;
    }
    else if (Real(iterator)) {
        cout << "Line " << p.line << " , <Primary> -> <Real> matched." << endl;
        p = iterator;
        return true;
    }
    else if (str.compare("true") == 0) {
        cout << "Line " << p.line << " , <Primary> -> true matched." << endl;
        p = iterator;
        return true;
    }
    else if (str.compare("false") == 0) {
        cout << "Line " << p.line << " , <Primary> -> false matched." << endl;
        p = iterator;
        return true;
    }
    else {
        return false;
    }
}

bool Identifier(NormalNode& p) {
    string str(p.describe);
    if (str.compare("Identifier") == 0 ) {
        cout << "Line " << p.line << ", id = " << p.content << " , <Identifier> -> id matched." << endl;
        return true;
    }
    return false;
}

bool Real(NormalNode& p) {
    string str(p.describe);
    if (str.compare("real") == 0) {
        //cout << "Line " << p.line << " , <Real> -> real matched." << endl;
        cout << "No real type is allowed in Rat18S compiler." << endl;
        return false;
    }
    return false;
}

bool Integer(NormalNode& p) {
    string str(p.describe);
    if (str.compare("int") == 0) {
        string pContent(p.content);
        Sym_table[p.addr].type_ = SYMBOL_TYPE;
        Sym_table[p.addr].address_ = atoi(p.content);
        Sym_table[p.addr].symbol_ = pContent;
        gen_instr("PUSHI", to_string(get_address(p)));
        cout << "Line " << p.line << " , <Integer> -> int matched." << endl;
        return true;
    }
    return false;
}

bool Empty(NormalNode& p) {
    cout << "Line " << p.line << " , <Empty> -> EPSILON matched." << endl;
    return true;
}

bool ExpressionP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("+") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!Term(iterator)) {
            return false;
        }

        gen_instr("ADD", " ");
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!ExpressionP(iterator)) {
            return false;
        }
        cout << "Line " << p.line << " , <ExpressionP> -> + <Term> <ExpressionP> matched." << endl;
        p = iterator;
        return true;
    }
    else if (str.compare("-") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!Term(iterator)) {
            return false;
        }

        gen_instr("SUB", " ");
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!ExpressionP(iterator)) {
            return false;
        }
        cout << "Line " << p.line << " , <ExpressionP> -> - <Term> <ExpressionP> matched." << endl;
        p = iterator;
        return true;
    }
    else {
        cout << "Line " << p.line << " , <ExpressionP> -> EPSILON matched." << endl;
        p = *p.prev;
        return true;
    }
}

bool TermP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("*") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!Factor(iterator)) {
            return false;
        }

        gen_instr("MUL", " ");
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!TermP(iterator)) {
            return false;
        }
        else {
            p = iterator;
            cout << "Line " << p.line << " , <TermP> -> * <Factor> <TermP>  matched." << endl;
            return true;
        }
    }
    else if (str.compare("/") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!Factor(iterator)) {
            return false;
        }

        gen_instr("DIV", " ");
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;


        if (!TermP(iterator)) {
            return false;
        }
        else {
            p = iterator;
            cout << "Line " << p.line << " , <TermP> -> / <Factor> <TermP>  matched." << endl;
            return true;
        }
    }
    else {
        cout << "Line " << p.line << " , <TermP> -> EPSILON matched." << endl;
        p = *p.prev;
        return true;
    }
}


bool FunctionDefinitionsP(NormalNode& p) {
    NormalNode iterator = p;
    if (FunctionDefinitions(iterator)) {
        p = iterator;
        cout << "Line " << p.line << " , <FunctionDefinitionsP> -> <FunctionDefinitions>  matched." << endl;
        return true;
    }
    else {
        p = *p.prev;
        cout << "Line " << p.line << " , <FunctionDefinitionsP> -> EPSILON matched." << endl;
        return true;
    }
}

bool ParameterListP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare(",") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!ParameterList(iterator)) {
            return false;
        }
        else {
            p = iterator;
            cout << "Line " << p.line << " , <ParameterListP> -> <ParameterList> matched." << endl;
            return true;
        }
    }
    else {
        p = *p.prev;
        cout << "Line " << p.line << " , <ParameterListP> -> EPSILON matched." << endl;
        return true;
    }
}

bool DeclarationListP(NormalNode& p) {
    NormalNode iterator = p;
    if (DeclarationList(iterator)) {
        p = iterator;
        cout << "Line " << p.line << " , <DeclarationListP> -> <DeclarationList> matched." << endl;
        return true;
    }
    else {
        p = *p.prev;
        cout << "Line " << p.line << " , <DeclarationListP> -> EPSILON matched." << endl;
        return true;
    }
}

bool IDsP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare(",") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!IDs(iterator)) {
            return false;
        }
        else {
            p = iterator;
            cout << "Line " << p.line << " , <IDsP> -> , <IDs> matched." << endl;
            return true;
        }
    }
    else {
        p = *p.prev;
        cout << "Line " << p.line << " , <IDsP> -> EPSILON matched." << endl;
        return true;
    }
}

bool StatementListP(NormalNode& p) {
    NormalNode iterator = p;

    if (StatementList(iterator)) {
        p = iterator;
        cout << "Line " << p.line << " , <StatementListP> -> <StatementList> matched." << endl;
        return true;
    }
    else {
        p = *p.prev;
        cout << "Line " << p.line << " , <StatementListP> -> EPSILON matched." << endl;
        return true;
    }
}


bool IfP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("endif") == 0) {
        cout << "Line " << p.line << " , <IfP> -> endif matched." << endl;
        return true;
    }
    else if (str.compare("else") == 0) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;
        if (!Statement(iterator)) {
            return false;
        }

        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        string str2(p.content);
        if (str2.compare("endif") != 0) {
            cout << "Syntax Error: " << "Line " << p.line << " , \"endif\" is missing." << endl;
            return false;
        }

        p = iterator;
        cout << "Line " << p.line << " , <IfP> -> else <Statement> endif matched." << endl;
        return true;
    }
    else {
        cout << "Syntax Error: " << "Line " << p.line << " , \"endif or else\" is missing." << endl;
        return false;
    }
}

bool ReturnP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare(";") == 0) {
        cout << "Line " << p.line << " , <ReturnP> -> ; matched." << endl;
        return true;
    }
    else if (Expression(iterator)) {
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        string str2(p.content);
        if (str2.compare(";") != 0) {
            cout << "Syntax Error: " << "Line " << p.line << " , \";\" is missing." << endl;
            return false;
        }
        else {
            cout << "Line " << p.line << " , <ReturnP> -> <Expression> matched." << endl;
            p = iterator;
            return true;
        }
    }
    cout << "Syntax Error: " << "Line " << p.line << " , \";\" is missing." << endl;
    return false;
}

bool PrimaryP(NormalNode& p) {
    NormalNode iterator = p;
    string str(p.content);
    if (str.compare("(") == 0) {
        cout << "Line " << p.line << " , seperator \"(\" matched." << endl;
        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        if (!IDs(iterator)) {
            return false;
        }

        if (iterator.next == NULL) {
            p = iterator;
            cout << "EOF: " << "Line " << p.line << "." << endl;
            return true;
        }
        p = *iterator.next;
        iterator = p;

        string str2(p.content);
        if (str2.compare(")") != 0) {
            cout << "Syntax Error: " << "Line " << p.line << " , seperator \")\" not matched." << endl;
            return false;
        }
        else {
            cout << "Line " << p.line << " , <PrimaryP> -> ( <IDs> ) matched." << endl;
            p = iterator;
            return true;
        }
    }
    else {
        cout << "Line " << p.line << " , <PrimaryP> -> EPSILON is matched." << endl;
        p = *p.prev;
        return true;
    }
}


void analysis(NormalNode& head) {
    NormalNode p = head;
    p = *p.next;
    if (Rat18S(p) && p.next == NULL) {
        cout << "success" << endl;
        gen_instr("", "");
        //Symbol_Table* Sym_table = new Symbol_Table[100]();
        Symbol_Table* Sym_table_iterator = Sym_table;
        //Instruction_Table* Inst_table = new Instruction_Table[500]();
        Instruction_Table* Inst_table_iterator = Inst_table;
        cout << endl << endl;
        //Analysis Result output file
        resultfile.open("Symbol_Table.txt",std::ios::out);
        cout << "************************ Symbol Table *****************************" << endl << endl;
        cout << "\t\t" << "Identifier" << "  \t\t\t" << "Type" << "\t\t" << "Memory Addr." << endl;
        resultfile << "************************ Symbol Table *****************************" << endl << endl;
        resultfile << "\t" << "Identifier" << "\t\t" << "Type" << "\t\t" << "Memory Addr." << endl;
        for (int i = 1 ; i < 10 ; i++) {
            if (Sym_table_iterator[i].address_ == 0) break;
            cout << setw(15) << Sym_table_iterator[i].symbol_ << setw(20) << Sym_table_iterator[i].type_ << setw(15) <<
Sym_table_iterator[i].address_ << endl;
            resultfile << setw(15) << Sym_table_iterator[i].symbol_ << setw(20) << Sym_table_iterator[i].type_ <<
setw(20) << Sym_table_iterator[i].address_ << endl;
        }
        cout << endl;
        resultfile.close();

        resultfile.open("Instruction_Table.txt",std::ios::out);
        cout << "************************* Instruction Table *****************************" << endl << endl;
        cout << "\t\t" << "Instruction Addr." << "  \t\t\t" << "Operation" << "\t\t" << "Operand" << endl;
        resultfile << "******************************* Instruction Table ***********************************" << endl <<
endl;
        resultfile << "\t\t" << "Instruction Addr." << "  \t\t" << "Operation" << "\t\t" << "Operand" << endl;
        for (int i = 1 ; i < instr_address; i++) {
            cout  << setw(18) << Inst_table_iterator[i].inst_address_ << setw(26) << Inst_table_iterator[i].op_ <<
setw(14) << Inst_table_iterator[i].oprnd_ << endl;
            resultfile << setw(18) << Inst_table_iterator[i].inst_address_ << setw(35) << Inst_table_iterator[i].op_ <<
setw(24) << Inst_table_iterator[i].oprnd_ << endl;
        }
        cout << endl;
        resultfile.close();
    }
    else cout << "Syntax Error" << endl;
}
```