编译专题实验报告

语义分析

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完成模式：独立完成

实验平台

1. 操作系统：WSL2 Ubuntu 20.04
2. 编程语言：C++
3. g++版本：13.1.0

实验目的

1. 目的：构建语法制导的语义分析程序能在语法分析的同时生成符号表和中间语言代码，并输出结果到文件中。
2. 功能：
   SLR(1)制导的语义分析框架实现；
   中间语言代码形式：四元式；

实验内容

1. cifa.cpp：词法分析程序，生成token序列；

```cpp
#include <algorithm> // 包含 std::transform
#include <cctype> // 包含 std::tolower
#include <fstream>
#include <iostream>
#include <map>
#include <stdio.h>
#include <string>
#include <unistd.h>
#include <vector>

using namespace std;
int state;          //当前状态指示
char C;             //当前读入字符
string nowstr;      //当前读入的字符串
char *buffer;       //文件缓冲区
int forwar = -1;        //向前指针
int rows = 1;           //文件行数
int sum_char = 0;       //文件总字符数
vector<string> keyword = {"auto", "break", "case", "char", "const",
"continue", "default",
                          "do", "double", "else", "enum", "extern",
"float", "for", "goto",
                          "if", "int", "long", "register", "return",
"short", "signed",
```

```
                        "sizeof", "static", "struct", "switch",
"typedef", "union",
                        "unsigned", "void", "volatile", "while",
"define","include"};    //关键字表
```

完整代码见附录1. cifa.cpp。

cifa.cpp由第二次实验修改而来，主要功能是词法分析，生成token序列。从文件input.txt中读取内容，识别出关键字、标识符、常数、运算符、界符等，并输出到文件outputofcifa.txt中。作为后面语法分析的输入。

输入：

```
s=a+b+c+(a*a )
```

输出：

```
(id, s)(OPERATOR, =)(id, a)(OPERATOR, +)(id, b)(OPERATOR, +)(id, c)
(OPERATOR, +)(DELIMITER, ()(id, a)(OPERATOR, *)(id, a)(DELIMITER, ))
```

2. slr.cpp:

```
#include<stdio.h>
#include<string.h>
#include<stdlib.h>
#include<iostream>
#define MAX_LEN 1000
using namespace std;
struct stack {
    char s[MAX_LEN];
    int i[MAX_LEN];
    int point[MAX_LEN];
    int top;
}; // 分析栈数据结构

struct quadruple {
    char op[MAX_LEN];
    char arg1[MAX_LEN];
    char arg2[MAX_LEN];
    char result[MAX_LEN];
}; // 四元式数据结构

struct quadruple quad[MAX_LEN]; // 存储四元式
int quadTop = 0; // 四元式栈顶

// 1.S→V=E  2.E→E+T  3.E→E-T  4.E→T  5.T→T*F  6.T→T/F  7.T→F  8.F→(E)
9.F→i  10.V→i
// 表中大于0对应移进，小于0则对应先归约后移进，0为不存在的状态
//          GOTO           |    ACTION
//i, =, +, -, *, /, (, ), #, S, E, T, F, V
int table[20][14] ={{ 3, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 2},// 0
                    { 0, 0, 0, 0, 0, 0, 0, 0,-11,0,0, 0, 0, 0},// 1
                    { 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},// 2
                    {-10,-10,-10,-10,-10,-10,-10,-10,-10, 0, 0, 0, 0,
0},//3
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 5, 6, 7, 0},// 4
```

```
                    {-1,-1,10,11,-1,-1,-1,-1,-1, 0, 0, 0, 0, 0},// 5
                    {-4,-4,-4,-4,12,13,-4,-4,-4, 0, 0, 0, 0, 0},// 6
                    {-7,-7,-7,-7,-7,-7,-7,-7,-7, 0, 0, 0, 0, 0},// 7
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0,14, 6, 7, 0},// 8
                    {-9,-9,-9,-9,-9,-9,-9,-9,-9, 0, 0, 0, 0, 0},// 9
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0,15, 7, 0},//10
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0,16, 7, 0},//11
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0,17, 0},//12
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0,18, 0},//13
                    { 0, 0,10,11, 0, 0, 0,19, 0, 0, 0, 0, 0, 0},//14
                    {-2,-2,-2,-2,12,13,-2,-2,-2, 0, 0, 0, 0, 0},//15
                    {-3,-3,-3,-3,12,13,-3,-3,-3, 0, 0, 0, 0, 0},//16
                    {-5,-5,-5,-5,-5,-5,-5,-5,-5, 0, 0, 0, 0, 0},//17
                    {-6,-6,-6,-6,-6,-6,-6,-6,-6, 0, 0, 0, 0, 0},//18
                    {-8,-8,-8,-8,-8,-8,-8,-8,-8, 0, 0, 0, 0, 0}};//19

int getindex(char ch) {
    switch(ch) {
        case 'i': return 0;
        case '=': return 1;
        case '+': return 2;
        case '-': return 3;
        case '*': return 4;
        case '/': return 5;
        case '(': return 6;
        case ')': return 7;
        case '#': return 8;
        case 'S': return 9;
        case 'E': return 10;
        case 'T': return 11;
        case 'F': return 12;
        case 'V': return 13;
        default: return -1;
    }
}

void printSLR(char *str, struct stack *stk, int now) { // 打印分析状态
    for(int i = 0; i <= stk->top; i++) {
        printf("%c:%2d   ", stk->s[i], stk->i[i]); // 栈状态
    }
    for(int i = 0; i <= 60 - stk->top*7; i++) {
        printf(" ");
    }
    for(int i = now; i < strlen(str); i++) {
        printf("%c", str[i]); // 串状态
    }
    printf("\n");
}

void printQuad() { // 打印四元式
    printf("Quadruples:\n");
    for(int i = 1; i <= quadTop; i++) {
        printf("(%s, %s, %s, %s)\n", quad[i].op, quad[i].arg1,
quad[i].arg2, quad[i].result);
```

```
    }
}

int SLR(char *str, struct stack *stk) { // SLR1分析函数
    quadTop = 0;
    int i = 0;
    int next;
    printf("stack:
         str:                  operate:\n");
    while(i < strlen(str)) {
        if(stk->top < 0) return 0; // 分析栈不可能为空
        int y; // 列坐标
        if (str[i] ⩾ 'a' && str[i] ⩽ 'z') y = getindex('i'); // 终结符i
        else y = getindex(str[i]);
        if(y == -1 || table[stk->i[stk->top]][y] == 0) { // 表中不存在的状态，分析报错
            return 0;
        }
        if(table[stk->i[stk->top]][y] > 0) { // 移进操作
            next = table[stk->i[stk->top]][y];
            stk->top++;
            stk->s[stk->top] = str[i];
            stk->i[stk->top] = next;
            stk->point[stk->top] = i;
            i++;
            printSLR(str, stk, i);
        }
        else if(table[stk->i[stk->top]][y] < 0) { // 归约操作
            int tmp = -table[stk->i[stk->top]][y]; // 查GOTO表
            if(tmp == 4 || tmp == 7 || tmp == 9 || tmp == 10) {
                stk->top--; // 要归约1位
            }
            else if(tmp == 2 || tmp == 3 || tmp == 5 || tmp == 6){
                // 生成四元式
                quadTop++;
                if(tmp == 2) strcpy(quad[quadTop].op, "+");
                else if(tmp == 3) strcpy(quad[quadTop].op, "-");
                else if(tmp == 5) strcpy(quad[quadTop].op, "*");
                else strcpy(quad[quadTop].op, "/");
                if(stk->point[stk->top - 2] < 0)
sprintf(quad[quadTop].arg1, "t%d", -stk->point[stk->top - 2]);
                else {
                    char arg1[2] = {str[stk->point[stk->top - 2]], '\0'};
                    strcpy(quad[quadTop].arg1, arg1);
                }
                if(stk->point[stk->top] < 0)
sprintf(quad[quadTop].arg2, "t%d", -stk->point[stk->top]);
                else {
                    char arg2[2] = {str[stk->point[stk->top]], '\0'};
                    strcpy(quad[quadTop].arg2, arg2);
                }
                for(int j = 0; j < 90; j++) printf(" ");
```

```
                printf("t%d = %s %s %s\n", quadTop, quad[quadTop].arg1, quad[quadTop].op, quad[quadTop].arg2); // 打印语义动作
                sprintf(quad[quadTop].result, "t%d", quadTop);
                stk->top -= 3; // 归约3位
                stk->point[stk->top + 1] = -quadTop; // 记录归约产生的中间变量
            }
            else if(tmp == 8) {
                stk->top -= 3; // 归约3位
                stk->point[stk->top + 1] = stk->point[stk->top + 2]; // 消除括号规约
            }
            else if(tmp == 1){
                quadTop++;
                strcpy(quad[quadTop].op, "=");
                if(stk->point[stk->top] < 0) sprintf(quad[quadTop].arg1, "t%d", abs(stk->point[stk->top]));
                else {
                    char arg1[2] = {str[stk->point[stk->top]], '\0'};
                    strcpy(quad[quadTop].arg1, arg1);
                }
                sprintf(quad[quadTop].arg2, " ");
                char res[2] = {str[stk->point[stk->top - 2]], '\0'};
                strcpy(quad[quadTop].result, res);
                for(int i = 0; i < 90; i++) printf(" ");
                printf("%s = %s\n", quad[quadTop].result, quad[quadTop].arg1);
                stk->top -= 3; // 归约V=E
            }
            else stk->top -= 3;
            if(tmp == 1) {
                y = getindex('S');
                next = table[stk->i[stk->top]][y]; // 查ACTION表
                stk->top++;
                stk->s[stk->top] = 'S';
                stk->i[stk->top] = next; // 归约要修改栈顶
            }
            else if(tmp == 2 || tmp ==3 || tmp == 4) {
                y = getindex('E');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'E';
                stk->i[stk->top] = next;
            }
            else if(tmp == 5 || tmp == 6 || tmp == 7) {
                y = getindex('T');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'T';
                stk->i[stk->top] = next;
            }
            else if(tmp == 8 || tmp == 9) {
                y = getindex('F');
```

```
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'F';
                stk->i[stk->top] = next;
            }
            else if(tmp == 10) {
                y = getindex('V');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'V';
                stk->i[stk->top] = next;
            }
            else if(tmp == 11) {
                return 1;
            }
            printSLR(str, stk, i);
        }
    }
    return 0;
}

int main() {
    char txt[MAX_LEN] = "outputofcifa.txt";

    FILE *fp = fopen(txt, "r");
    if(fp == NULL) {
        perror("Error opening file");
        return 1;
    }

    char buf[MAX_LEN] = "";
    char input[MAX_LEN] = "";
    fgets(buf, MAX_LEN, fp);
    fclose(fp);
    cout <<"file content: "<< buf << endl;
    int j = 0, k = 0;
    // buf:(id, s)(OPERATOR, =)(id, a)(OPERATOR, +)(id, b)(OPERATOR,
+)(id, c)(OPERATOR, +)(DELIMITER, ()(id, a)(OPERATOR, *)(id, a)
(DELIMITER, ))
    while (k<strlen(buf)){

        if (buf[k] == '(') {
            while (buf[k]≠',') {
                k++;
            }
            k = k + 2;
            input[j] = buf[k];
            j++;
        } else {
            k++;
        }
    }
    input[j++] = '#'; // 在串尾添加结束符
    input[j++] = '\0'; // 确保输入串结束
```

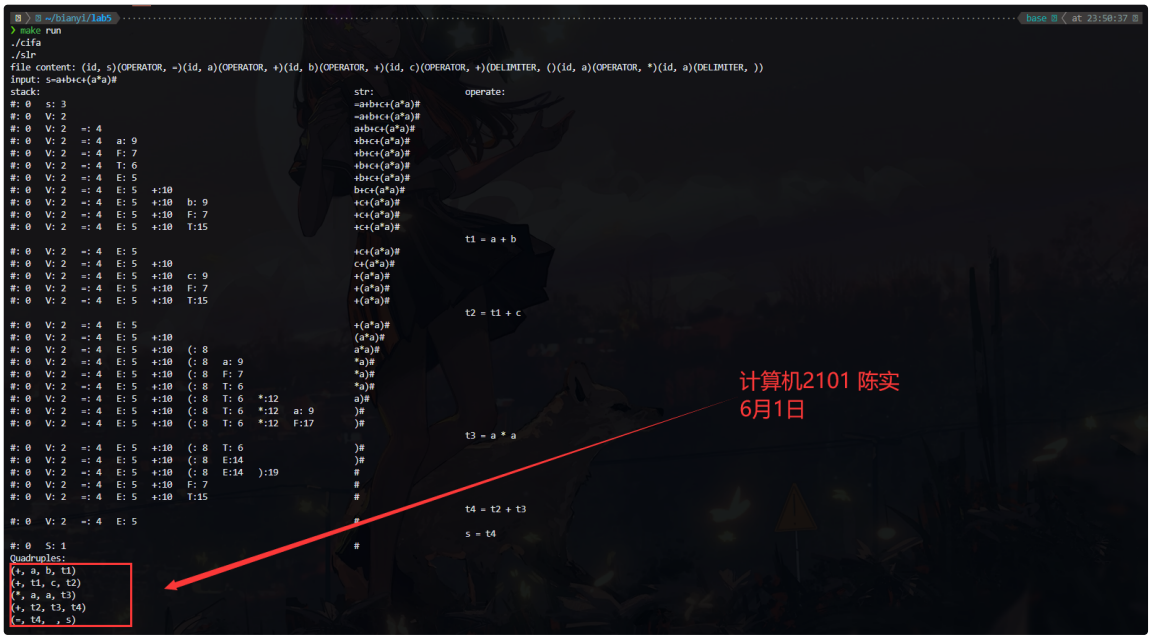
```
    cout << "input: "<<input << endl;
    struct stack *stk = (struct stack *)malloc(sizeof(struct stack));
    if(stk == NULL) {
        perror("Error allocating memory for stack");
        return 1;
    }
    stk->s[0] = '#';
    stk->i[0] = 0;
    stk->point[0] = -1;
    stk->top = 0; // 初始化分析栈

    if(!SLR(input, stk)) {
        printf("Gramma illegal\n");
    } else {
        printQuad(); // 打印四元式
    }

    free(stk); // 释放栈内存

    return 0;
}

```

1. slr.cpp是一个SLR(1)分析程序，用于语法分析，生成四元式。输入为词法分析生成的token序列，输出为四元式序列。Action和Goto表源自第四次实验。
2. 思路：
    1. 读取文件outputofcifa.txt中的内容，将其转换为输入串；
    2. 初始化分析栈，开始SLR分析；
    3. 通过Action和Goto表，进行移进和归约操作；
    4. 生成四元式；
    5. 输出四元式序列。
    6. 四元式的格式为(op, arg1, arg2, result)。
    7. 当遇到某些规约的时候，例如 E→E+T，会生成四元式 t = E + T。

实验结果

1. 输入：

```
s=a+b+c+(a*a )
```

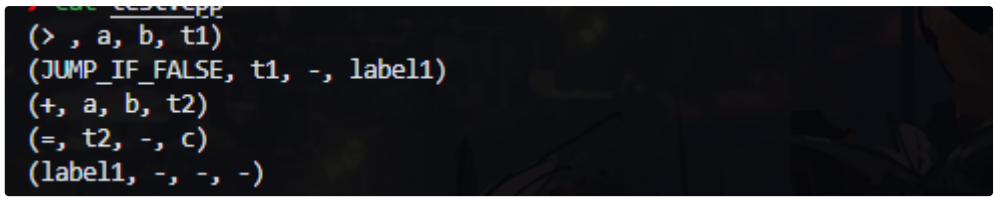


2. 选做实验：

   1. 输入：

```
if (a > b) {
    c = a + b
}
```

   输出：



实验总结

1. 本次实验需要构建语法制导的语义分析程序，能在语法分析的同时生成符号表和中间语言代码，并输出结果到文件中。通过实验，我对语义分析有了更深入的了解。
2. 本次实验需要结合实验2实现的词法分析程序来识别token序列，需要实验4实现的SLR(1)分析表来进行语法分析获取action和goto表。让我对整个编译原理的流程有了更深入的了解。

附录

1. cifa.cpp：词法分析程序，生成token序列；

```
#include <algorithm> // 包含 std::transform
#include <cctype> // 包含 std::tolower
#include <fstream>
#include <iostream>
#include <map>
#include <stdio.h>
#include <string>
#include <unistd.h>
#include <vector>

```

```cpp
using namespace std;
int state;          //当前状态指示
char C;             //当前读入字符
string nowstr;      //当前读入的字符串
char *buffer;       //文件缓冲区
int forwar = -1;        //向前指针
int rows = 1;           //文件行数
int sum_char = 0;       //文件总字符数

vector<string> keyword = {"auto", "break", "case", "char", "const", "continue", "default",
                          "do", "double", "else", "enum", "extern", "float", "for", "goto",
                          "if", "int", "long", "register", "return", "short", "signed",
                          "sizeof", "static", "struct", "switch", "typedef", "union",
                          "unsigned", "void", "volatile", "while", "define","include"};   //关键字表
std::multimap<string,string> item;  //符号表(type,value)
//typelist: KEYWORD, ID, INT, FLOAT, CHAR, STRING, OPERATOR, DELIMITER, ERROR
void get_char() {
    forwar=forwar+1;
    C = buffer[forwar];
}
//从buf中读一个字符到C中，向前指针移动。
void cat() {
    nowstr.push_back(C);
}
//将字符C连接到nowstr字符串后面
std::string toLower(const std::string& str) {
    // 创建一个副本以避免修改原始字符串
    std::string lowerStr = str;

    // 使用 std::transform 和 std::tolower 将字符串转换为全小写
    std::transform(lowerStr.begin(), lowerStr.end(), lowerStr.begin(), ::tolower);

    return lowerStr; // 返回转换后的字符串
}
std::string toUper(const std::string& str) {
    // 创建一个副本以避免修改原始字符串
    std::string upperStr = str;

    // 使用 std::transform 和 std::tolower 将字符串转换为全小写
    std::transform(upperStr.begin(), upperStr.end(), upperStr.begin(), ::toupper);

    return upperStr; // 返回转换后的字符串
}

bool is_letter(char ch) {
    if (isalpha(ch) || ch=='_')
```

```
        return true;
    else
        return false;
}
//判断ch是否为字母或下划线

int iskeyword() {
    for (int i = 0; i < keyword.size(); i++){
        if (nowstr == keyword[i]) {
            return 1;
        }
        if (toLower(nowstr) == keyword[i]) {
            return 2;
        }
    }
    return 0;
}
//判断nowstr中是否为关键字，1表示匹配正确，2表示匹配正确但大小写不同，0表示不匹配

bool iseven() {
    int num = 0;
    int i = nowstr.size() - 2;
    while (nowstr[i] == '\\') {
        num++;
        i--;
    }
    if (num % 2 == 0)
        return true;
    return false;
}

//根据传入的type和value，将其插入符号表
void insert_item(string type, string value) {
    item.insert(pair<string,string>(type,value));
    sleep(0.5);
    if (type == "ERROR") {
        cout << "\033[31m"  // 31对应红色
            << rows << ": (" << type << ", " << value << ")"
            << "\033[0m" << endl;
    }
    else {
        cout << "(" << type << ", " << value << ")";
    }
}

//根据文件名，读取文件内容到buffer中
void read_file(const char *filename) {
    FILE *fp = fopen(filename, "r");  // 用二进制模式打开
    if (fp == NULL) {
        cout << "文件打开失败" << endl;
        exit(0);
    }
    fseek(fp, 0, SEEK_END);
    sum_char = ftell(fp);
```

```
    fseek(fp, 0, SEEK_SET);
    buffer = new char[sum_char+1];
    fread(buffer, 1, sum_char, fp);
    fclose(fp);
    //Buffer末尾加上EOF
    buffer[sum_char] = EOF;
}

void scanner(){
    bool isEnd = false;
    while(!isEnd){
        get_char();
        if (C == '\n'){
            rows++;
        }
        if (C == EOF){
            isEnd = true;
        }
        switch (state) {
            case 0: //初始状态
                if (is_letter(C)){
                    state =1;   //id or keyword
                    cat();
                }
                else if (isdigit(C)){
                    state = 2; //num or wrong id
                    cat();
                }
                else if (C=='0'){
                    state=28;
                    cat();
                }
                else{
                    switch (C) {
                        case '<': state = 8; break;
                        case '>': state = 9; break;
                        case'?':
                            insert_item("OPERATOR", "?");
                            break;
                        case ':':
                            insert_item("OPERATOR", ":");
                            break;
                        case '/': state = 11; break;
                        case '=': state = 12; break;
                        case '+': state = 13; break;
                        case '-': state = 14; break;
                        case '*': state = 15; break;
                        case '%': state = 16; break;
                        case '(':
                            insert_item("DELIMITER", "(");
                            break;
                        case ')':
                            insert_item("DELIMITER", ")");
                            break;
```

```
                        case ',':
                            insert_item("DELIMITER", ",");
                            break;
                        case ';':
                            insert_item("DELIMITER", ";");
                            break;
                        case '{':
                            insert_item("DELIMITER", "{");
                            break;
                        case '}':
                            insert_item("DELIMITER", "}");
                            break;
                        case '[':
                            insert_item("DELIMITER", "[");
                            break;
                        case ']':
                            insert_item("DELIMITER", "]");
                            break;
                        case '^': state = 17; break;
                        case '|': state = 18; break;
                        case '~': state = 19; break;
                        case '!': state = 20; break;
                        case '&': state = 21; break;
                        case '"': state = 22; cat(); break;
                        case '\'':state = 23; cat(); break;
                        case '.': state = 24; break;
                        case '#': insert_item("OPERATOR", "#"); break;
                        case ' ':
                        case '\n':
                        case'   ':
                        case EOF : break; //跳过空白符
                        default: cout << "error:第" << rows << "行出现非法字符" << C << endl;
                            break;
                    }
                }
                break;
            case 1:         //id or keyword
                if (is_letter(C) || isdigit(C)) {
                    cat();
                    state = 1;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    int flag = iskeyword();
                    if (flag == 1) {
                        insert_item("keyword", nowstr);
                    } else if (flag == 2) {
                        insert_item("ERROR", nowstr+" --- Keyword should be lower case");
```

```
                    } else {
                        insert_item("id", nowstr);
                    }
                    nowstr.clear();
                }
                break;
            case 2:
                if (isdigit(C)) {
                    cat();
                    state = 2;
                }
                else if (C == '.') {
                    cat();
                    state = 3;
                }
                else if (C == 'E' || C == 'e') {
                    cat();
                    state = 5;
                }
                //wrong id
                else if (is_letter(C)) {
                    cat();
                    state = 31;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    insert_item("int", nowstr);
                    nowstr.clear();
                }
                break;
            case 3:     // .
                if (isdigit(C)) {
                    cat();
                    state = 4;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    nowstr.push_back('0');
                    insert_item("float", nowstr);
                    nowstr.clear();
                }
                break;

            case 4:     // .num
                if (isdigit(C)) {
                    cat();
```

```
                    state = 4;
                }
                else if (C == 'E' || C == 'e') {
                    cat();
                    state = 5;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    insert_item("float", nowstr);
                    nowstr.clear();
                }
                break;

            case 5:     // .numE
                if (C == '+' || C == '-') {
                    cat();
                    state = 6;
                }
                else if (isdigit(C)) {
                    cat();
                    state = 7;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    insert_item("ERROR", nowstr + " --- Missing
digit");
                    nowstr.clear();
                }
                break;

            case 6:     // .numE+ or .numE-
                if (isdigit(C)) {
                    cat();
                    state = 7;
                }
                else {
                    forwar--;
                    state = 0;
                    if (C == '\n') {
                        rows--;
                    }
                    insert_item("ERROR", nowstr + " --- Missing
digit");
                    nowstr.clear();
                }
                break;
```

```
323
324             case 7:     // .numE+num
325                 if (isdigit(C)) {
326                     cat();
327                     state = 7;
328                 }
329                 else {
330                     forwar--;
331                     state = 0;
332                     if (C == '\n') {
333                         rows--;
334                     }
335                     insert_item("float", nowstr);
336                     nowstr.clear();
337                 }
338                 break;
339 
340             case 8:
341                 if (C == '=') {
342                     insert_item("OPERATOR", "≤");
343                 }
344                 else if (C == '<') {
345                     insert_item("OPERATOR", "<<");
346                 }
347                 else {
348                     forwar--;
349                     insert_item("OPERATOR", "<");
350                     if (C == '\n') {
351                         rows--;
352                     }
353                 }
354                 state = 0;
355                 break;
356 
357             case 9:
358                 if (C == '=') {
359                     insert_item("OPERATOR", "≥");
360                 }
361                 else if (C == '>') {
362                     insert_item("OPERATOR", ">>");
363                 }
364                 else {
365                     forwar--;
366                     insert_item("OPERATOR", ">");
367                     if (C == '\n') {
368                         rows--;
369                     }
370                 }
371                 state = 0;
372                 break;
373 
374             case 11:
375                 switch (C) {
376                     case '/': //单行注释
```

```
                        state = 27;
                        break;
                    case '*':   //多行注释
                        state = 26;
                        break;
                    default:
                        forwar--;
                        insert_item("OPERATOR", "/");
                        state = 0;
                        if (C == '\n') {
                            rows--;
                        }
                        break;
                }
                break;

            case 12:    // =
                if (C == '=') {
                    insert_item("OPERATOR", "==");
                }
                else {
                    forwar--;
                    insert_item("OPERATOR", "=");
                    if (C == '\n') {
                        rows--;
                    }
                }
                state = 0;
                break;

            case 13:    // +
                if (C == '+') {
                    insert_item("OPERATOR", "++");
                }
                else if (C == '=') {
                    insert_item("OPERATOR", "+=");
                }
                else if (isdigit(C)) {
                    cat();
                    state = 2;
                }
                else {
                    forwar--;
                    insert_item("OPERATOR", "+");
                    if (C == '\n') {
                        rows--;
                    }
                }
                state = 0;
                break;

            case 14:    // -
                if (C == '-') {
                    insert_item("OPERATOR", "--");
```

```
431                 }
432                 else if (C == '=') {
433                     insert_item("OPERATOR", "-=");
434                 }
435                 else if (C == '>') {
436                     insert_item("OPERATOR", "→");
437                 }
438                 else if (isdigit(C)) {
439                     cat();
440                     state = 2;
441                 }
442                 else {
443                     forwar--;
444                     insert_item("OPERATOR", "-");
445                     if (C == '\n') {
446                         rows--;
447                     }
448                 }
449                 state = 0;
450                 break;
451 
452             case 15:    // *
453                 if (C == '=') {
454                     insert_item("OPERATOR", "*=");
455                 }
456                 else {
457                     forwar--;
458                     insert_item("OPERATOR", "*");
459                     if (C == '\n') {
460                         rows--;
461                     }
462                 }
463                 state = 0;
464                 break;
465 
466             case 16:    // %
467                 if (C == '=') {
468                     insert_item("OPERATOR", "%=");
469                 }
470                 else {
471                     forwar--;
472                     insert_item("OPERATOR", "%");
473                     if (C == '\n') {
474                         rows--;
475                     }
476                 }
477                 state = 0;
478                 break;
479 
480             case 17:    // ^
481                 if (C == '=') {
482                     insert_item("OPERATOR", "^=");
483                 }
484                 else {
```

```
485                     forwar--;
486                     insert_item("OPERATOR", "^");
487                     if (C == '\n') {
488                         rows--;
489                     }
490                 }
491                 state = 0;
492                 break;
493 
494             case 18:    // |
495                 if (C == '|') {
496                     insert_item("OPERATOR", "||");
497                 }
498                 else if (C == '=') {
499                     insert_item("OPERATOR", "⊨");
500                 }
501                 else {
502                     forwar--;
503                     insert_item("OPERATOR", "|");
504                     if (C == '\n') {
505                         rows--;
506                     }
507                 }
508                 state = 0;
509                 break;
510 
511             case 19:    // ~
512                 if (C == '=') {
513                     insert_item("OPERATOR", "~=");
514                 }
515                 else {
516                     forwar--;
517 
518                     insert_item("OPERATOR", "~");
519                     if (C == '\n') {
520                         rows--;
521                     }
522                 }
523                 state = 0;
524                 break;
525 
526             case 20:    // !
527                 if (C == '=') {
528                     insert_item("OPERATOR", "≠");
529                 }
530                 else {
531                     forwar--;
532 
533                     insert_item("OPERATOR", "!");
534                     if (C == '\n') {
535                         rows--;
536                     }
537                 }
538                 state = 0;
```

```
                break;

            case 21:    // &
                if (C == '&') {
                    insert_item("OPERATOR", "&&");
                }
                else if (C == '=') {
                    insert_item("OPERATOR", "&=");
                }
                else {
                    forwar--;

                    insert_item("OPERATOR", "&");
                    if (C == '\n') {
                        rows--;
                    }
                }
                state = 0;
                break;

            case 22:    // "
                if (C == '\"') {
                    cat();
                    if (iseven()) {
                        insert_item("STRING", nowstr);
                        nowstr.clear();
                        state = 0;
                    }
                    else {
                        state = 22;
                    }
                }
                else if (C == EOF) {
                    insert_item("ERROR", nowstr + " --- String should
end with \"");
                    nowstr.clear();
                    state = 0;
                }
                else {
                    cat();
                    state = 22;
                }
                break;

            case 23:    // '
                if (C == '\'') {
                    cat();
                    //判断是否是转义字符
                    if (nowstr.size() == 4 && nowstr[1] == '\\') {
                        insert_item("CHAR", nowstr);
                    }
                    //单独处理'\''这种情况
                    else if (nowstr[0]='\'' && nowstr[1]=='\\' &&
nowstr[2]=='\'') {
```

```
591                         get_char();
592                         if (C == '\'') {
593                             cat();
594                             insert_item("CHAR", nowstr);
595                         }
596                         else {
597                             forwar--;
598 
599                         }
600                     }
601                     else if (nowstr.size() == 3) {
602                         insert_item("CHAR", nowstr);
603                     }
604                     else {
605                         insert_item("ERROR", nowstr + " --- Char
    should be one character");
606                     }
607                     nowstr.clear();
608                     state = 0;
609                 }
610                 else if (C == EOF) {
611                     insert_item("ERROR", nowstr + " --- Char should
    end with \'");
612                     nowstr.clear();
613                     state = 0;
614                 }
615                 else {
616                     cat();
617                     state = 23;
618                 }
619                 break;
620 
621             case 24:    // .
622                 if (isdigit(C)) {
623                     cat();
624                     state = 4;
625                 }
626                 else {
627                     forwar--;
628 
629                     insert_item("OPERATOR", ".");
630                     if (C == '\n') {
631                         rows--;
632                     }
633                     state = 0;
634                 }
635                 break;
636 
637             case 26:    // /*
638                 if (C == '*') {
639                     state = 25;
640                 }
641                 break;
642 
```

```
643             case 25:    // /*...*
644                 if (C == '*') {
645                     state = 25;
646                 }
647                 else if (C == '/') {
648                     state = 0;
649                 }
650                 else if (C == EOF) {
651                     insert_item("ERROR", nowstr + " --- Multi-line
    comment should end with */");
652                     nowstr.clear();
653                     state = 0;
654                 }
655                 break;
656 
657             case 27:    // //
658                 if (C == '\n' || C == EOF) {
659                     state = 0;
660                 }
661                 break;
662 
663             case 28:    // 0
664                 if (C == 'x' || C == 'X') {
665                     cat();
666                     state = 29;
667                 }
668                 else if (isdigit(C)) {
669                     cat();
670                     state = 2;
671                 }
672                 else if (C == '.') {
673                     cat();
674                     state = 3;
675                 }
676                 else {
677                     forwar--;
678 
679                     insert_item("int", nowstr);
680                     nowstr.clear();
681                     state = 0;
682                 }
683                 break;
684 
685             case 29:    // 0x
686                 if (isdigit(C) || (C ⩾ 'a' && C ⩽ 'f') || (C ⩾ 'A'
    && C ⩽ 'F')) {
687                     cat();
688                     state = 30;
689                 }
690                 else {
691                     forwar--;
692 
693                     insert_item("ERROR", nowstr + " --- Hexadecimal
    number should have at least one digit");
```

```
                    nowstr.clear();
                    state = 0;
                }
                break;

            case 30:    // 0x...
                if (isdigit(C) || (C >= 'a' && C <= 'f') || (C >= 'A' && C <= 'F')) {
                    cat();
                    state = 30;
                }
                else {
                    forwar--;

                    insert_item("int", nowstr);
                    nowstr.clear();
                    state = 0;
                }
                break;

            case 31:    //wrong id with num at first
                if (is_letter(C) || isdigit(C)) {
                    cat();
                    state = 31;
                }
                else {
                    forwar--;

                    insert_item("ERROR", nowstr + " --- ID should start with a letter");
                    nowstr.clear();
                    state = 0;
                }
                break;
            default:
                break;
        }
    }
}

int main() {
    const char *input_filename = "input.txt";  // 默认输入文件名
    const char *output_filename = "outputofcifa.txt";

    freopen(output_filename, "w", stdout);  // 将输出重定向到指定的输出文件
    read_file(input_filename);  // 读取指定输入文件
    scanner();  // 扫描内容
    delete[] buffer;  // 释放分配的内存

    return 0;
}
```

2. slr.cpp

```
#include<stdio.h>
```

```
#include<string.h>
#include<stdlib.h>
#include<iostream>
#define MAX_LEN 1000
using namespace std;
struct stack {
    char s[MAX_LEN];
    int i[MAX_LEN];
    int point[MAX_LEN];
    int top;
}; // 分析栈数据结构

struct quadruple {
    char op[MAX_LEN];
    char arg1[MAX_LEN];
    char arg2[MAX_LEN];
    char result[MAX_LEN];
}; // 四元式数据结构

struct quadruple quad[MAX_LEN]; // 存储四元式
int quadTop = 0; // 四元式栈顶

// 1.S→V=E  2.E→E+T  3.E→E-T  4.E→T  5.T→T*F  6.T→T/F  7.T→F  8.F→(E)  9.F→i  10.V→i
// 表中大于0对应移进，小于0则对应先归约后移进，0为不存在的状态
//          GOTO          |    ACTION
//i, =, +, -, *, /, (, ), #, S, E, T, F, V
int table[20][14] ={{ 3, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 2},// 0
                    { 0, 0, 0, 0, 0, 0, 0, 0,-11,0,0, 0, 0, 0},// 1
                    { 0, 4, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},// 2
                    {-10,-10,-10,-10,-10,-10,-10,-10,-10, 0, 0, 0, 0, 0},//3
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 5, 6, 7, 0},// 4
                    {-1,-1,10,11,-1,-1,-1,-1,-1, 0, 0, 0, 0, 0},// 5
                    {-4,-4,-4,-4,12,13,-4,-4,-4, 0, 0, 0, 0, 0},// 6
                    {-7,-7,-7,-7,-7,-7,-7,-7,-7, 0, 0, 0, 0, 0},// 7
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0,14, 6, 7, 0},// 8
                    {-9,-9,-9,-9,-9,-9,-9,-9,-9, 0, 0, 0, 0, 0},// 9
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0,15, 7, 0},//10
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0,16, 7, 0},//11
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0,17, 0},//12
                    { 9, 0, 0, 0, 0, 0, 8, 0, 0, 0, 0, 0,18, 0},//13
                    { 0, 0,10,11, 0, 0, 0,19, 0, 0, 0, 0, 0, 0},//14
                    {-2,-2,-2,-2,12,13,-2,-2,-2, 0, 0, 0, 0, 0},//15
                    {-3,-3,-3,-3,12,13,-3,-3,-3, 0, 0, 0, 0, 0},//16
                    {-5,-5,-5,-5,-5,-5,-5,-5,-5, 0, 0, 0, 0, 0},//17
                    {-6,-6,-6,-6,-6,-6,-6,-6,-6, 0, 0, 0, 0, 0},//18
                    {-8,-8,-8,-8,-8,-8,-8,-8,-8, 0, 0, 0, 0, 0}};//19

int getindex(char ch) {
    switch(ch) {
        case 'i': return 0;
        case '=': return 1;
        case '+': return 2;
```

```
        case '-': return 3;
        case '*': return 4;
        case '/': return 5;
        case '(': return 6;
        case ')': return 7;
        case '#': return 8;
        case 'S': return 9;
        case 'E': return 10;
        case 'T': return 11;
        case 'F': return 12;
        case 'V': return 13;
        default: return -1;
    }
}

void printSLR(char *str, struct stack *stk, int now) { // 打印分析状态
    for(int i = 0; i <= stk->top; i++) {
        printf("%c:%2d   ", stk->s[i], stk->i[i]); // 栈状态
    }
    for(int i = 0; i <= 60 - stk->top*7; i++) {
        printf(" ");
    }
    for(int i = now; i < strlen(str); i++) {
        printf("%c", str[i]); // 串状态
    }
    printf("\n");
}

void printQuad() { // 打印四元式
    printf("Quadruples:\n");
    for(int i = 1; i <= quadTop; i++) {
        printf("(%s, %s, %s, %s)\n", quad[i].op, quad[i].arg1,
quad[i].arg2, quad[i].result);
    }
}

int SLR(char *str, struct stack *stk) { // SLR1分析函数
    quadTop = 0;
    int i = 0;
    int next;
    printf("stack:
         str:                  operate:\n");
    while(i < strlen(str)) {
        if(stk->top < 0) return 0; // 分析栈不可能为空
        int y; // 列坐标
        if (str[i] >= 'a' && str[i] <= 'z') y = getindex('i'); // 终结
符i
        else y = getindex(str[i]);
        if(y == -1 || table[stk->i[stk->top]][y] == 0) { // 表中不存在的
状态，分析报错
            return 0;
        }
        if(table[stk->i[stk->top]][y] > 0) { // 移进操作
            next = table[stk->i[stk->top]][y];
```

```
            stk->top++;
            stk->s[stk->top] = str[i];
            stk->i[stk->top] = next;
            stk->point[stk->top] = i;
            i++;
            printSLR(str, stk, i);
        }
        else if(table[stk->i[stk->top]][y] < 0) { // 归约操作
            int tmp = -table[stk->i[stk->top]][y]; // 查GOTO表
            if(tmp == 4 || tmp == 7 || tmp == 9 || tmp == 10) {
                stk->top--; // 要归约1位
            }
            else if(tmp == 2 || tmp == 3 || tmp == 5 || tmp == 6){
                // 生成四元式
                quadTop++;
                if(tmp == 2) strcpy(quad[quadTop].op, "+");
                else if(tmp == 3) strcpy(quad[quadTop].op, "-");
                else if(tmp == 5) strcpy(quad[quadTop].op, "*");
                else strcpy(quad[quadTop].op, "/");
                if(stk->point[stk->top - 2] < 0)
sprintf(quad[quadTop].arg1, "t%d", -stk->point[stk->top - 2]);
                else {
                    char arg1[2] = {str[stk->point[stk->top - 2]],
'\0'};
                    strcpy(quad[quadTop].arg1, arg1);
                }
                if(stk->point[stk->top] < 0)
sprintf(quad[quadTop].arg2, "t%d", -stk->point[stk->top]);
                else {
                    char arg2[2] = {str[stk->point[stk->top]], '\0'};
                    strcpy(quad[quadTop].arg2, arg2);
                }
                for(int j = 0; j < 90; j++) printf(" ");
                printf("t%d = %s %s %s\n", quadTop,
quad[quadTop].arg1, quad[quadTop].op, quad[quadTop].arg2); // 打印语义动
作
                sprintf(quad[quadTop].result, "t%d", quadTop);
                stk->top -= 3; // 归约3位
                stk->point[stk->top + 1] = -quadTop; // 记录归约产生的中
间变量
            }
            else if(tmp == 8) {
                stk->top -= 3; // 归约3位
                stk->point[stk->top + 1] = stk->point[stk->top + 2];
// 消除括号规约
            }
            else if(tmp == 1){
                quadTop++;
                strcpy(quad[quadTop].op, "=");
                if(stk->point[stk->top] < 0)
sprintf(quad[quadTop].arg1, "t%d", abs(stk->point[stk->top]));
                else {
                    char arg1[2] = {str[stk->point[stk->top]], '\0'};
                    strcpy(quad[quadTop].arg1, arg1);
```

```
                }
                sprintf(quad[quadTop].arg2, " ");
                char res[2] = {str[stk->point[stk->top - 2]], '\0'};
                strcpy(quad[quadTop].result, res);
                for(int i = 0; i < 90; i++) printf(" ");
                printf("%s = %s\n", quad[quadTop].result,
quad[quadTop].arg1);
                stk->top -= 3; // 归约V=E
            }
            else stk->top -= 3;
            if(tmp == 1) {
                y = getindex('S');
                next = table[stk->i[stk->top]][y]; // 查ACTION表
                stk->top++;
                stk->s[stk->top] = 'S';
                stk->i[stk->top] = next; // 归约要修改栈顶
            }
            else if(tmp == 2 || tmp ==3 || tmp == 4) {
                y = getindex('E');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'E';
                stk->i[stk->top] = next;
            }
            else if(tmp == 5 || tmp == 6 || tmp == 7) {
                y = getindex('T');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'T';
                stk->i[stk->top] = next;
            }
            else if(tmp == 8 || tmp == 9) {
                y = getindex('F');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'F';
                stk->i[stk->top] = next;
            }
            else if(tmp == 10) {
                y = getindex('V');
                next = table[stk->i[stk->top]][y];
                stk->top++;
                stk->s[stk->top] = 'V';
                stk->i[stk->top] = next;
            }
            else if(tmp == 11) {
                return 1;
            }
            printSLR(str, stk, i);
        }
    }
    return 0;
}

```

```
int main() {
    char txt[MAX_LEN] = "outputofcifa.txt";

    FILE *fp = fopen(txt, "r");
    if(fp == NULL) {
        perror("Error opening file");
        return 1;
    }
    char buf[MAX_LEN] = "";
    char input[MAX_LEN] = "";
    fgets(buf, MAX_LEN, fp);
    fclose(fp);
    cout <<"file content: "<< buf << endl;
    int j = 0, k = 0;
    // buf:(id, s)(OPERATOR, =)(id, a)(OPERATOR, +)(id, b)(OPERATOR, +)(id, c)(OPERATOR, +)(DELIMITER, ()(id, a)(OPERATOR, *)(id, a)(DELIMITER, ))
    while (k<strlen(buf)){

        if (buf[k] == '(') {
            while (buf[k]≠',') {
                k++;
            }
            k = k + 2;
            input[j] = buf[k];
            j++;
        } else {
            k++;
        }
    }
    input[j++] = '#'; // 在串尾添加结束符
    input[j++] = '\0'; // 确保输入串结束
    cout << "input: "<<input << endl;
    struct stack *stk = (struct stack *)malloc(sizeof(struct stack));
    if(stk == NULL) {
        perror("Error allocating memory for stack");
        return 1;
    }
    stk→s[0] = '#';
    stk→i[0] = 0;
    stk→point[0] = -1;
    stk→top = 0; // 初始化分析栈

    if(!SLR(input, stk)) {
        printf("Gramma illegal\n");
    } else {
        printQuad(); // 打印四元式
    }

    free(stk); // 释放栈内存

    return 0;
}
```

3. Makefile

```
# 定义编译器
CXX = g++

# 定义目标文件
TARGETS = cifa slr

# 定义源文件
SOURCES = cifa.cpp slr.cpp

# 定义编译选项
CXXFLAGS = -Wall -g

# 默认目标
all: $(TARGETS)

# 规则：编译cifa
cifa: cifa.cpp
    $(CXX) $(CXXFLAGS) -o cifa cifa.cpp

# 规则：编译slr
slr: slr.cpp
    $(CXX) $(CXXFLAGS) -o slr slr.cpp

# 运行目标：先运行cifa再运行slr
run: all
    ./cifa
    ./slr

# 清理目标：删除生成的可执行文件
clean:
    rm -f $(TARGETS)

# 声明伪目标
.PHONY: all run clean
```