

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

22 January 2021

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### UCS 1602 - Compiler Design

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#### Exercise 1: Lexical Analyser Using C

##### **Aim:**

To write a program using C to perform the basic functionalities of a **Lexical Analyser**.

## Code:

```
1 /* C Program that performs a basic lexical analysis of a given string */
2
3 #include <stdio.h>
4 #include <string.h>
5 #include <stdlib.h>
6 #include <ctype.h>
7 #include <unistd.h>
8 #include <fcntl.h>
9
10 int isOperator(char ch);
11 int isSeparator(char ch);
12 int isDelimiter(char ch);
13 int isValidIdentifier(char *str);
14 int isInteger(char *str);
15 int isKeyword(char *str);
16 int isPreprocessorDirective(char ch);
17 char *subString(char *str, int start, int end);
18 int printOperator(char ch1, char ch2);
19 int lexicalParse(char *str);
20
21 int main(void){
22     int status = 0, len, fp;
23     char text[10000], file[100];
24
25     printf("\n\t\t\tLexical Analyser Using C\n");
26     printf("\n\t\t\tEnter file name to parse: ");
27     scanf("%[^\n]", file);
28
29     fp = open(file, O_RDONLY);
30
31     if(fp < 0){
32         printf("\nError: File does not exist.\n");
33         return 0;
34     }
35
36     len = read(fp, text, 10000);
37     close(fp);
38
39     printf("\nText to be parsed:\n\n%s\n", text);
40
41     status = lexicalParse(text);
42
43     if(status){
44         printf("\n\n\t\tThe given expression is lexically valid.\n");
45     }
46
47     else{
```

```

48     printf("\n\n\t\tThe given expression is lexically invalid.\n");
49 }
50
51 return 0;
52 }
53
54 int isOperator(char ch){
55     //Checks if the character is a valid operator
56
57     if (ch == '+' || ch == '-' || ch == '*' ||
58         ch == '/' || ch == '>' || ch == '<' ||
59         ch == '=' || ch == '%' || ch == '!'){
60         return 1;
61     }
62
63     return 0;
64 }
65
66 int isSeparator(char ch){
67     //Checks if the character is a valid separator
68
69     if (ch == ';' || ch == '{' || ch == '}' || ch == ','){
70         return 1;
71     }
72
73     return 0;
74 }
75
76 int isDelimiter(char ch){
77     //Checks if the character is a valid delimiter
78
79     if (ch == ' ' || ch == '(' || ch == ')',
80         || isSeparator(ch) == 1 || isOperator(ch) == 1){
81         return 1;
82     }
83
84     return 0;
85 }
86
87 int isValidIdentifier(char *str){
88     //Checks if the character is a valid identifier
89
90     if(isdigit(str[0]) > 0 || isDelimiter(str[0]) == 1){
91         //First character shouldn't be a digit or a special character
92         return 0;
93     }
94
95     return 1;
96 }
97
98 int isInteger(char *str){

```

```

99     //Checks if the string is a valid integer
100
101     int i = 0, len = strlen(str);
102
103     if(!len){
104         return 0;
105     }
106
107     for(i = 0; i < len; i++){
108         if(!isdigit(str[i])){
109             return 0;
110         }
111     }
112
113     return 1;
114 }
115
116 int isKeyword(char *str){
117     //Checks if the string is a valid keyword
118
119     if(!strcmp(str, "if") || !strcmp(str, "else") || !strcmp(str, "while")
120        || !strcmp(str, "for") || !strcmp(str, "do") || !strcmp(str, "break")
121        || !strcmp(str, "switch") || !strcmp(str, "continue") || !strcmp(str,
122        "return") || !strcmp(str, "case") || !strcmp(str, "default") || !strcmp(str, "
123        void") || !strcmp(str, "int") || !strcmp(str, "char") || !strcmp(str, "bool"
124        ) || !strcmp(str, "struct") || !strcmp(str, "goto") || !strcmp(str, "
125        typedef") || !strcmp(str, "unsigned") || !strcmp(str, "long") || !strcmp(str, "
126        short") || !strcmp(str, "float") || !strcmp(str, "double") || !strcmp(str, "
127        sizeof")){
128         return 1;
129     }
130
131     return 0;
132 }
133
134 int isPreprocessorDirective(char ch){
135     //Checks if the string is a valid preprocessor directive
136
137     if(ch == '#'){
138         //Basic check, works for header files, macros and const
139         declarations
140         return 1;
141     }
142
143     return 0;

```

```

141 }
142
143 char *subString(char *str, int start, int end){
144     //Get a substring from the given string
145     int i = 0;
146     char *sub = (char *)malloc(sizeof(char) * (end - start + 2));
147
148     for(i = start; i <= end; i++){
149         sub[i - start] = str[i];
150     }
151
152     sub[end - start + 1] = '\0';
153
154     return sub;
155 }
156
157 int printOperator(char ch1, char ch2){
158     //Print the details of the parsed operator
159
160     switch(ch1){
161         case '+':
162             if(ch2 == '='){
163                 printf("ASSIGN ");
164             }
165             else if(ch2 == ' '){
166                 printf("ADD ");
167             }
168             else{
169                 printf("INVALID-OP ");
170                 return 0;
171             }
172             break;
173
174
175         case '-':
176             if(ch2 == '='){
177                 printf("SUB-ASSIGN ");
178             }
179             else if(ch2 == ' '){
180                 printf("SUB ");
181             }
182             else{
183                 printf("INVALID-OP ");
184                 return 0;
185             }
186             break;
187
188         case '*':
189             if(ch2 == '='){
190                 printf("PRODUCT-ASSIGN ");
191             }

```

```

192     else if(ch2 == ' '){
193         printf("PRODUCT ");
194     }
195     else{
196         printf("INVALID-OP");
197         return 0;
198     }
199     break;
200
201 case '/':
202     if(ch2 == '='){
203         printf("DIVISION-ASSIGN ");
204     }
205     else if(ch2 == ' '){
206         printf("DIVISION ");
207     }
208     else{
209         printf("INVALID-OP ");
210         return 0;
211     }
212     break;
213
214 case '%':
215     if(ch2 == '='){
216         printf("MODULO-ASSIGN ");
217     }
218     else if(ch2 == ' '){
219         printf("MODULO ");
220     }
221     else{
222         printf("INVALID-OP ");
223         return 0;
224     }
225     break;
226
227 case '=':
228     if(ch2 == '='){
229         printf("EQUALITY ");
230     }
231     else if(ch2 == ' '){
232         printf("ASSIGN ");
233     }
234     else{
235         printf("INVALID-OP ");
236         return 0;
237     }
238     break;
239
240 case '>':
241     if(ch2 == '='){
242         printf("GT-EQ ");

```

```

243     }
244     else if(ch2 == ' '){
245         printf("GT ");
246     }
247     else{
248         printf("INVALID-OP ");
249         return 0;
250     }
251     break;
252
253     case '<':
254         if(ch2 == '='){
255             printf("LT-EQ ");
256         }
257         else if(ch2 == ' '){
258             printf("LT ");
259         }
260         else{
261             printf("INVALID-OP ");
262             return 0;
263         }
264         break;
265
266     case '!':
267         printf("NOT ");
268         break;
269
270     default:
271         printf("INVALID-OP ");
272         return 0;
273 }
274
275 return 1;
276 }
277
278 int lexicalParse(char *str){
279     //Parse the given string to check for validity
280     int left = 0, right = 0, len = strlen(str), status = 1, i;
281
282     printf("\nLexical Analysis:\n\t");
283
284     while(right <= len && left <= right){
285         //While we are within the valid bounds of the string, check:
286
287         while(isPreprocessorDirective(str[right]) == 1){
288             //Check if string is preprocessor directive
289             printf("PPDIR ");
290
291             for(right; str[right] != '\n'; right++);
292             right++;
293             left = right;

```

```

294     }
295
296     for(i = right; i < len; i++){
297         //Clearing linebreaks & tabs to spaces for efficient
processing
298         if(str[i] == '\n' || str[i] == '\t'){
299             str[i] = ' ';
300         }
301     }
302
303     if(isDelimiter(str[right]) == 0){
304         //If we do not encounter a delimiter, keep moving forward
305         //"right" points to the next character
306         right++;
307     }
308
309     else if(isDelimiter(str[right]) == 1 && left == right){
310         //If it is a delimiter, and we haven't parsed it yet
311
312         if(isSeparator(str[right]) == 1){
313             //Check if the delimiter is a separator
314             printf("SP ");
315         }
316
317         else if(isOperator(str[right]) == 1){
318             //Check if the delimiter is an operator
319             if((right + 1) <= len && isOperator(str[right + 1]) == 1){
320                 //Check if the next character is also an operator
321                 status = status & printOperator(str[right], str[right
+ 1]);
322                 right++;
323             }
324
325             else{
326                 //Next character is not an operator
327                 status = status & printOperator(str[right], ' ');
328             }
329
330             //printf("\n\t\t%c' is an operator.", str[right]);
331         }
332
333         right++;
334         left = right;
335     }
336
337     else if(str[right] == '(' && left != right || (right == len &&
left != right)){
338         //Special case, to check for functions
339
340         char *sub = subString(str, left, right - 1);
341

```



```

342         if(isKeyword(sub) == 1){
343             //Check if the function is a keyword based function, like
"if" & "for"
344             printf("KW ");
345             left = right;
346             continue; //Go ahead with the next check
347         }
348
349         //Otherwise, its some other function, parse it.
350
351         for(i = right + 1; i < len; i++){
352             if(str[i] == ')'){
353                 //Finish parsing till the end of the block and break
354                 printf("FUNCT ");
355                 right = i + 1;
356                 left = right;
357                 status = status & 1;
358                 break;
359             }
360         }
361     }
362
363     else if(isDelimiter(str[right]) == 1 && left != right || (right ==
len && left != right)){
364         //We encountered a delimiter in the "right" position, but left
!= right
365         //thus a chunk of unparsed characters exist between left and
right
366
367         //Make a substring of the unparsed characters
368         char *sub = subString(str, left, right - 1);
369
370         if(isInteger(sub) == 1){
371             //Check if substring is an integer
372             printf("NUMCONST ");
373         }
374         else if(isKeyword(sub) == 1){
375             //Check if substring is a keyword
376             printf("KW ");
377         }
378         else if(isValidIdentifier(sub) == 1){
379             //Check if substring is a valid identifier
380             printf("ID ");
381         }
382         else if(isValidIdentifier(sub) == 0 && isDelimiter(str[right -
1]) == 0){
383             //Otherwise, print that it is not a valid identifier
384             status = status & 0;
385             printf("INVALID-ID");
386         }
387

```

```
388         left = right;    //We have parsed the chunk, thus "left" = "  
    right"  
389     }  
390  
391 }  
392  
393     return status;  
394 }
```

## Output - Valid Case:

Figure 1: Console Output for a Valid Program.

```
vishakan@Legion:~/Desktop/Compiler Design/Ex01
> gcc Lex.c -o l
> ./l

          Lexical Analyser Using C

Enter file name to parse: Sample.c

Text to be parsed:

#include<stdio.h>
#include<stdlib.h>

int main(){
    int a, b;
    printf("Hello");

    a = b + 100;

    if(a > b){
        printf("Greater");
    }

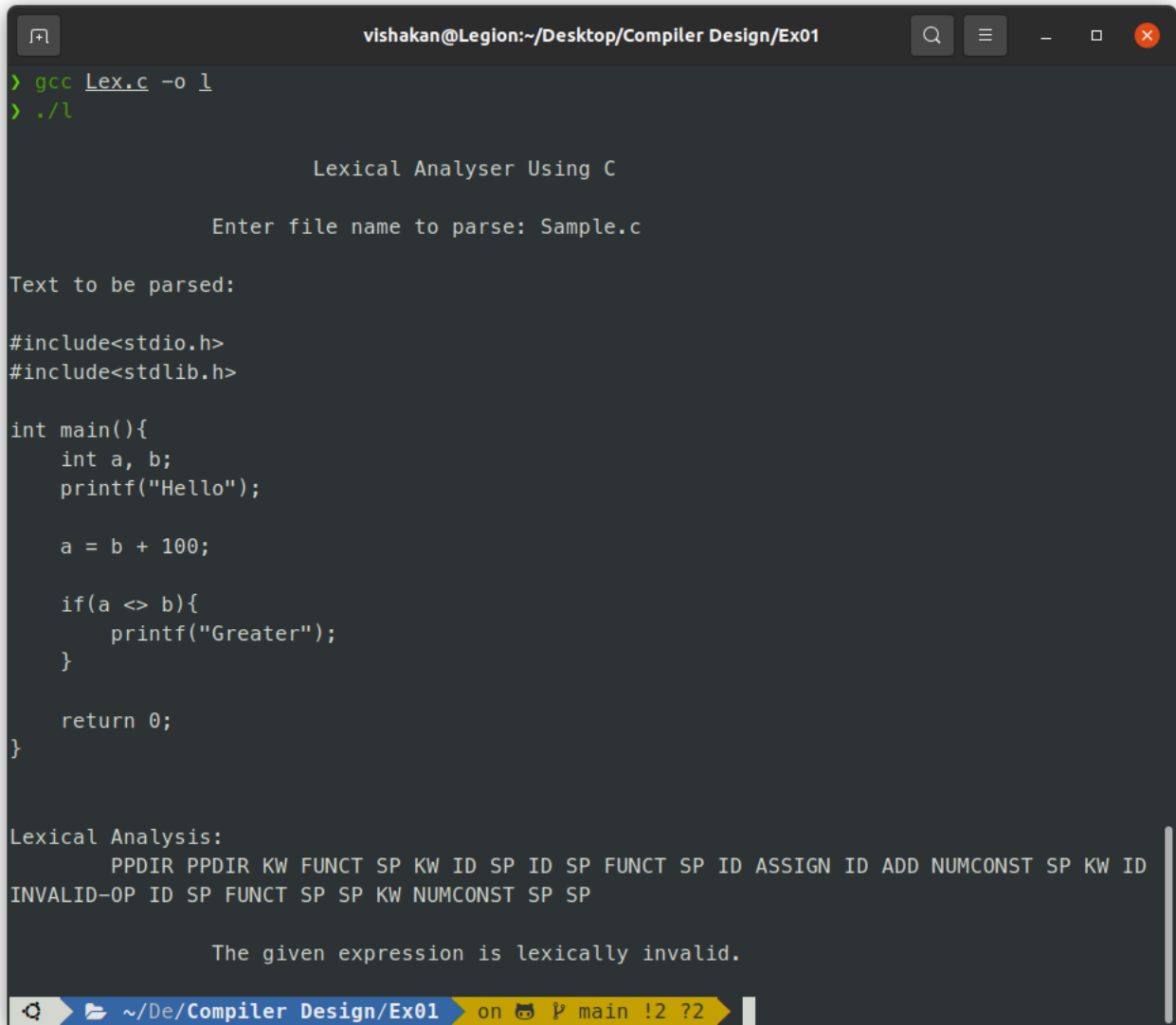
    return 0;
}

Lexical Analysis:
PPDIR PPDIR KW FUNCT SP KW ID SP ID SP FUNCT SP ID ASSIGN ID ADD NUMCONST SP KW ID
GT ID SP FUNCT SP SP KW NUMCONST SP SP

          The given expression is lexically valid.
```

## Output - Invalid Case:

Figure 2: Console Output for an Invalid Program.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex01
> gcc Lex.c -o l
> ./l

          Lexical Analyser Using C

Enter file name to parse: Sample.c

Text to be parsed:

#include<stdio.h>
#include<stdlib.h>

int main(){
    int a, b;
    printf("Hello");

    a = b + 100;

    if(a <> b){
        printf("Greater");
    }

    return 0;
}

Lexical Analysis:
PPDIR PPDIR KW FUNCT SP KW ID SP ID SP FUNCT SP ID ASSIGN ID ADD NUMCONST SP KW ID
INVALID-OP ID SP FUNCT SP SP KW NUMCONST SP SP

          The given expression is lexically invalid.
```

## Learning Outcome:

- From the experiment, I understood how a basic **Lexical Analyser** works.
- I was able to formulate ideas on how to implement recognition of specific tokens in programs for identification by the Lexical Analyser.
- I was able to implement simple regular expressions in C.
- I learnt how to parse a program for lexical validity, utilising the concept of **lexemes**.
- I was able to visualize the complexity that goes behind the compilation process and the significance of a Lexical Analyser phase in the compilation flow.

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12 February 2021

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### UCS 1602 - Compiler Design

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#### Exercise 2: Lexical Analyser Using Lex Tool

##### **Aim:**

To write a program using Lex to perform the basic functionalities of a **Lexical Analyser**, and to form a symbol table on the parsed program.

## Code:

```
1 /* Lexical Analyser Using Lex Tool */
2
3 /*Definitions*/
4
5 %{
6 #include<stdio.h>
7 #include<stdlib.h>
8 #include<string.h>
9
10 struct symbol{
11     char type[10];
12     char name[20];
13     char value[100];
14 }; //For Symbol Table
15
16 typedef struct symbol sym;
17
18 sym sym_table[1000];
19 int cur_size = -1;
20 char current_type[10];
21 %}
22
23 number_const [-+]?[0-9]+(\.[0-9]+)?
24 char_const \'.\'
25 string_const \".*\"
26 identifier [a-zA-Z_][a-zA-Z0-9_]*
27 function [a-zA-Z_][a-zA-Z0-9]*([.]*[()])
28 keyword (int|float|char|unsigned|typedef|struct|return|continue|break|if|
        else|for|while|do|extern|auto|case|switch|enum|goto|long|double|sizeof|
        void|default|register)
29 pp_dir ~[#].*[>]$
30 rel_ops (<|>|<=|>=|==|!=)
31 assign_ops (=|+=|-=|%=|/=|*=)
32 arith_ops (+|-|%|/|*)
33 single_cmt [/][/].*
34 multi_cmt ([/][/].*)|([/][*](.[\n\r])*[*][/])
35 spl_chars [{ } ( ) , ; \ [ \ ]
36
37 /*Rules*/
38
39 %%
40
41 {pp_dir} {
42     printf("PPDIR ");
43     strcpy(current_type, "INVALID");
44 }
45
```

```

46 {keyword} {
47     printf("KW ");
48
49     if(strcmp(yytext, "int") == 0){
50         strcpy(current_type, "int");
51     }
52     else if(strcmp(yytext, "float") == 0){
53         strcpy(current_type, "float");
54     }
55     else if(strcmp(yytext, "double") == 0){
56         strcpy(current_type, "double");
57     }
58     else if(strcmp(yytext, "char") == 0){
59         strcpy(current_type, "char");
60     }
61     else{
62         strcpy(current_type, "INVALID");
63     }
64 }
65
66 {function} {
67     printf("FUNCT ");
68 }
69
70 {identifier} {
71     printf("ID ");
72
73     if(strcmp(current_type, "INVALID") != 0){
74         cur_size++;
75         strcpy(sym_table[cur_size].name, yytext);
76         strcpy(sym_table[cur_size].type, current_type);
77
78         if(strcmp(current_type, "char") == 0){
79             strcpy(sym_table[cur_size].value, "NULL");
80         }
81         else if(strcmp(current_type, "int") == 0){
82             strcpy(sym_table[cur_size].value, "0");
83         }
84         else{
85             strcpy(sym_table[cur_size].value, "0.0");
86         }
87     }
88 }
89
90 {single_cmt} {
91     printf("SCMT ");
92 }
93
94 {multi_cmt} {
95     printf("MCMT ");
96 }

```



```

97
98 {number_const} {
99     printf("NUM_CONST ");
100
101     if(strcmp(current_type, "INVALID") != 0){
102         strcpy(sym_table[cur_size].value, yytext);
103     }
104 }
105
106 {char_const} {
107     printf("CHAR_CONST ");
108
109     if(strcmp(current_type, "char") == 0){
110         strcpy(sym_table[cur_size].value, yytext);
111     }
112 }
113
114 {string_const} {
115     printf("STR_CONST ");
116 }
117
118 {rel_ops} {
119     printf("REL_OP ");
120 }
121
122 {arith_ops} {
123     printf("ARITH_OP ");
124 }
125
126 {assign_ops} {
127     printf("ASSIGN_OP ");
128 }
129
130 {spl_chars} {
131     if(strcmp(yytext, ";") == 0){
132         strcpy(current_type, "INVALID");
133     }
134
135 }
136
137 \n {
138     printf("\n");
139 }
140
141 [ \t] { }
142
143
144 %%
145
146 int yywrap(void){
147     return 1;

```

```

148 }
149
150
151 /*User Subroutines*/
152
153 int main(int argc, char *argv[]){
154     int i = 0;
155
156     yyin = fopen(argv[1], "r");
157     yylex();
158
159     printf("\n\t-----\n");
160
161     printf("\n\t\t\tSYMBOL TABLE");
162     printf("\n\t\tNAME\tTYPE\tVALUE\n");
163     for(i = 0; i <= cur_size; i++){
164         printf("\t\t%s\t%s\t%s\n", sym_table[i].name, sym_table[i].type,
sym_table[i].value);
165     }
166
167     printf("\t-----\n");
168
169     return 0;
170 }

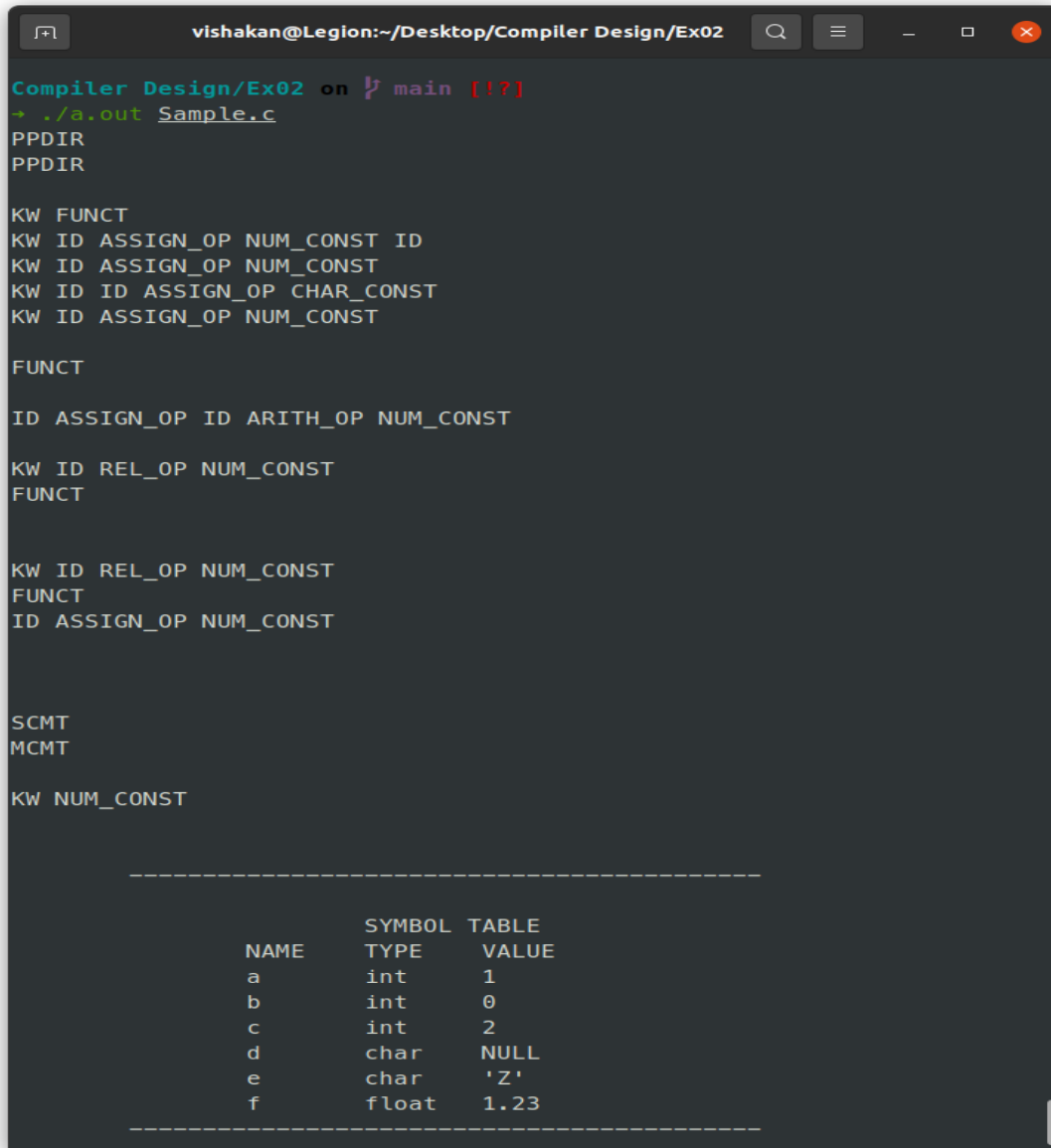
```

## Parsed C Code:

```
1 #include<stdio.h>
2 #include<stdlib.h>
3
4 int main(){
5     int a = 1, b;
6     int c = 2;
7     char d, e = 'Z';
8     float f = 1.23;
9
10    printf("Hello to %d", c);
11
12    a = b + 100;
13
14    if (c > 100){
15        printf("Greater");
16    }
17
18    while (c > 0) {
19        printf("Hello to Lex!");
20        c -= 1;
21    }
22
23
24    //a is GREATER than b!
25    /* Multi-line
26    comment */
27
28    return 0;
29 }
```

## Output:

Figure 1: Console Output



```
vishakan@Legion:~/Desktop/Compiler Design/Ex02
Compiler Design/Ex02 on main [!?]
→ ./a.out Sample.c
PPDIR
PPDIR

KW FUNCT
KW ID ASSIGN_OP NUM_CONST ID
KW ID ASSIGN_OP NUM_CONST
KW ID ID ASSIGN_OP CHAR_CONST
KW ID ASSIGN_OP NUM_CONST

FUNCT

ID ASSIGN_OP ID ARITH_OP NUM_CONST

KW ID REL_OP NUM_CONST
FUNCT

KW ID REL_OP NUM_CONST
FUNCT
ID ASSIGN_OP NUM_CONST

SCMT
MCMT

KW NUM_CONST

-----
              SYMBOL TABLE
              TYPE  VALUE
              a    int    1
              b    int    0
              c    int    2
              d    char   NULL
              e    char   'Z'
              f    float  1.23
              -----
```

## **Learning Outcome:**

- From the experiment, I understood the basics of Lex tool.
- I was able to implement recognition for regular expressions using Lex terminology.
- I understood the working of a Lex program.
- I learnt about the three sections of a Lex program, namely, definitions, rules and user subroutines.
- I learnt to implement a basic symbol table using Lex on the parsed C program.
- I understood that Lex tool is more powerful and easy-to-use for Lexical Analysis task compared to conventional C programming.

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20 February 2021

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### UCS 1602 - Compiler Design

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#### Exercise 3: Elimination of Left Recursion Using C

##### **Aim:**

Write a program in C to find whether the given grammar is **Left Recursive** or not. If it is found to be left recursive, convert the grammar in such a way that the left recursion is removed.

## Code:

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <string.h>
4
5 int main(){
6     /*
7         Sample Input Format:      E->E+T|T
8                                   T->T*F|F
9                                   F->i
10    */
11
12    char productions[100][100], sub_prods[100][100];
13    char non_terminal;
14    int num_prods, i, j, k, flag = 0;
15
16    printf("\n\t\tElimination of Left Recursion\n");
17    printf("\nEnter the number of Productions: ");
18    scanf("%d", &num_prods);
19
20    printf("\nEnter the Grammar:\n");
21
22    for(i = 0; i < num_prods; i++){
23        //Getting Input
24        scanf("%s", productions[i]);
25    }
26
27    printf("\nGiven Grammar:\n");
28
29    for(i = 0; i < num_prods; i++){
30        //Printing the Grammar, and checking for left recursions
31        printf("%s\n", productions[i]);
32
33        if(productions[i][0] == productions[i][3]){
34            flag = 1;
35        }
36    }
37
38    if(flag == 0){
39        //If Grammar is not left recursive, exit
40        printf("\nGrammar is not Left Recursive.");
41        return 0;
42    }
43
44    //Otherwise, Grammar is left recursive, parse and remove it
45    printf("\nGrammar is Left Recursive.");
46    printf("\n\nGrammar after removal of Left Recursion:");
47
```

```

48     for(i = 0; i < num_prods; i++){
49         //Parse each production one by one
50         non_terminal = productions[i][0];
51
52         char *split, production[100];
53         flag = 0;
54
55         //Store the RHS of the production alone
56         for(j = 0; productions[i][j + 3] != '\0'; j++){
57             production[j] = productions[i][j + 3];
58         }
59
60         production[j] = '\0';
61         j = 0;
62
63         //Split at the sub-expression level when there is an OR operator
64         split = strtok(production, "|");
65
66         while(split != NULL){
67             //Store the subexpression in a new productions array
68             strcpy(sub_prods[j], split);
69
70             if(split[0] == non_terminal && flag == 0){
71                 //Seeing an immediate left recursion, with no other
productions
72                 //for the same non-terminal
73                 //This type of Left Recursion cannot be removed
74                 flag = 1;
75             }
76             else if(split[0] != non_terminal && flag == 1){
77                 //Already seen a left recursion, but now we have seen
78                 //another production with some terminal symbol
79                 //for the same non-terminal
80                 flag = 2;
81             }
82
83             j++;
84             split = strtok(NULL, "|");
85             //split and loop till all productions are parsed
86         }
87
88         if(flag != 2){
89             //flag == 0 => no LR
90             //flag == 1 => LR of the form A->Ab which cannot be removed
91             printf("%s\n", productions[i]);
92         }
93
94         if(flag == 2){
95             //Remove the left recursion if there's another production with
terminal symbol
96             printf("\n");

```



```

97         flag = 0;
98
99         for(k = 0; k < j; k++){
100             if(sub_prods[k][0] != non_terminal){
101                 //Loop until the non-terminal causing the LR is not
102                 found, for 1st production rule
103                 if(flag != 0){
104                     //Removed the LR by starting with the other non-
105                     terminal/ID,
106                     //thus add the remaining sub-productions
107                     printf("|%s%c\'", sub_prods[k], non_terminal);
108                 }
109                 else{
110                     //No left recursion with that particular sub-
111                     production
112                     //thus make it as a new production with a new non-
113                     terminal
114                     flag = 1;
115                     printf("%c->%s%c\'", non_terminal, sub_prods[k],
116                     non_terminal);
117                 }
118             }
119             printf("\n");
120             flag = 0;
121
122             for(k = 0; k < j; k++){
123                 if(sub_prods[k][0] == non_terminal){
124                     //Loop until the non-terminal causing the LR is found,
125                     for 2nd production rule
126                     if(flag != 0){
127                         //Add the remaining sub-productions, since the LR
128                         has been removed
129                         printf("|%s%c\'", sub_prods[k] + 1, non_terminal);
130                     }
131                     else{
132                         //k sub-production contains the LR causing term,
133                         thus first print the
134                         //next sub-production followed by a new non-
135                         terminal as a new production
136                         //2D Array Manipulation, sub_prods[k] + 1
137                         essentially prints
138                         //the string sub_prods[k][1] till sub_prods[k][n]
139                         flag = 1;
140                         printf("%c\'->%s%c\'", non_terminal, sub_prods[k]
141                         + 1, non_terminal);
142                     }
143                 }
144             }
145             printf("|e\n");
146         }

```

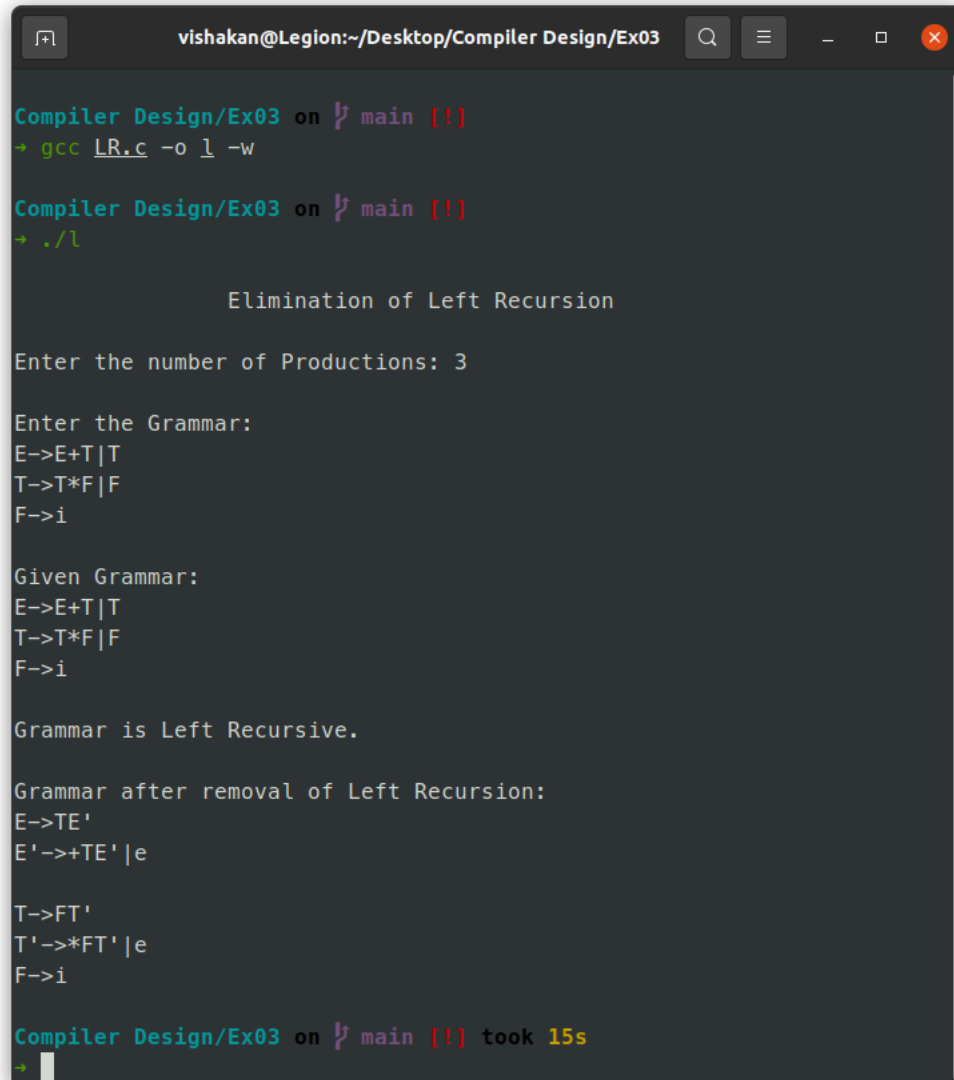
```

137
138     }
139
140
141     return 0;
142 }
143
144 /*
145 OUTPUT:
146
147 gcc LR.c -o l -w
148 ./l
149
150     Elimination of Left Recursion
151
152 Enter the number of Productions: 3
153
154 Enter the Grammar:
155 E->E+T|T
156 T->T*F|F
157 F->i
158
159 Given Grammar:
160 E->E+T|T
161 T->T*F|F
162 F->i
163
164 Grammar is Left Recursive.
165
166 Grammar after removal of Left Recursion:
167 E->TE'
168 E'->+TE'|e
169
170 T->FT'
171 T'->*FT'|e
172 F->i
173
174 */

```

## Output - Left Recursive Grammar:

Figure 1: Console Output for a Left Recursive Grammar.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex03
Compiler Design/Ex03 on  main [!]
+ gcc LR.c -o l -w

Compiler Design/Ex03 on  main [!]
+ ./l

          Elimination of Left Recursion

Enter the number of Productions: 3

Enter the Grammar:
E->E+T|T
T->T*F|F
F->i

Given Grammar:
E->E+T|T
T->T*F|F
F->i

Grammar is Left Recursive.

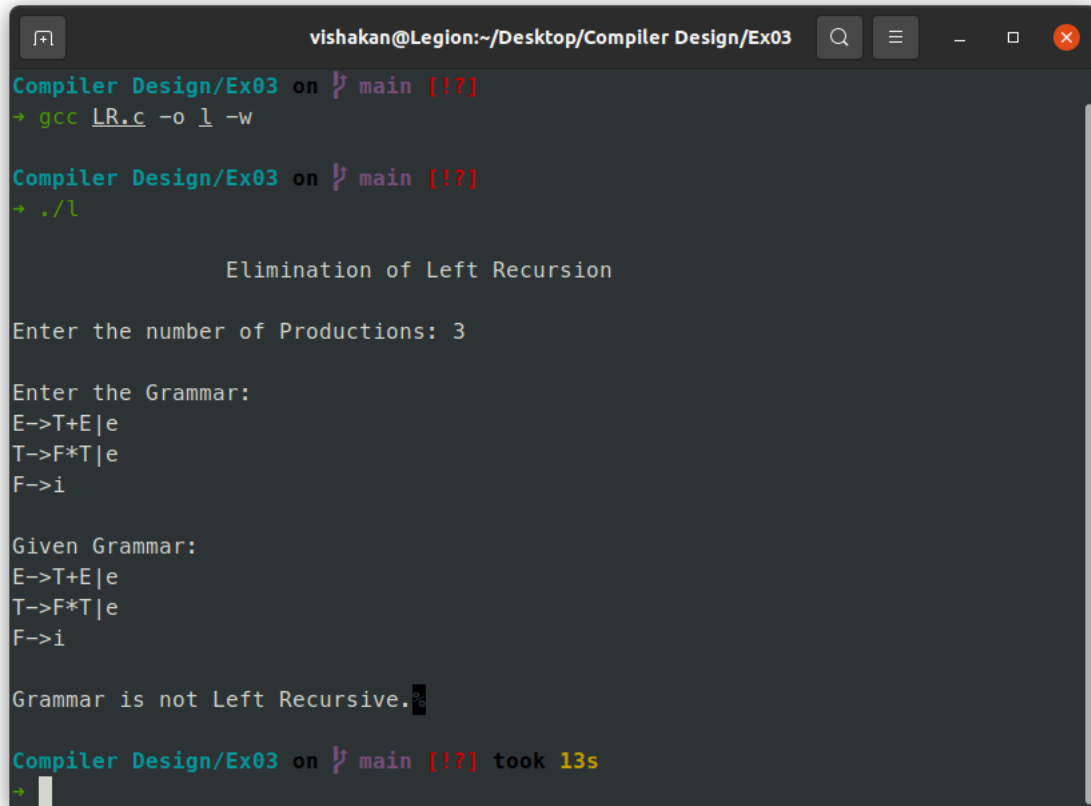
Grammar after removal of Left Recursion:
E->TE'
E'->+TE'|e

T->FT'
T'->*FT'|e
F->i

Compiler Design/Ex03 on  main [!] took 15s
+ 
```

## Output - Non Left Recursive Grammar:

Figure 2: Console Output for a Non Left Recursive Grammar.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex03
Compiler Design/Ex03 on  main [!?]
+ gcc LR.c -o l -w

Compiler Design/Ex03 on  main [!?]
+ ./l

      Elimination of Left Recursion

Enter the number of Productions: 3

Enter the Grammar:
E->T+E|e
T->F*T|e
F->i

Given Grammar:
E->T+E|e
T->F*T|e
F->i

Grammar is not Left Recursive.

Compiler Design/Ex03 on  main [!?] took 13s
+ 
```

## **Learning Outcome:**

- I understood about left recursive grammars.
- I understood the need for this type of conversion, as top-down parsers cannot handle left recursive grammars.
- I was able to perform a check of whether or not a grammar is left recursive using C.
- I implemented a conversion in C which converts left recursive grammar to non left recursive grammar.
- I refreshed my 2D-char array manipulation concepts in C.

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

26 February 2021

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### UCS 1602 - Compiler Design

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#### Exercise 4: Recursive Descent Parser Using C

##### Aim:

Write a program in C to construct **Recursive Descent Parser** for the following grammar which is for arithmetic expression involving + and \*. Check the Grammar for left recursion and convert into suitable for this parser. Write recursive functions for every non-terminal. Call the function for start symbol of the Grammar in main().

G1:

$$\begin{aligned} E &\rightarrow E + T \mid T \\ T &\rightarrow T * F \mid F \\ F &\rightarrow i \end{aligned}$$

Extend this parser to include division, subtraction and parenthesis operators.

G2:

$$\begin{aligned} E &\rightarrow E + T \mid E - T \mid T \\ T &\rightarrow T * F \mid T / F \mid F \\ F &\rightarrow (E) \mid i \end{aligned}$$

## Code - Grammar 1:

```
1 #include<stdio.h>
2 #include<stdlib.h>
3 #include<string.h>
4
5 /*Recursive Descent Parser*/
6
7 /*
8 Grammar: G: E->E+T|T
9           T->T*F|F
10          F->i
11 */
12
13 /*
14 Removed Left Recursion
15 Grammar G': E->TE'
16             E'->+TE'|e
17             T->FT'
18             T'->*FT'|e
19             F->i
20 */
21
22 struct parse_struct{
23     char str[100];
24     int pos;
25     int len;
26 };
27
28 typedef struct parse_struct parser;
29
30 parser E(parser p);
31 parser T(parser p);
32 parser EPrime(parser p);
33 parser F(parser p);
34 parser TPrime(parser p);
35 parser parse(parser p, char s);
36
37 int main(void){
38     parser p;
39
40     printf("\n\t\tRecursive Descent Parser\n");
41     printf("\nEnter a string to parse: ");
42     scanf("%s", p.str);
43
44     p.len = strlen(p.str);
45     p.pos = 0;
46
47     p = E(p);
```

```

48
49     if(p.pos == p.len){
50         //All characters have been parsed
51         printf("\nParse Success!\n");
52     }
53
54     else{
55         //Some characters haven't been parsed, but returned to main
56         printf("\nError parsing at Position %d!\n", p.pos);
57     }
58
59
60     return 0;
61 }
62
63 parser E(parser p){
64     //printf("\nAt E");
65     p = T(p);
66     p = EPrime(p);
67
68     return p;
69 }
70
71 parser T(parser p){
72     //printf("\nAt T");
73     p = F(p);
74     p = TPrime(p);
75
76     return p;
77 }
78
79 parser EPrime(parser p){
80     //printf("\nAt EPrime");
81     if(p.str[p.pos] == '+'){
82         p = parse(p, '+');
83         p = T(p);
84         p = EPrime(p);
85     }
86
87     return p;
88 }
89
90 parser TPrime(parser p){
91     //printf("\nAt TPrime");
92     if(p.str[p.pos] == '*'){
93         p = parse(p, '*');
94         p = F(p);
95         p = TPrime(p);
96     }
97
98     return p;

```



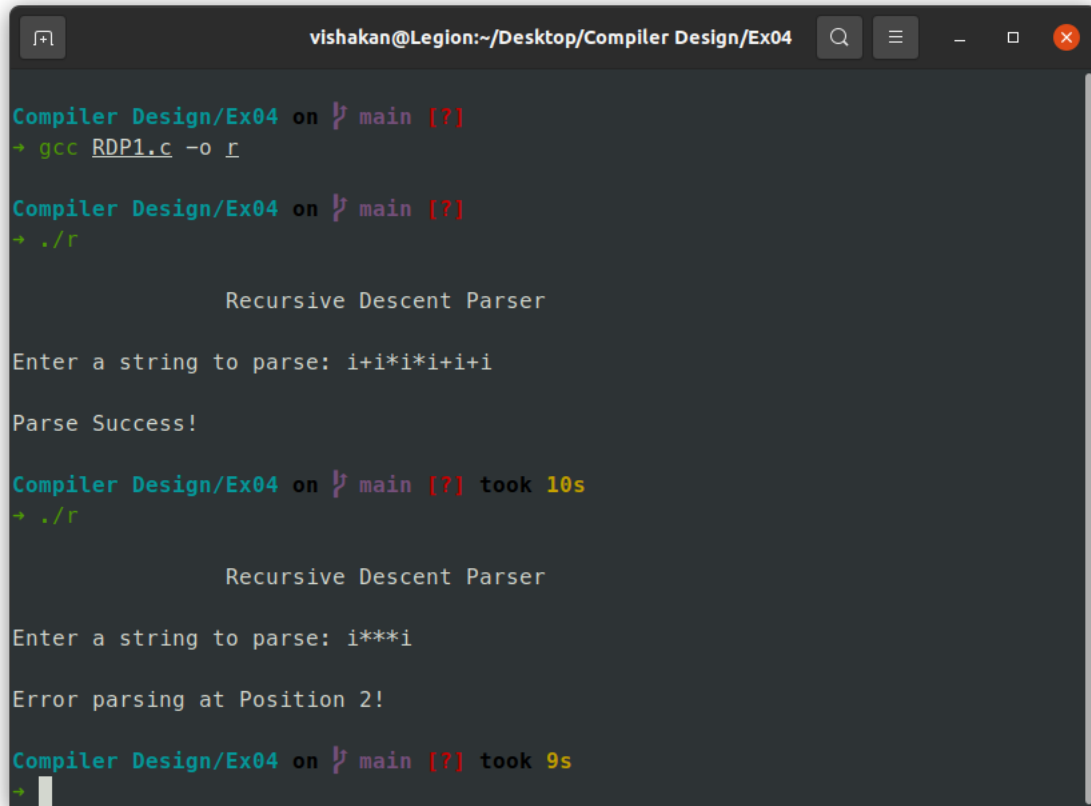
```

99 }
100
101 parser F(parser p){
102     //printf("\nAt F");
103     if(p.str[p.pos] == 'i'){
104         p = parse(p, 'i');
105     }
106     else{
107         printf("\nError parsing at Position %d!\n", p.pos);
108         exit(0);
109     }
110
111     return p;
112 }
113
114 parser parse(parser p, char s){
115     if(p.str[p.pos] != s){
116         printf("\nError parsing at Position %d!\n", p.pos);
117         exit(0);
118     }
119     else{
120         p.pos++;
121     }
122
123     return p;
124 }

```

## Output - Grammar 1:

Figure 1: Console Output for parsed strings of Grammar 1.



```
Compiler Design/Ex04 on main [?]
→ gcc RDP1.c -o r

Compiler Design/Ex04 on main [?]
→ ./r

Recursive Descent Parser

Enter a string to parse: i+i*i+i+i

Parse Success!

Compiler Design/Ex04 on main [?] took 10s
→ ./r

Recursive Descent Parser

Enter a string to parse: i***i

Error parsing at Position 2!

Compiler Design/Ex04 on main [?] took 9s
→
```

## Code - Grammar 2:

```
1 #include<stdio.h>
2 #include<stdlib.h>
3 #include<string.h>
4
5 /*Recursive Descent Parser*/
6
7 /*
8 Grammar: G: E->E+T|E-T|T
9           T->T*F|T/F|F
10          F->(E)|i
11 */
12
13 /*
14 Removed Left Recursion
15 Grammar G': E->TE'
16             E'->+TE'|-TE'|e
17             T->FT'
18             T'->*FT'|/FT'|e
19             F->(E)|i
20 */
21
22 struct parse_struct{
23     char str[100];
24     int pos;
25     int len;
26 };
27
28 typedef struct parse_struct parser;
29
30 parser E(parser p);
31 parser T(parser p);
32 parser EPrime(parser p);
33 parser F(parser p);
34 parser TPrime(parser p);
35 parser parse(parser p, char s);
36
37 int main(void){
38     parser p;
39
40     printf("\n\t\tRecursive Descent Parser\n");
41     printf("\nEnter a string to parse: ");
42     scanf("%s", p.str);
43
44     p.len = strlen(p.str);
45     p.pos = 0;
46
47     p = E(p);
```

```

48
49     if(p.pos == p.len){
50         //All characters have been parsed
51         printf("\nParse Success!\n");
52     }
53
54     else{
55         //Some characters haven't been parsed, but returned to main
56         printf("\nError parsing at Position %d!\n", p.pos);
57     }
58
59     return 0;
60 }
61
62 parser E(parser p){
63     //printf("\nAt E");
64     p = T(p);
65     p = EPrime(p);
66
67     return p;
68 }
69
70 parser T(parser p){
71     //printf("\nAt T");
72     p = F(p);
73     p = TPrime(p);
74
75     return p;
76 }
77
78 parser EPrime(parser p){
79     //printf("\nAt EPrime");
80     if(p.str[p.pos] == '+'){
81         p = parse(p, '+');
82         p = T(p);
83         p = EPrime(p);
84     }
85     else if(p.str[p.pos] == '-'){
86         p = parse(p, '-');
87         p = T(p);
88         p = EPrime(p);
89     }
90
91     return p;
92 }
93
94 parser TPrime(parser p){
95     //printf("\nAt TPrime");
96     if(p.str[p.pos] == '*'){
97         p = parse(p, '*');
98         p = F(p);

```

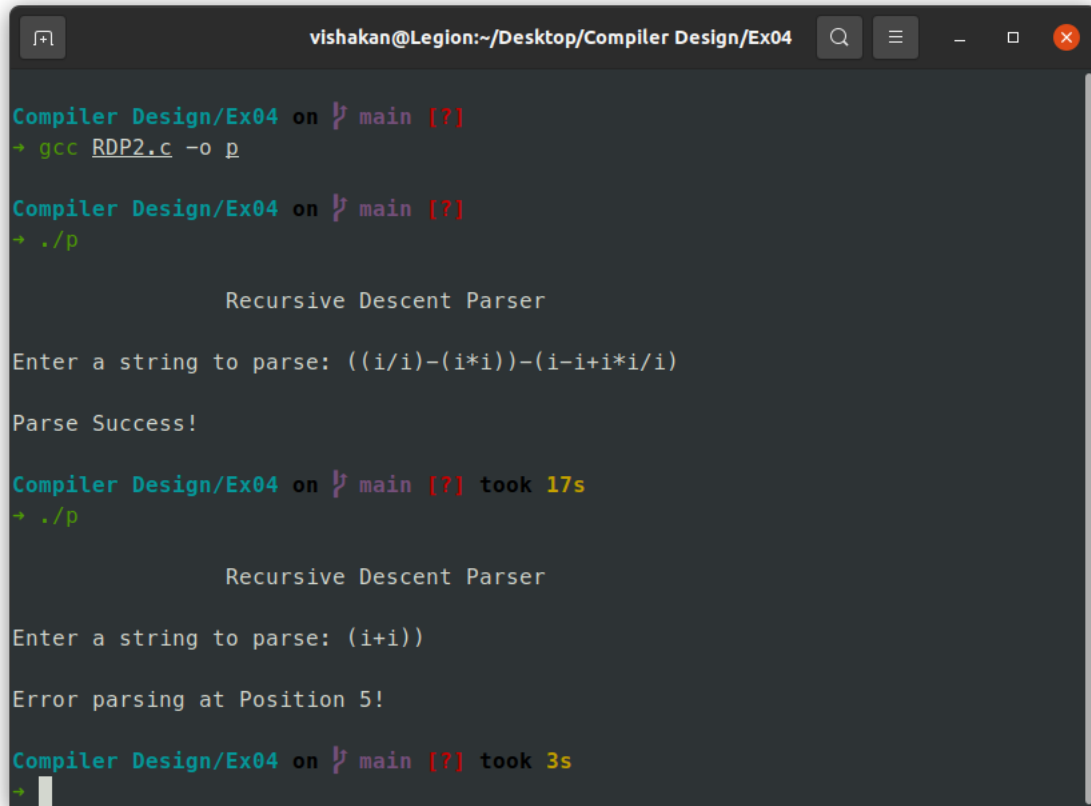
```

99         p = TPrime(p);
100     }
101     else if(p.str[p.pos] == '/'){
102         p = parse(p, '/');
103         p = F(p);
104         p = TPrime(p);
105     }
106
107     return p;
108 }
109
110 parser F(parser p){
111     //printf("\nAt F");
112     if(p.str[p.pos] == '('){
113         p = parse(p, '(');
114         p = E(p);
115         p = parse(p, ')');
116     }
117     else if(p.str[p.pos] == 'i'){
118         p = parse(p, 'i');
119     }
120     else{
121         printf("\nError parsing at Position %d!\n", p.pos);
122         exit(0);
123     }
124
125     return p;
126 }
127
128 parser parse(parser p, char s){
129     if(p.str[p.pos] != s){
130         printf("\nError parsing at Position %d!\n", p.pos);
131         exit(0);
132     }
133     else{
134         p.pos++;
135     }
136
137     return p;
138 }

```

## Output - Grammar 2:

Figure 2: Console Output for parsed strings of Grammar 2.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex04
Compiler Design/Ex04 on 1 main [?]
→ gcc RDP2.c -o p

Compiler Design/Ex04 on 1 main [?]
→ ./p

Recursive Descent Parser
Enter a string to parse: ((i/i)-(i*i))-(i-i+i*i/i)
Parse Success!

Compiler Design/Ex04 on 1 main [?] took 17s
→ ./p

Recursive Descent Parser
Enter a string to parse: (i+i))
Error parsing at Position 5!

Compiler Design/Ex04 on 1 main [?] took 3s
→
```

## Learning Outcome:

- I understood about the working of a **Recursive Descent Parser**.
- I understood that Recursive Descent Parser, being a Top-Down Parser, does not work with Left-Recursive Grammars.
- I was able to implement a working Recursive Descent Parser for a simple grammar.
- I was able to extend the concept to implement a Recursive Descent Parser for a complicated grammar with more productions.
- I refreshed my concepts with recursion & return handling in functions with C.
- I understood how to manually perform the Recursive Descent Parsing Process.

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

7 March 2021

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### UCS 1602 - Compiler Design

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#### Exercise 5: Implementation of Desk Calculator Using Yacc Tool

##### Aim:

Write a Lex program to recognize relevant tokens required for the **Yacc** parser to implement desk calculator. Write the Grammar for the expression involving the operators namely,  $+$ ,  $-$ ,  $*$ ,  $/$ ,  $^$ ,  $(, )$ . Precedence and associativity has to be preserved. Yacc is available as a command in Linux. The grammar should have non terminals E, OP and a terminal id.

Verify your calculator with the following inputs:

1.  $3 + 9$
2.  $3 + 9 * 6$
3.  $(3 + 4) * 7$
4.  $(3 - 4) + (7 * 6)$
5.  $5/7 + 2$
6.  $(4^2)^1$
7.  $(2^3)^2$



## Code - Yacc Parser File:

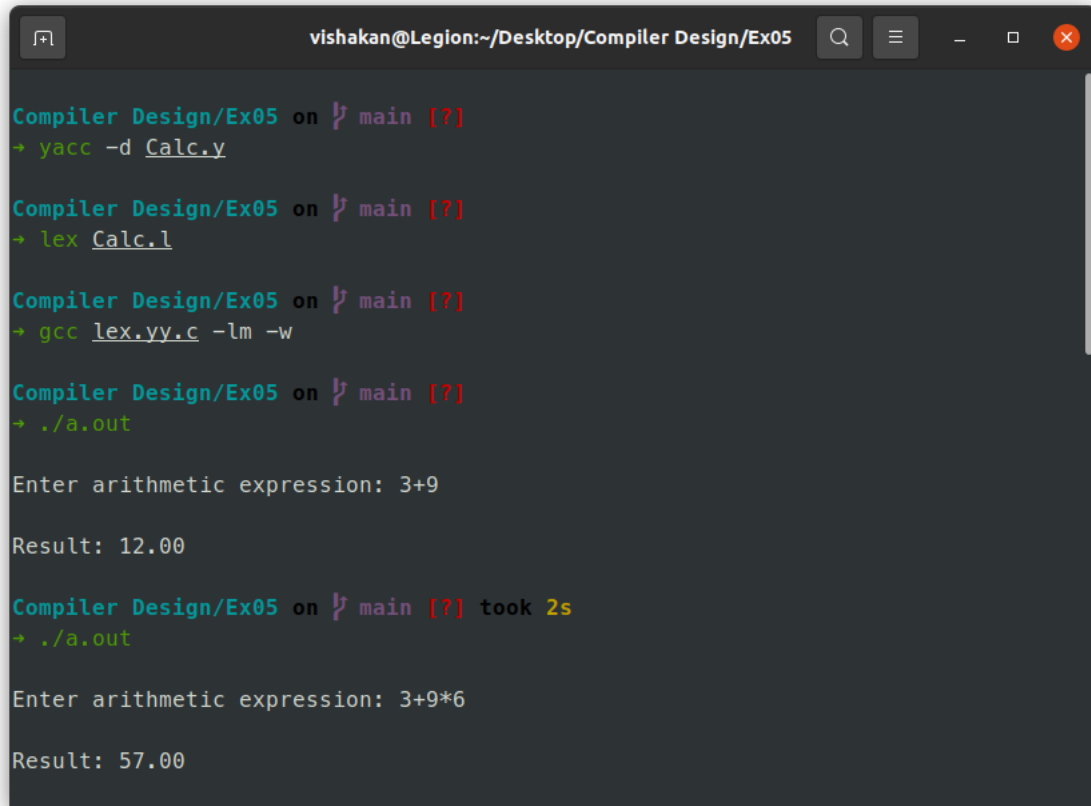
```
1 %{
2     #include <stdio.h>
3     #include <math.h>
4     #define YYSTYPE double
5     int flag = 0;
6 %}
7
8 %token NUM
9 /*Defining the precedence*/
10 %left '+', '-'
11 %left '/', '*'
12 %right '^'
13 %left '(', ')'
14
15 %%
16 Line : Expr {printf("\nResult: %.2f\n", $$);}
17 Expr : Expr '+' Expr {$$ = $1 + $3;}
18      | Expr '-' Expr {$$ = $1 - $3;}
19      | Expr '*' Expr {$$ = $1 * $3;}
20      | Expr '/' Expr {$$ = $1 / $3;}
21      | Expr '^' Expr {$$ = pow($1, $3);}
22      | '(' Expr ')' {$$ = $2;}
23      | NUM {$$ = $1;}
24 %%
25
26 int yyerror(){
27     flag = 1;
28     return 1;
29 }
30
31 int main(void){
32     printf("\nEnter arithmetic expression: ");
33     yyparse();
34
35     if(flag){
36         printf("\nEntered Unexpected Tokens.\n");
37     }
38
39     return 0;
40 }
41
42 /* Usage:
43     Run yacc -d Calc.y
44     Run lex Calc.l
45     Run gcc lex.yy.c -lm -w
46     Run ./a.out
47 */
```

## Code - Lex Grammar File:

```
1 %{
2     #include <stdio.h>
3     #include "y.tab.c"
4     extern YYSTYPE yylval;
5 %}
6
7 %%
8
9 [0-9]+ {yylval = atoi(yytext); return NUM;}
10 [\t]   ;
11 [\n]   return 0;
12 .      return yytext[0];
13
14 %%
15
16 int yywrap(){
17     return 1;
18 }
```

## Output 1:

Figure 1: Console Output - 1.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex05
Compiler Design/Ex05 on 1 main [?]
→ yacc -d Calc.y

Compiler Design/Ex05 on 1 main [?]
→ lex Calc.l

Compiler Design/Ex05 on 1 main [?]
→ gcc lex.yy.c -lm -w

Compiler Design/Ex05 on 1 main [?]
→ ./a.out

Enter arithmetic expression: 3+9

Result: 12.00

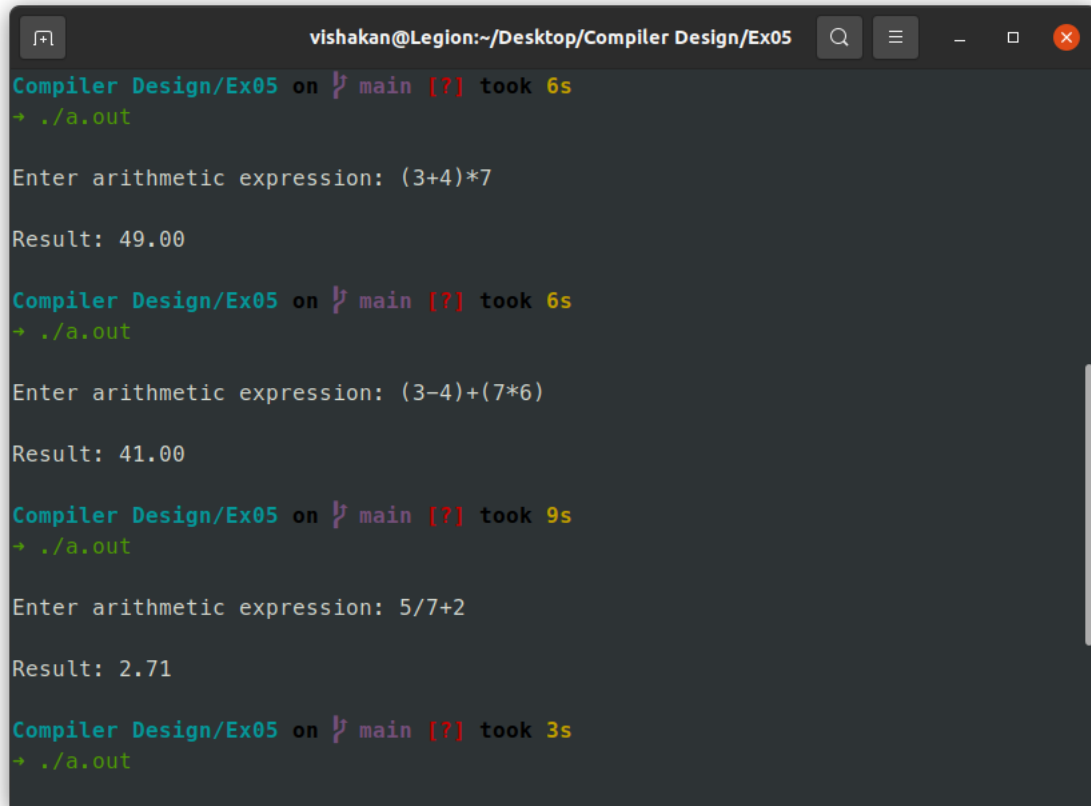
Compiler Design/Ex05 on 1 main [?] took 2s
→ ./a.out

Enter arithmetic expression: 3+9*6

Result: 57.00
```

## Output 2:

Figure 2: Console Output - 2.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex05
Compiler Design/Ex05 on  main [?] took 6s
→ ./a.out

Enter arithmetic expression: (3+4)*7

Result: 49.00

Compiler Design/Ex05 on  main [?] took 6s
→ ./a.out

Enter arithmetic expression: (3-4)+(7*6)

Result: 41.00

Compiler Design/Ex05 on  main [?] took 9s
→ ./a.out

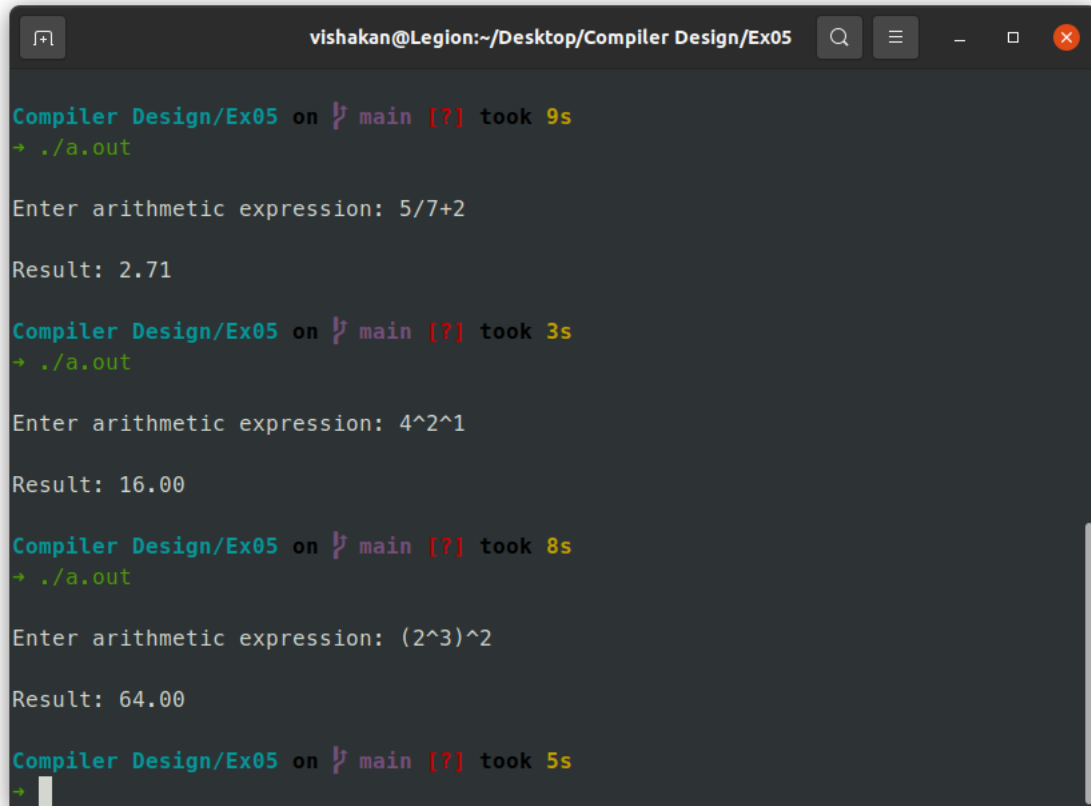
Enter arithmetic expression: 5/7+2

Result: 2.71

Compiler Design/Ex05 on  main [?] took 3s
→ ./a.out
```

## Output 3:

Figure 3: Console Output - 3.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex05

Compiler Design/Ex05 on  main [?] took 9s
→ ./a.out

Enter arithmetic expression: 5/7+2

Result: 2.71

Compiler Design/Ex05 on  main [?] took 3s
→ ./a.out

Enter arithmetic expression: 4^2^1

Result: 16.00

Compiler Design/Ex05 on  main [?] took 8s
→ ./a.out

Enter arithmetic expression: (2^3)^2

Result: 64.00

Compiler Design/Ex05 on  main [?] took 5s
→
```

## Learning Outcome:

- I learnt the basic theory behind **Yacc Parser Generator**.
- I learnt that Yacc stands for Yet Another Compiler-Compiler.
- I understood that Yacc is a LALR(1) parser.
- I understood Yacc's basic syntax and programming logic.
- I learnt that Yacc needs a Lex file along with it to work as intended, to detect and give the tokens to the Yacc parser.
- I was able to visualize how the parser works with the scanner.
- I learnt how to define a simple grammar in Yacc's syntax.
- I was able to implement a parser with Yacc to mimic the features of a desk calculator with precedence logic.
- I understood how to compile and run the Yacc and Lex file together.

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

28 March 2021

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### UCS 1602 - Compiler Design

---

#### Exercise 6: Implementation of Syntax Checker Using Yacc Tool

##### **Aim:**

Develop a **Syntax Checker** to recognize the tokens necessary for the following statements by writing suitable grammars.

- Assignment Statement
- Conditional Statement
- Looping Statement

## Code - Yacc Parser File:

```
1 %{
2     #include <stdio.h>
3     #define YYSTYPE double
4     int flag = 0;
5 %}
6
7 %token  NUM ASSIGN ID
8 %token  RELOP LOGIC ARITH INCDEC
9 %token  IF ELIF ELSE
10 %token  FOR WHILE
11
12 %%
13 Block   :   Stmt Block
14         |   Stmt
15         ;
16
17 Stmt    :   Loop '{' Block '}'
18         |   ConStmt '{' Block '}'
19         |   Expr ';'
20
21 Loop    :   FOR '(' Expr ';' Condns ';' Expr ')'
22         |   FOR '(' ';' Condns ';' ')'
23         |   WHILE '(' Condns ')'
24         ;
25
26 ConStmt :   IF '(' Condns ')'
27         |   ELIF '(' Condns ')'
28         |   ELSE
29         ;
30
31 Condns  :   Condn LOGIC Condns
32         |   Condn
33         ;
34
35 Condn   :   ID RELOP ID
36         |   ID RELOP NUM
37         |   ID
38         ;
39
40 Expr    :   Init
41         |   ID ASSIGN ID ARITH ID
42         |   ID ASSIGN ID ARITH NUM
43         |   ID ASSIGN NUM ARITH NUM
44         |   ID INCDEC
45         |   INCDEC ID
46         ;
47
```



```

48 Init      :    ID ASSIGN Init
49          |    ID ASSIGN ID
50          |    ID ASSIGN NUM
51          ;
52 %%
53
54 int yyerror(char *s){
55     flag = 1;
56     //fprintf(stderr, "%s\n", s);
57     return 1;
58 }
59
60 int main(void){
61     printf("\n\n\t\tSYNTAX CHECKER USING YACC\n");
62     printf("\nNote: Enter the code snippet in Code.txt.\n");
63     printf("\nCode Obtained:\n\n");
64     system("cat Code.txt");
65     yyparse();
66
67     if(flag){
68         printf("\nSyntactically Incorrect.\n");
69     }
70
71     else{
72         printf("\nSyntactically Correct.\n");
73     }
74
75     return 0;
76 }
77
78 /* Usage:
79     Run yacc -d Check.y
80     Run lex Check.l
81     Run gcc lex.yy.c -lm -w
82     Run ./a.out < Code.txt
83 */

```

## Code - Lex Grammar File:

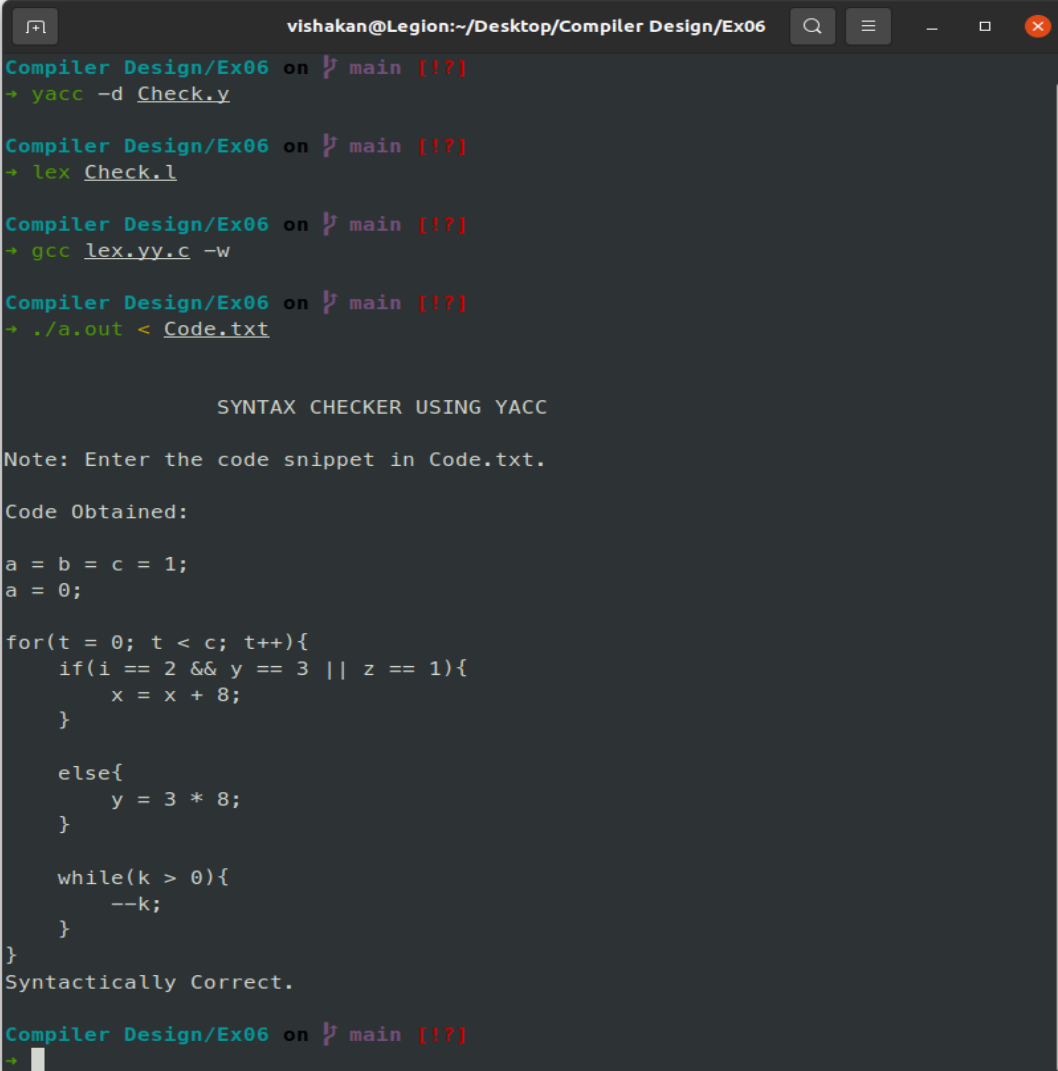
```
1 %{
2     #include <stdio.h>
3     #include "y.tab.c"
4     extern YYSTYPE yylval;
5 %}
6
7 assign      ("=")
8 relop       ("==" | "!=" | ">=" | "<=" | "<" | ">")
9 arithop     ("+" | "-" | "/" | "%" | "*")
10 incdec      ("++" | "--")
11 logical     ("||" | "&&")
12 identifier  [a-zA-Z_][a-zA-Z0-9_]*
13
14
15 %%
16
17 [0-9]+      {return NUM;}
18 {assign}    {return ASSIGN;}
19 {relop}     {return RELOP;}
20 {logical}   {return LOGIC;}
21 {arithop}   {return ARITH;}
22 {incdec}    {return INCDEC;}
23 "if"        {return IF;}
24 "else if"   {return ELIF;}
25 "else"      {return ELSE;}
26 "for"       {return FOR;}
27 "while"     {return WHILE;}
28 {identifier} {return ID;}
29
30
31 [ \t]       {;}
32 [\n]        {;}
33 .           {return *yytext;}
34
35 %%
36
37 int yywrap(){
38     return 1;
39 }
```

## Sample - Parsed C Code:

```
1 a = b = c = 1;
2 a = 0;
3
4 for(t = 0; t < c; t++){
5     if(i == 2 && y == 3 || z == 1){
6         x = x + 8;
7         a = b + c;
8     }
9
10    else{
11        y = 3 * 8;
12    }
13
14    while(k > 0){
15        --k;
16    }
17 }
```

## Output 1 - Valid Case:

Figure 1: Console Output - Valid Case.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex06
Compiler Design/Ex06 on main [!?]
→ yacc -d Check.y

Compiler Design/Ex06 on main [!?]
→ lex Check.l

Compiler Design/Ex06 on main [!?]
→ gcc lex.yy.c -w

Compiler Design/Ex06 on main [!?]
→ ./a.out < Code.txt

SYNTAX CHECKER USING YACC

Note: Enter the code snippet in Code.txt.

Code Obtained:

a = b = c = 1;
a = 0;

for(t = 0; t < c; t++){
    if(i == 2 && y == 3 || z == 1){
        x = x + 8;
    }

    else{
        y = 3 * 8;
    }

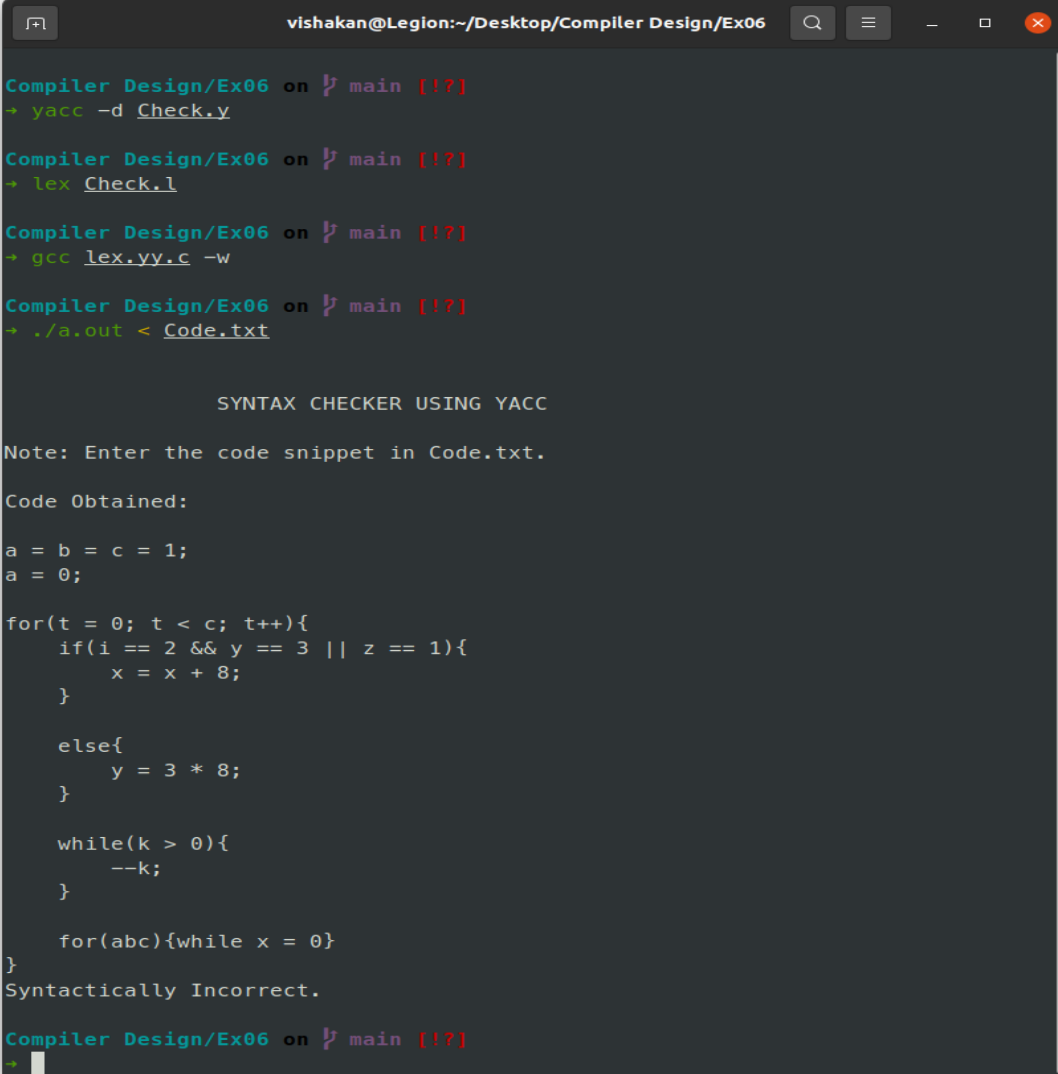
    while(k > 0){
        --k;
    }
}

Syntactically Correct.

Compiler Design/Ex06 on main [!?]
→
```

## Output 2 - Invalid Case:

Figure 2: Console Output - Invalid Case.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex06

Compiler Design/Ex06 on  main [!?]
+ yacc -d Check.y

Compiler Design/Ex06 on  main [!?]
+ lex Check.l

Compiler Design/Ex06 on  main [!?]
+ gcc lex.yy.c -w

Compiler Design/Ex06 on  main [!?]
+ ./a.out < Code.txt

          SYNTAX CHECKER USING YACC

Note: Enter the code snippet in Code.txt.

Code Obtained:

a = b = c = 1;
a = 0;

for(t = 0; t < c; t++){
    if(i == 2 && y == 3 || z == 1){
        x = x + 8;
    }

    else{
        y = 3 * 8;
    }

    while(k > 0){
        --k;
    }

    for(abc){while x = 0}
}
Syntactically Incorrect.

Compiler Design/Ex06 on  main [!?]
+ 
```

## Learning Outcome:

- I learnt more theory behind **Yacc Parser Generator**.
- I understood how to construct a grammar for a basic syntax checker.
- I learnt that grammar can be built upon layer by layer, each one adding more detail and complexity.
- I learnt that Yacc parser is able to handle Left Recursive grammar as well, since it is a LALR(1) parser.
- I was able to implement the required token recognition with Lex tool.
- I was able to implement a parser with Yacc to mimic the features of a syntax checker.
- I realized key implementation differences between the syntax checker and the desk calculator.
- I learnt how the Yacc parser catches an error using the inbuilt `yyerror()` function.

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

14 April 2021

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### UCS 1602 - Compiler Design

---

#### Exercise 7: Generation of Intermediate Code Using Lex and Yacc

##### **Aim:**

The new Language Pascal-2021 is introduced with the following programming constructs:

##### **Datatypes**

- Integer
- Real
- Char

##### **Declaration Statement**

- var: type;
- var: type = constant;

##### **Conditional Statement**

- if condition then — else — endif

Generate Intermediate code in the form of Three Address Code sequence for the sample input program written using declaration, conditional and assignment statements in new language Pascal-2021.

## Code - Yacc Parser File:

```
1 %{
2     #include <stdio.h>
3     #include <stdlib.h>
4     #include <string.h>
5     #include <math.h>
6
7     int yylex(void);
8     int yyerror(char *);
9     int yywrap();
10
11     int vars = 0, labels = 0;
12
13     struct info{
14         char *var;
15         char *code;
16         int intval;
17         float floatval;
18         char charval;
19     };
20
21     typedef struct info node;
22
23     node *makeNode(){
24         //creating a new node to store intermediate code
25
26         node *n = (node *)malloc(sizeof(node));
27         n->intval = 0;
28         n->floatval = 0;
29         n->charval = 0;
30         n->var = (char *)malloc(50 * sizeof(char));
31         n->code = (char *)malloc(5000 * sizeof(char));
32
33         return n;
34     }
35 %}
36
37 /*Declaration of tokens and precedence*/
38 %token BGN END IF THEN ELSE INT CHAR
39 %token REAL CHCONST VAR NUM RELOP ADDOP MULOP
40
41 /*Increasing precedence*/
42 %right MULOP
43 %left ADDOP
44
45 /*Declaration of the types that YYSTYPE can take with the union*/
46 %union{
47     int intval;
```



```

48     float floatval;
49     char ch;
50     char *str;
51     struct info *Node;
52 }
53
54 /*Declaring types for the tokens*/
55 %type<str>      VAR RELOP ADDOP MULOP
56 %type<intval>   NUM
57 %type<floatval> REAL
58 %type<ch>       CHCONST
59 %type<Node>     Program Structure Declarations Statements
60 %type<Node>     Declaration Type Value Statement
61 %type<Node>     Assignment Conditional Condition Expr
62 %type<Node>     E T F
63
64 %%
65
66 Program          :   Structure{
67                     printf("\nL%-5d - |\n%s", 0, $$->code);
68                     }
69                 ;
70
71 Structure        :   Declarations BGN Statements END{
72                     sprintf($$->code, "%s%10s\n%s", $1->code, "|", $3
->code);
73                     }
74                 ;
75
76 Declarations     :   Declaration Declarations{
77                     $$ = makeNode();
78                     sprintf($$->code, "%s%s", $1->code, $2->code);
79                     }
80
81                 |   Declaration{
82                     $$ = $1;
83                     }
84                 ;
85
86 Declaration      :   VAR ':' Type ';' {
87                     $$ = makeNode();
88                     sprintf($$->code, "%10s %-5s := %s\n", "|", $1, $3
->var);
89                     }
90
91                 |   VAR ':' Type '=' Value ';' {
92                     $$ = makeNode();
93                     sprintf($$->code, "%10s %-5s := %s\n", "|", $1, $5
->var);
94                     }
95                 ;

```

```

96
97 Type      :    INT{
98             $$ = makeNode();
99             $$->intval = 0;
100             sprintf($$->var, "%d", 0);
101             sprintf($$->code, "");
102         }
103
104     |    REAL{
105         $$ = makeNode();
106         $$->floatval = 0.0;
107         sprintf($$->var, "%.2f", 0.0);
108         sprintf($$->code, "");
109     }
110
111     |    CHAR{
112         $$ = makeNode();
113         $$->charval = 0;
114         sprintf($$->var, "%s", "NULL");
115         sprintf($$->code, "");
116     }
117 ;
118
119 Value      :    NUM{
120             $$ = makeNode();
121             $$->intval = $1;
122             sprintf($$->var, "%d", $1);
123             sprintf($$->code, "");
124         }
125
126     |    REAL{
127         $$ = makeNode();
128         $$->floatval = $1;
129         sprintf($$->var, "%.2f", $1);
130         sprintf($$->code, "");
131     }
132
133     |    CHCONST{
134         $$ = makeNode();
135         $$->intval = $1;
136         sprintf($$->var, "%c", $1);
137         sprintf($$->code, "");
138     }
139 ;
140
141 Statements :    Statement Statements{
142             $$ = makeNode();
143             sprintf($$->code, "%s%s", $1->code, $2->code);
144         }
145
146     |    Statement{

```

```

147         $$ = $1;
148     }
149 ;
150
151 Statement      :   Assignment {
152                     $$ = $1;
153                 }
154
155     |   Conditional{
156         $$ = $1;
157     }
158 ;
159
160 Assignment     :   VAR '=' Expr ';' {
161                     $$ = makeNode();
162                     char tac[100];
163                     sprintf($$->var, "%s", $1);
164                     sprintf(tac, "%10s %-5s := %s\n", "|", $$->var, $3
->var);
165
166                     sprintf($$->code, "%s%s", $3->code, tac);
167                 }
168 ;
169 Expr           :   E{
170                     $$ = $1;
171                 }
172 ;
173
174 E             :   T MULOP E{
175                     $$ = makeNode();
176                     char tac[100];
177                     sprintf($$->var, "x%d", ++vars);
178                     sprintf(tac, "%10s %-5s := %s %s %s\n", "|", $$->
var, $1->var, $2, $3->var);
179                     sprintf($$->code, "%s%s%s", $1->code, $3->code,
tac);
180                 }
181
182     |   T{
183         $$ = $1;
184     }
185
186     |   F{
187         $$ = $1;
188     }
189 ;
190
191 T             :   T ADDOP F{
192                     $$ = makeNode();
193                     char tac[100];
194                     sprintf($$->var, "x%d", ++vars);

```

```

195         sprintf(tac, "%10s %-5s := %s %s %s\n", "|", $$->
var, $1->var, $2, $3->var);
196         sprintf($$->code, "%s%s%s", $1->code, $3->code,
tac);
197     }
198
199     |   F{
200         $$ = $1;
201     }
202 ;
203
204 F   :   VAR{
205         $$ = makeNode();
206         sprintf($$->var, "%s", $1);
207         sprintf($$->code, "");
208     }
209
210     |   NUM{
211         $$ = makeNode();
212         $$->intval = $1;
213         sprintf($$->var, "%d", $1);
214         sprintf($$->code, "");
215     }
216
217     |   REAL{
218         $$ = makeNode();
219         $$->floatval = $1;
220         sprintf($$->var, "%.2f", $1);
221         sprintf($$->code, "");
222     }
223
224     |   CHCONST{
225         $$ = makeNode();
226         $$->charval = $1;
227         sprintf($$->var, "'%c'", $1);
228         sprintf($$->code, "");
229     }
230 ;
231
232 Conditional   :   IF '(' Condition ')' THEN Statements ELSE Statements
END IF{
233         $$ = makeNode();
234         int condnBlock = ++labels;
235         int endBlock = ++labels;
236         sprintf($$->code, "%s%10s if %s then goto L%d\n%s
%10s goto L%d\n%10s\nL%-5d - |\n%s%10s\nL%-5d - |\n", $3->code, "|", $3
->var, condnBlock, $8->code, "|", endBlock, "|", condnBlock, $6->code,
"|", endBlock);
237     }
238 ;
239

```

```

240 Condition      :      Expr RELOP Expr{
241                  $$ = makeNode();
242                  char tac[100];
243                  sprintf($$->var, "%s%s%s", $1->var, $2, $3->var);
244                  sprintf($$->code, "%s%s", $1->code, $3->code);
245                  }
246                  ;
247 %%
248
249 int yyerror(char* str){
250     printf("\n%s", str);
251     return 0;
252 }
253
254 int yywrap(){
255     return 1;
256 }
257
258 int main(){
259     printf("\n\t\tIntermediate Code Generation\n");
260     printf("\nYour Code:\n\n");
261     system("cat Code.txt");
262     printf("\n\nThree Address Code:\n");
263
264     yyparse();
265     return 0;
266 }
267
268 /*
269 Usage:
270
271 yacc -d -Wnone TAC.y
272 lex TAC.l
273 gcc y.tab.c lex.yy.c -w
274 ./a.out < Code.txt
275
276 */

```

## Code - Lex Grammar File:

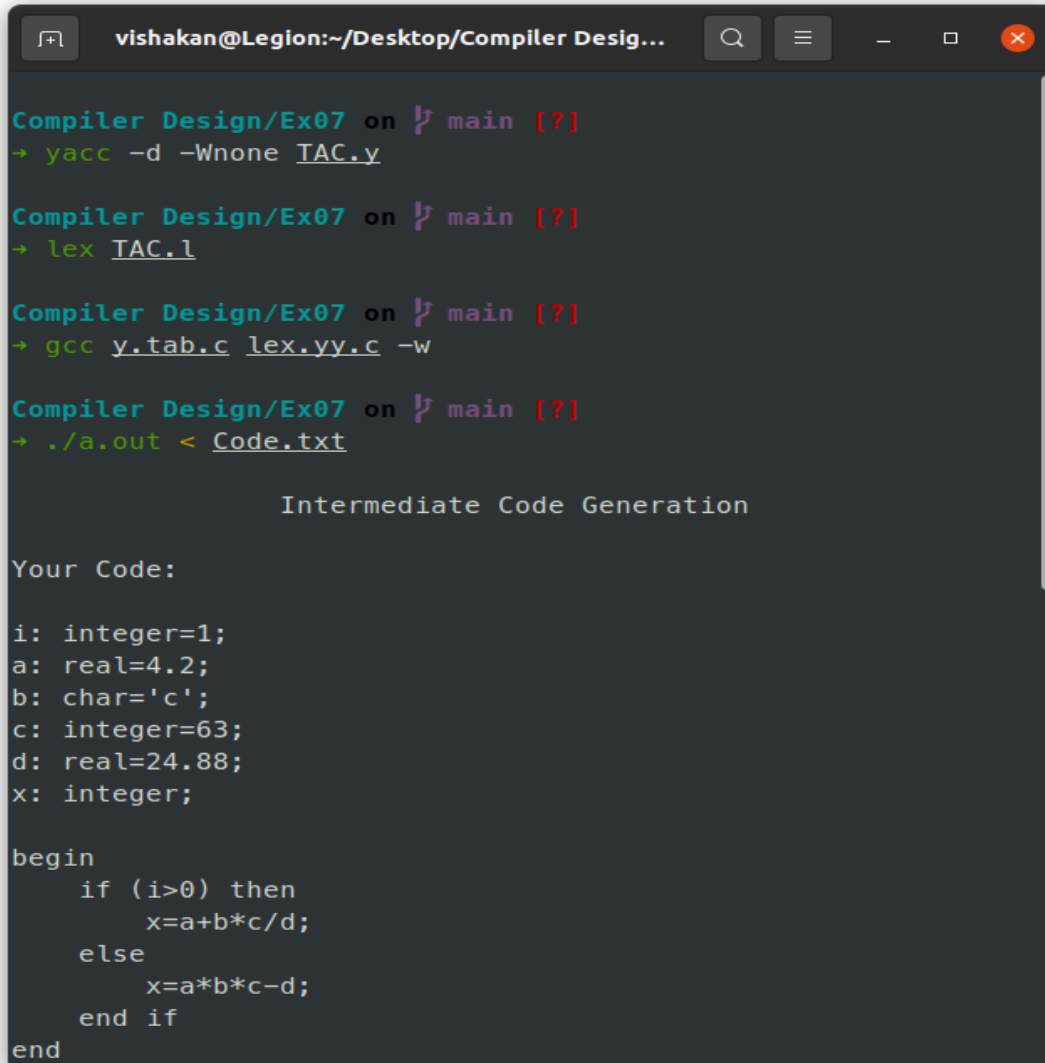
```
1 %{
2     #include <stdio.h>
3     #include <stdlib.h>
4     #include <string.h>
5     #include "y.tab.h"
6 %}
7
8 term      ([a-zA-Z\_][a-zA-Z\_0-9]*)
9 num       ([0-9]+)
10 real      {num}\.{num}
11 relop     ("<" | "<=" | ">" | ">=" | "==" | "!=")
12 addop     ("+" | "-")
13 mulop     ("*" | "/" | "%")
14 spl       (";" | "," | "{" | "}" | "(" | ")" | "=" | "&" | "|" | "!" | ":")
15
16 %%
17 "begin"    {return BGN;}
18 "end"      {return END;}
19 "if"       {return IF;}
20 "then"     {return THEN;}
21 "else"     {return ELSE;}
22 "integer"  {return INT;}
23 "char"     {return CHAR;}
24 "real"     {return REAL;}
25 '['. '[']  {yylval.ch = yytext[1]; return CHCONST;}
26 {term}     {yylval.str = strdup(yytext); return VAR;}
27 {real}     {yylval.floatval = atof(yytext); return REAL;}
28 {num}      {yylval.intval = atoi(yytext); return NUM;}
29 {relop}    {yylval.str = strdup(yytext); return RELOP;}
30 {mulop}    {yylval.str = strdup(yytext); return MULOP;}
31 {addop}    {yylval.str = strdup(yytext); return ADDOP;}
32 {spl}      {return *yytext;}
33 [ \t\n]+   {;}
34
35 .          {char errmsg[100];
36             strcpy(errmsg, "Invalid Character: ");
37             strcat(errmsg, yytext);
38             strcat(errmsg, "\n");
39             yyerror(errmsg);}
40
41 %%
```

## Sample - Parsed Pascal-2021 Code:

```
1 i: integer=1;
2 a: real=4.2;
3 b: char='c';
4 c: integer=63;
5 d: real=24.88;
6 x: integer;
7
8 begin
9     if (i>0) then
10         x=a+b*c/d;
11     else
12         x=a*b*c-d;
13     end if
14 end
```

## Output 1 - Compilation & Code:

Figure 1: Console Output - Compilation & Code.




```
vishakan@Legion:~/Desktop/Compiler Desig...  
Compiler Design/Ex07 on main [?]  
→ yacc -d -Wnone TAC.y  
  
Compiler Design/Ex07 on main [?]  
→ lex TAC.l  
  
Compiler Design/Ex07 on main [?]  
→ gcc y.tab.c lex.yy.c -w  
  
Compiler Design/Ex07 on main [?]  
→ ./a.out < Code.txt  
  
Intermediate Code Generation  
  
Your Code:  
  
i: integer=1;  
a: real=4.2;  
b: char='c';  
c: integer=63;  
d: real=24.88;  
x: integer;  
  
begin  
  if (i>0) then  
    x=a+b*c/d;  
  else  
    x=a*b*c-d;  
  end if  
end
```



## Output 2 - Intermediate Code:

Figure 2: Console Output - Intermediate Code.

A terminal window with a dark background and light text. The window title is "vishakan@Legion:~/Desktop/Compiler Desig...". The output shows a code snippet, followed by the heading "Three Address Code:", and then three labeled blocks of code (L0, L1, L2) separated by vertical lines. At the bottom, it says "Compiler Design/Ex07 on main [?]" with a cursor.

```
x=a*b*c-d;  
end if  
end  
  
Three Address Code:  
  
L0 - |  
    | i      := 1  
    | a      := 4.20  
    | b      := c  
    | c      := 63  
    | d      := 24.88  
    | x      := 0  
    |  
    | if i>0 then goto L1  
    | x4     := c - d  
    | x5     := b * x4  
    | x6     := a * x5  
    | x      := x6  
    | goto L2  
    |  
L1 - |  
    | x1     := a + b  
    | x2     := c / d  
    | x3     := x1 * x2  
    | x      := x3  
    |  
L2 - |  
  
Compiler Design/Ex07 on main [?]  
→
```

## Learning Outcome:

- I learnt more theory behind **Yacc Parser Generator**.
- I understood how to construct a grammar for a basic syntax checker.
- I learnt that grammar can be built upon layer by layer, each one adding more detail and complexity.
- I was able to implement the required token recognition with Lex tool.
- I was able to implement the required intermediate code generator with the Yacc tool and Lex tool.
- I understood the use of the %union declaration for **yyval**'s types for passing different values from Lex to Yacc.
- I declared a custom structure to store intermediate code and variables/values and assigned them values while parsing the respective grammar using the \$\$ operator of Yacc.
- I made use of the **sprintf()** function to create intermediate code conveniently.
- I understood that precedences can only be given to tokens in Yacc, and not for grammar symbols.
- I was able to construct intermediate code for conditional block with appropriate grammar definition.
- I came to know that there was no need to return the structures I created inside the parsing of a lower grammar to pass it up to the higher grammar, as it gets implicitly passed up and can be called with the \$ operator.
- I understood that subtle grammar differences need to be made in the Yacc grammar definition to work for right and left associativity & precedences.
- I learnt to call yyerror() with a custom error message within the Lex code.

# Department of CSE

## SSN College of Engineering

Vishakan Subramanian - 18 5001 196 - Semester VI

29 April 2021

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### UCS 1602 - Compiler Design

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#### Exercise 8: Code Optimization Using C

##### **Aim:**

Implement a program in C to perform code expression for simple code expressions, including simple mathematical identities and strength reduction.

## Code: Optimizer.c:

```
1 #include <stdio.h>
2 #include <string.h>
3 #include <stdlib.h>
4
5 int main(int argc, char *argv[]){
6     stdin = fopen(argv[1], "r");
7     char line[100];
8
9     printf("\n---Parsed Code Starts---\n\n");
10    system("cat Code.txt");
11    printf("\n\n---Parsed Code Ends---\n");
12
13    printf("\n---Optimized Code Starts---\n\n");
14
15    scanf(" %s[^\n]", line);
16
17    while (strcmp(line, "END") != 0){
18
19        //FOR: x=y+0; x=y*1;
20        if ((line[3] == '+' && line[4] == '0') || (line[3] == '*' && line
21[4] == '1')){
22            if (line[0] == line[2]){
23                scanf(" %s[^\n]", line);
24                continue;
25            }
26            printf("%c=%c\n", line[0], line[2]);
27        }
28
29        //FOR: x=y-0; x=y/1;
30        else if ((line[3] == '-' && line[4] == '0') || (line[3] == '/' &&
31line[4] == '1')){
32            if (line[0] == line[2]){
33                scanf(" %s[^\n]", line);
34                continue;
35            }
36            printf("%c=%c\n", line[0], line[2]);
37        }
38
39        //FOR: x=0+x; x=1*y
40        else if ((line[3] == '+' && line[2] == '0') || (line[3] == '*' &&
41line[2] == '1')){
42            if (line[0] == line[4]){
43                scanf(" %s[^\n]", line);
44                continue;
45            }
46            printf("%c=%c\n", line[0], line[4]);
47        }
48    }
```

```

45     }
46
47     //FOR: x=y*2
48     else if (line[3] == '*' && line[4] == '2'){
49         printf("%c=%c+%c\n", line[0], line[2], line[2]);
50     }
51
52     //FOR: x=2*y
53     else if (line[3] == '*' && line[2] == '2'){
54         printf("%c=%c+%c\n", line[0], line[4], line[4]);
55     }
56
57     //FOR: x=pow(y,2);
58     else if (line[2] == 'p' && line[3] == 'o' && line[4] == 'w' &&
line[5] == '(' && line[8] == '2'){
59         printf("%c=%c*%c\n", line[0], line[6], line[6]);
60     }
61
62     else{
63         printf("%s\n", line);
64     }
65
66     scanf(" %s[^\n]", line);    //next line
67 }
68
69 printf("\n---Optimized Code Ends---\n");
70
71 return 0;
72 }

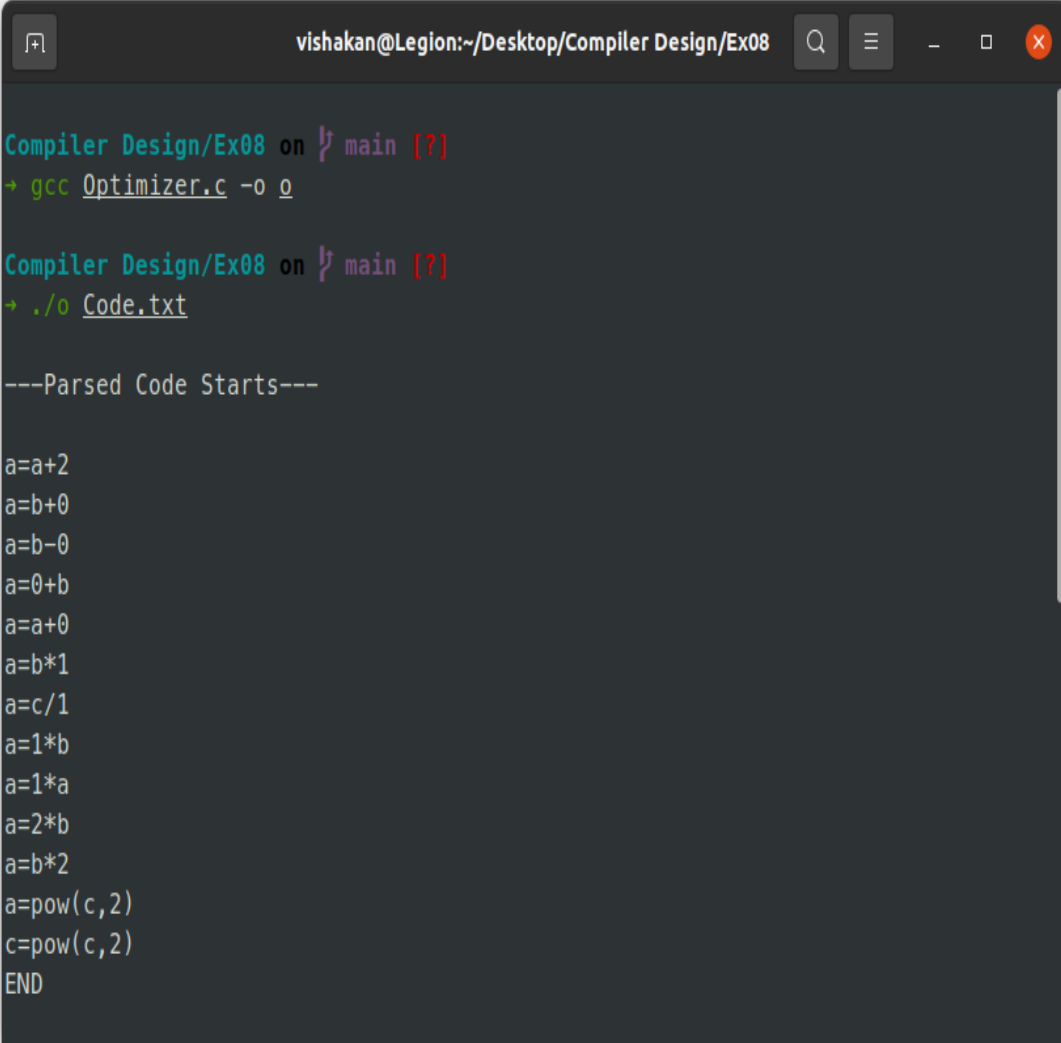
```

## Parsed Code:

```
1 a=a+2
2 a=b+0
3 a=b-0
4 a=0+b
5 a=a+0
6 a=b*1
7 a=c/1
8 a=1*b
9 a=1*a
10 a=2*b
11 a=b*2
12 a=pow(c,2)
13 c=pow(c,2)
14 END
```

## Output: Parsed Code:

Figure 1: Console Output - Parsed Code.



```
vishakan@Legion:~/Desktop/Compiler Design/Ex08

Compiler Design/Ex08 on  main [?]
→ gcc Optimizer.c -o o

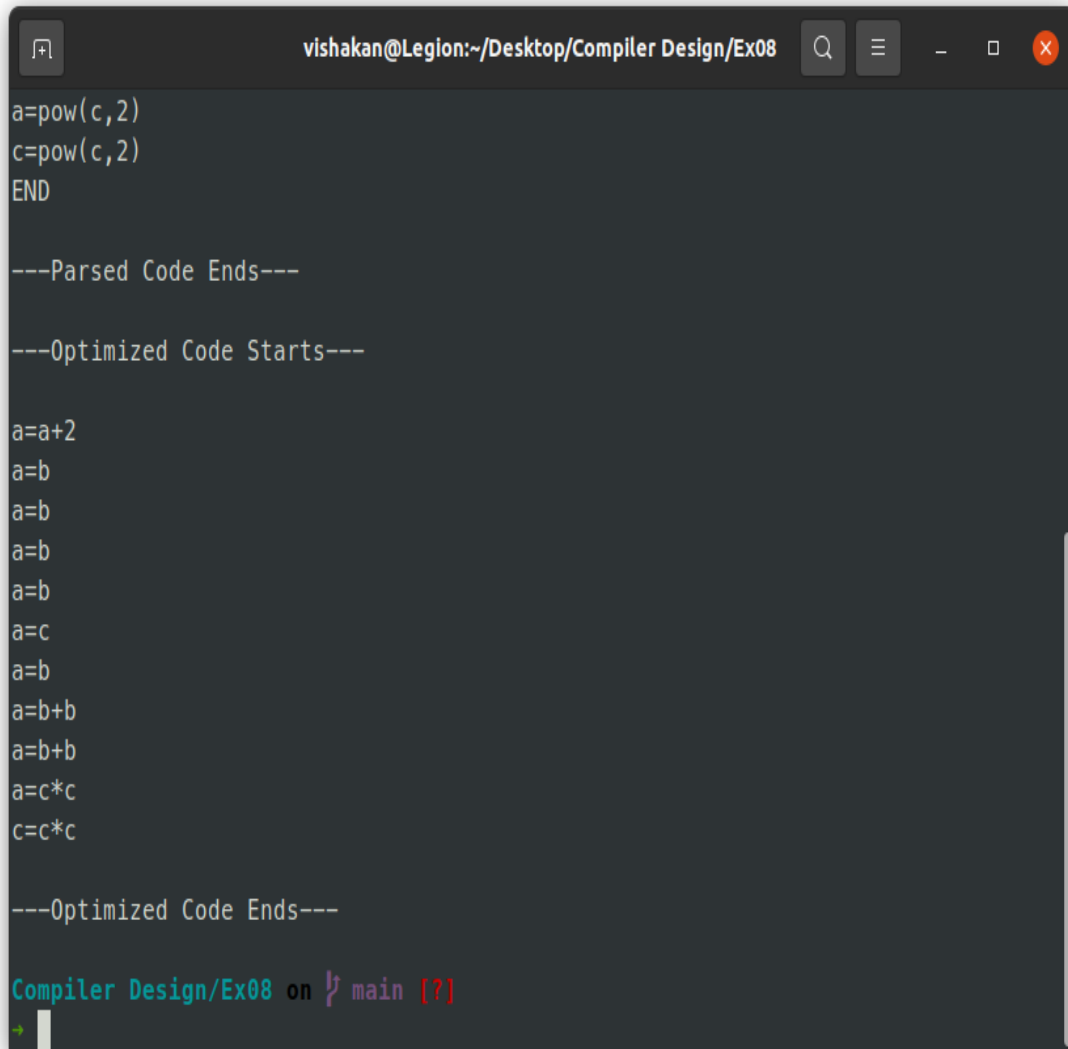
Compiler Design/Ex08 on  main [?]
→ ./o Code.txt

---Parsed Code Starts---

a=a+2
a=b+0
a=b-0
a=0+b
a=a+0
a=b*1
a=c/1
a=1*b
a=1*a
a=2*b
a=b*2
a=pow(c,2)
c=pow(c,2)
END
```

## Output: Optimized Code:

Figure 2: Console Output - Optimized Code.

A terminal window with a dark background and light text. The window title bar shows the user 'vishakan@Legion' and the path '~/Desktop/Compiler Design/Ex08'. The output text is as follows:

```
a=pow(c,2)
c=pow(c,2)
END

---Parsed Code Ends---

---Optimized Code Starts---

a=a+2
a=b
a=b
a=b
a=b
a=c
a=b
a=b+b
a=b+b
a=c*c
c=c*c

---Optimized Code Ends---

Compiler Design/Ex08 on main [?]
```

The terminal window displays the output of a compiler optimization process. It starts with the original code: `a=pow(c,2)`, `c=pow(c,2)`, and `END`. This is followed by a separator `---Parsed Code Ends---`. Then, the optimized code is shown, starting with `---Optimized Code Starts---`. The optimized code consists of a series of assignment and arithmetic operations: `a=a+2`, `a=b` (repeated three times), `a=c`, `a=b`, `a=b+b` (repeated twice), `a=c*c`, and `c=c*c`. This is followed by the separator `---Optimized Code Ends---`. At the bottom, the prompt `Compiler Design/Ex08 on main [?]` is visible with a cursor.



## Learning Outcome:

- I learnt about code optimization.
- I learnt why code optimization is useful in the compilation process.
- I understood the different logical techniques that go behind the implementation of a code optimizer.
- I was able to implement some simple optimization techniques using C.
- I successfully optimized basic code containing redundant operations.
- I successfully optimized code using the strength reduction technique, in which I converted powers of 2 to simple multiplication.
- From the implementation, I was able to visualize different other similar code optimization techniques that I learnt in Compiler Theory and how it proves to be effective in code execution.