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Compiler Design Lab  
Report - 1

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# Introduction

A compiler is a computer program that translates instruction text (source language) into a different language (target language) of instruction text. Typically, the source language is a high-level language, while the target code is machine code. Compilers normally convert into machine code for the machine it compiles in, but special compilers known as cross-compiler.

User writes the program in C and gives it to the compiler. Then the compiler will compile the code i.e. it converts the high-level language to machine level language. That converted code is executed to get the desired output.

## ***Pre-processor:***

A pre-processor is considered as a part of the compiler, it is a tool that produces input for the compilers.

## ***Interpreter:***

An interpreter translates high level language to machine level language. The difference lies in the way they read the source code. A compiler will read the whole source code at once, creates tokens, check for syntax, etc... while the interpreter will read the statement from the input converts it to an intermediate code, executes it and then takes the next statement for execution. If error occurs interpreter will stop execution and reports the error.

## ***Linker:***

Linker is a computer program that links and merges various object files together in order to make the file executable. The major task of a linker is to search and locate referenced module/routines in a program and to determine the memory location where these codes will be loaded.

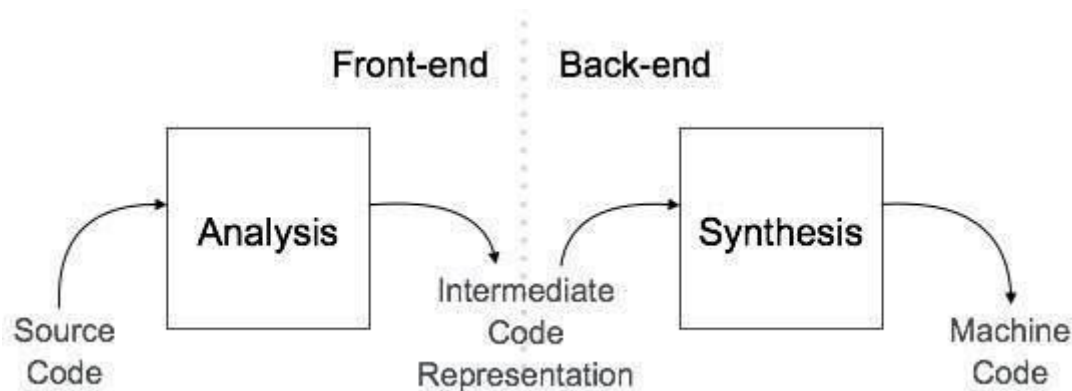
**Loader:**

Loader is a part of operating system and is responsible for loading executable files into memory and execute them. It calculates the size of a program (instructions and data) and creates memory space for it.

**Cross – Compiler:**

A compiler that runs on one platform and the generated code is capable of executed in another platform then it is called cross-compiler.

## Phases Involved in a Compiler



There may be many phases involved in a compiler, however they can be assigned to one of the two stages:

1. **The front end:** In this phase, the compiler verifies syntax and semantics according to the specific source language. In case of errors, warnings and highlighted erroneous code are shown. The input here is the source code and the output is an intermediate representation (IR) for further processing. More specifically, the intermediate outputs are token stream of the source code and sentences of the program.
2. **The back end:** This phase performs further analysis, transformations and optimizations specific to the target CPU architecture. As a result, the target assembly code and register allocation is performed. Further optimization to ensure maximum utilization of the target hardware is done. The input here is the optimized IR and the output is the target code.

**Pass:** A pass refers to the traversal of a compiler through the entire program.

**Phase:** A phase of a compiler is a distinguishable stage, which takes input from the previous stage, processes and yields output that can be used as input for the next stage.

The compilation process is a sequence of various phases. Each phase takes input from its previous stage, has its own representation of source program, and feeds its output to the next phase of the compiler.

In frontend there are four stages they are lexical analyser, syntax analyser, semantic analyser, intermediate code generator, machine independent code optimiser, machine dependent code optimiser.

### ***Lexical Analysis:***

A lexical analyser or scanner performs tokenization on a sequence of characters such as a computer program. Tokenization is a process of converting a sequence of characters into a sequence of tokens. A token is a string assigned with some meaning in a language. Lexical Analysis is the first stage in the front end of a compiler. A scanner also does other tasks, such as removing whitespaces and comments from the source program.

Lexical Analysis can be further divided into two stages - scanning and evaluating. In scanning, the source code is converted into syntactical units called lexemes and categorized into token classes. A lexeme is a sequence of characters that matches a pattern for a token. Types of tokens include identifiers, keywords, separators, operators, comments, etc. In evaluating, the lexemes are converted into processed values. This process is considered simpler when compared to parsing, etc. This can be performed using a lexer generator such as lex. A free implementation of lex found in Unix OS is called flex.

### ***Syntax Analysis***

The next phase is called the syntax analysis or **parsing**. It takes the token produced by lexical analysis as input. For syntax analysis, context-free grammars and the associated parsing techniques are to be used. In this phase, token arrangements are checked against the source code

grammar, i.e. the parser checks if the expression made by the tokens is syntactically correct.

The parse trees are used to show the structure of the sentence. There are many techniques for parsing the algorithms, the main techniques are top-down and bottom-up parsing.

### ***Semantic Analysis***

Semantic analysis checks whether the parse tree constructed follows the rules of language. For example, assignment of values is between compatible data types, and adding string to an integer. Also, the semantic analyser keeps track of identifiers, their types and expressions; whether identifiers are declared before use or not etc. The semantic analyser produces an annotated syntax tree as an output.

### ***Intermediate code generation:***

After semantic analysis the compiler generates an intermediate code of the source code for the target machine. It represents a program for some abstract machine. The code generated in here should be such a way that it would be easier to be translated into target code.

### ***Code optimization:***

In this phase, the code is optimized. It removes the unwanted code lines, and arranges the sequence of statements in order to speed up the execution of the program.

### ***Machine code generation:***

The code generator takes the optimized representation of the intermediate code and then it converts it to target machine language.

### ***Tokens:***

Lexemes are said to be a sequence characters in tokens. There are some rules where every lexeme is identified. These rules are defined by means of a pattern. A pattern explains what can be a token and these are represented by regular expressions.

Keywords, constant, identifiers, numbers, operators and punctuations symbols are possible tokens to be identified.

## **Issues in Lexical Analyser:**

It has two errors. They are lookahead, ambiguities. Lookahead is required to decide when one token will end and the next token will begin. The lexical analysis programs written with lex accept ambiguous specifications and choose the longest match possible at each input point.

## **Lexical errors:**

A character sequences that cannot be scanned into any valid token is a lexical error.

Lexical errors are uncommon, but they still must be handled by scanner.

# Code for Lexical Analyzer:

```
p3.l
1  %{
2  int comm=0;
3  #include<stdio.h>
4  #include<string.h>
5  #include<stdlib.h>
6  int var_cnt=0;
7  void insert(char *yytext,char t,int l);
8  struct Storage
9  {
10     char *name, token[20];
11     int val;
12     int li;
13     struct Storage *next;
14 }*st,*head;
15 int braces=0;
16 int opbrc=0; //open braces ( )
17 int quo=0;
18 int line=1;
19 %}
20
21 D [0-9]
22 L [a-zA-Z]
23 O [-+*/=<>]
24 op "-="|"+="|"*="|"/="|"<<"|">>"|"<="|">="|"=="
25 WS [ \t\n|\\""]
26 E [Ee][-+]?{D}+
27 PUN [.,;]
28 U [_]
29 Qu ["']
30 per [%&]
31 Keyword "break"|"case"|"continue"|"default"|"enum"|"register"|"return"|"sizeof"|"static"|"typedef"|"void"|"volatile"
32 Datatype "char"|"double"|"float"|"int"|"union"|"struct"
33 Loop "do"|"for"|"while"|"goto"
34 Condition "if"|"else"|"switch"
35
36 EDT "auto"|"short"|"long"|"const"|"extern"|"signed"|"unsigned"
37 FS "d"|"f"|"c"|"s"|"ld"|"lf"
38 SB "["|"]"
39 ws2 "\\\"{Qu}
40
41 headerFunc "printf"|"scanf"
42 header "#include<"
43 close ".h>"
44 def "#define"|"# define"
45 String {Qu}{L}{D}|{per}|{WS}|{0}|{ws2})*{Qu}
```

```

44  get "define" , " define
45  String {Qu}{L}{D}{per}{WS}{O}{ws2})*{Qu}
46  IFR ({L}|{U})(L){D}*
47  array {IFR}{SB}{D}*{SB}
48  w1 {D}{L}{D}*
49  %%
50  "\n" line++;
51  "/*" { if(comm==0) comm++; }
52  "**/" if(comm==1){ comm--; } else { printf("Error: Encountered a */ before /*\n"); }
53
54  {header}{L}*{close}                { insert(yytext,'P',line);}
55  {def}                                { insert(yytext,'P',line);}
56
57  {Keyword}                            {if(comm==0) { insert(yytext,'k',line);}}
58  {Datatype}                          {if(comm==0){ insert(yytext,'d',line);}}
59  {Loop}                              {if(comm==0){ insert(yytext,'l',line);}}
60  {Condition}                        {if(comm==0){ insert(yytext,'c',line);}}
61  {EDT}+" "+{EDT}+" "+{Datatype}      {if(comm==0){ insert(yytext,'e',line);}}
62
63  {headerFunc}                        {if(comm==0){ insert(yytext,'h',line);}}
64
65  ({D}+)+"."+{D}*                    {if(comm==0){ insert(yytext,'C',line);}}
66  {D}*                                {if(comm==0){ insert(yytext,'C',line);}}
67  {String}                            {if(comm==0){ insert(yytext,'s',line);}}
68
69
70  {Qu}+{IFR} { {printf(" %s Error Quotes not ended at line %d \n",yytext,line);}}
71  {IFR}+{Qu}+{IFR} { {printf(" %s Error Wrong usage of Quotes at line %d\n",yytext,line);}}
72  {IFR}+{Qu} { {printf(" %s Error Quotes not started at line %d\n",yytext,line);}}
73
74  {w1} { {printf(" %s Wrong language used\n",yytext);}}
75  {IFR}                                {if(comm==0&&quo==0){ insert(yytext,'v',line);}}
76
77  {IFR}+"."+{IFR}                    {if(comm==0){ insert(yytext,'v',line);}}
78  {PUN}                                { if(comm==0) insert(yytext,'p',line);}
79  "{"                                  { braces++; insert(yytext,'p',line);}
80  "\""                                { braces--; insert(yytext,'p',line);}
81  "("                                  { opbrc++; insert(yytext,'p',line);}
82  ")"                                  { opbrc--; insert(yytext,'p',line);}
83  {Qu} {}
84
85  "--"                                {if(comm==0){ insert(yytext,'o',line);}}
86  "++"                                {if(comm==0){ insert(yytext,'o',line);}}
87
88  {per}                                {if(comm==0){ insert(yytext,'o',line);}}
89  {op}                                {if(comm==0){ insert(yytext,'o',line);}}

```



```

89 {op} {if(comm==0){ insert(yytext,'o',line);}}
90 {0} {if(comm==0){ insert(yytext,'o',line);}}
91
92 {WS} {}
93 {SB} {if(comm==0){ insert(yytext,'p',line);} }
94 . { printf(" %s Errors at line %d\n",yytext,line);}
95 %%
96
97 int main()
98 {
99 yyin=fopen("test case 5.txt","r");
100 yyout=fopen("output 5.txt","w");
101 fprintf(yyout,"\n Symbol Table Format is:\n \tLexeme\t\t\t\tToken\t\t\tLine No\t\t\tAttribute Value\n");
102 yylex();
103 if(comm>0) { printf("Comments does not end"); }
104 }
105 int yywrap()
106 {
107 return(1);
108 }
109
110 void insert(char *yytext,char t,int l)
111 {
112 int len1 = strlen(yytext);
113 int i;
114 char token[20];
115 struct Storage *symbol,*temp,*nextptr;
116 nextptr=head;
117 switch(t)
118 {
119 case 'k':
120 case 'd':
121 case 'l':
122 case 'e':
123 case 'c':
124 strcpy(token,"Keyword");
125 break;
126
127 case 'C':
128 strcpy(token,"Constant");
129 break;
130
131 case 's':
132 strcpy(token,"String");
133 break;

```



p3.l



```
132         strcpy(token,"String");
133         break;
134     case 'a':
135     case 'v':
136     case 'I':
137     case 'h':
138         strcpy(token,"Identifier");
139         break;
140
141     case 'u':
142         strcpy(token,"User defined function");
143         break;
144
145     case 'p':
146         strcpy(token,"Punctuator");
147         break;
148
149     case 'o':
150         strcpy(token,"Operator");
151         break;
152
153     case 'P':
154         strcpy(token,"Pre processor");
155         break;
156 }
157
158 for(i=0;i<var_cnt;i++,nextptr=nextptr->next)
159 {
160     symbol = nextptr;
161     if(strcmp(symbol->name,yytext)==0)
162         break;
163 }
164 if(i==var_cnt)
165 {
166     temp = (struct Storage*)malloc(sizeof(struct Storage));
167     temp->name = (char*)malloc((len1+1)*sizeof(char));
168     strcpy(temp->name,yytext);
169     strcpy(temp->token,token);
170     temp->val = i;
171     temp->li = 1;
172     temp->next = NULL;
173     if(var_cnt==0)
174         head = temp;
175     else
176         symbol->next = temp;
```



p3.l



```
158     for (i=0; i<var_cnt; i++, nextptr=nextptr->next)
159     {
160         symbol = nextptr;
161         if(strcmp(symbol->name,yytext)==0)
162             break;
163     }
164     if(i==var_cnt)
165     {
166         temp = (struct Storage*)malloc(sizeof(struct Storage));
167         temp->name = (char*)malloc((len1+1)*sizeof(char));
168         strcpy(temp->name,yytext);
169         strcpy(temp->token,token);
170         temp->val = i;
171         temp->li = l;
172         temp->next = NULL;
173         if(var_cnt==0)
174             head = temp;
175         else
176             symbol->next = temp;
177         var_cnt++;
178     }
179     fprintf(yyout, "\n%20s%30.30s%20d%20d", yytext, token, l, i);
180 }
181
182
183
```

# Outputs:

## Test case 1:

The image shows a Notepad++ window with two files open: 'output 1.txt' and 'test case 1.txt'.

**output 1.txt - Notepad**

Symbol Table Format is:

Lexeme	Token	Line No	Attri
#include<stdio.h>	Pre processor	1	0
#define	Pre processor	2	1
A	Identifier	2	2
5	Constant	2	3
void	Keyword	4	4
main	Identifier	4	5
(	Punctuator	4	6
)	Punctuator	4	7
{	Punctuator	5	8
int	Keyword	7	9
a	Identifier	7	10
,	Punctuator	7	11
b	Identifier	7	12
;	Punctuator	7	13
float	Keyword	8	14
c	Identifier	8	15
,	Punctuator	8	11
d	Identifier	8	16
,	Punctuator	8	11
e	Identifier	8	17
;	Punctuator	8	13
int	Keyword	9	9
f	Identifier	9	18
[	Punctuator	9	19
10	Constant	9	20
]	Punctuator	9	21
;	Punctuator	9	13
a	Identifier	10	10
=	Operator	10	22
5	Constant	10	3
;	Punctuator	10	13
b	Identifier	11	12
=	Operator	11	22
a	Identifier	11	10
;	Punctuator	11	13
a	Identifier	12	10
=	Operator	12	22
a	Identifier	12	10

**test case 1.txt - Notepad**

```
#include<stdio.h>
#define A 5

void main()
{
    /* Normal comments*/
    int a,b;
    float c,d,e;
    int f[10];
    a=5;
    b=a;
    a=a+b;
    c=10.32;
    d=12.33;
    e=c-d;
    printf("%d %f",a,e);
}
```

**Anaconda Prompt**

```
(lex) G:\Coding files\lex>lex p3.1
p3.1:92: warning, rule cannot be matched

(lex) G:\Coding files\lex>lex p3.1

(lex) G:\Coding files\lex>gcc lex.yy.c

(lex) G:\Coding files\lex>a.exe

(lex) G:\Coding files\lex>
```

## Test case 2:

The image shows a Notepad window titled "output 2.txt - Notepad" displaying a symbol table. The table has four columns: Lexeme, Token, Line No, and Attri. The data is as follows:

Lexeme	Token	Line No	Attri
#include<stdio.h>	Pre processor	1	0
void	Keyword	3	1
main	Identifier	3	2
(	Punctuator	3	3
)	Punctuator	3	4
{	Punctuator	4	5
float	Keyword	5	6
a	Identifier	5	7
,	Punctuator	5	8
b	Identifier	5	9
,	Punctuator	5	8
c	Identifier	5	10
,	Punctuator	5	8
e	Identifier	5	11
;	Punctuator	5	12
char	Keyword	6	13
d	Identifier	6	14
[	Punctuator	6	15
10	Constant	6	16
]	Punctuator	6	17
=	Operator	6	18
"Hello"	String	6	19
;	Punctuator	6	12
a	Identifier	7	7
=	Operator	7	18
5.3	Constant	7	20
;	Punctuator	7	12
b	Identifier	8	9
=	Operator	8	18
2.65	Constant	8	21
;	Punctuator	8	12
c	Identifier	9	10
=	Operator	9	18
a	Identifier	9	7
+	Operator	9	22
b	Identifier	9	9
;	Punctuator	9	12
scanf	Identifier	10	23

Overlaid on the right is an Anaconda Prompt window showing the following commands and their outputs:

```
(lex) G:\Coding files\lex>lex p3.1
(lex) G:\Coding files\lex>gcc lex.yy.c
(lex) G:\Coding files\lex>a.exe
(lex) G:\Coding files\lex>
```

## Test case 3:

The screenshot shows a Notepad window titled 'output 3.txt - Notepad' containing a symbol table. The table has four columns: Lexeme, Token, Line No, and Attribute. The lexemes are from a C program, and the tokens are their corresponding lexical categories. The attributes are numerical values assigned to each token.

Lexeme	Token	Line No	Attribute
#include<stdio.h>	Pre processor	1	0
struct	Keyword	3	1
values	Identifier	3	2
{	Punctuator	4	3
int	Keyword	5	4
cd	Identifier	5	5
;	Punctuator	5	6
}	Punctuator	6	7
;	Punctuator	6	6
void	Keyword	8	8
main	Identifier	8	9
(	Punctuator	8	10
)	Punctuator	8	11
{	Punctuator	9	3
long long float	Keyword	10	12
d	Identifier	10	13
,	Punctuator	10	14
c	Identifier	10	15
=	Operator	10	16
0	Constant	10	17
;	Punctuator	10	6
struct	Keyword	11	1
values	Identifier	11	2
v	Identifier	11	18
;	Punctuator	11	6
int	Keyword	12	4
i	Identifier	12	19
=	Operator	12	16
3	Constant	12	20
;	Punctuator	12	6
v.cd	Identifier	13	21
=	Operator	13	16
5	Constant	13	22
;	Punctuator	13	6
scanf	Identifier	14	23
(	Punctuator	14	10
"%llf"	String	14	24
,	Punctuator	14	14

The second Notepad window, titled 'test case 3.txt - Notepad', contains the following C code:

```
#include<stdio.h>

struct values
{
    int cd;
};

void main()
{
    long long float d,c=0;
    struct values v;
    int i=3;
    v.cd=5;
    scanf("%llf",&d);
    while(d--)
    {
        c++;
    }
    while(i--)
    {
        while(d>0)
        {
            d--;
            v.cd++;
        }
    }
    printf("%llf",c);
}
```

An Anaconda Prompt window is visible in the background, showing a series of commands and their outputs:

```
(lex) G:\Coding files\lex>lex p3.1
(lex) G:\Coding files\lex>gcc lex.yy.c
(lex) G:\Coding files\lex>a.exe
(lex) G:\Coding files\lex>gcc lex.yy.c
(lex) G:\Coding files\lex>lex p3.1
(lex) G:\Coding files\lex>gcc lex.yy.c
(lex) G:\Coding files\lex>a.exe
(lex) G:\Coding files\lex>
```

## Test case 4:

output 4.txt - Notepad

File Edit Format View Help

Symbol Table Format is:  
Lexeme Token Line No Attri

#include<stdio.h>	Pre processor	1	0
Void	Identifier	3	1
main	Identifier	3	2
(	Punctuator	3	3
)	Punctuator	3	4
{	Punctuator	4	5
This	Identifier	5	6
is	Identifier	5	7
error	Identifier	5	8
char	Keyword	6	9
a	Identifier	6	10
[	Punctuator	6	11
10	Constant	6	12
]	Punctuator	6	13
=	Operator	6	14
;	Punctuator	6	15
int	Keyword	7	16
;	Punctuator	7	15
printf	Identifier	8	17
(	Punctuator	8	3
)	Punctuator	8	4
;	Punctuator	8	15
printf	Identifier	9	17
(	Punctuator	9	3
"hello /" hi "	String	9	18
)	Punctuator	9	4
;	Punctuator	9	15
}	Punctuator	10	19

test case 4.txt - Notepad

File Edit Format View Help

#include<stdio.h>

Void main()

{

/\*Nested /\* comments. \*/ This is error\*/

char a[10] = "asdas;

int a"b;

printf("hello);

printf("hello /" hi ");

}

Anaconda Prompt

(lex) G:\Coding files\lex>gcc lex.yy.c

(lex) G:\Coding files\lex>a.exe

(lex) G:\Coding files\lex>lex p3.1

(lex) G:\Coding files\lex>gcc lex.yy.c

(lex) G:\Coding files\lex>a.exe

Error: Encountered a \*/ before /\*

"asdas Error Quotes not ended at line 6

a"b Error Wrong usage of Quotes at line 7

"hello Error Quotes not ended at line 8

(lex) G:\Coding files\lex>

## Test Case 5:

output 5.txt - Notepad

File Edit Format View Help

Symbol Table Format is:  
Lexeme Token Line No Attri

#include<stdio.h>	Pre processor	1	0
void	Keyword	3	1
main	Identifier	3	2
(	Punctuator	3	3
)	Punctuator	3	4
{	Punctuator	4	5
int	Keyword	5	6
a	Identifier	5	7
[	Punctuator	5	8
10	Constant	5	9
]	Punctuator	5	10
;	Punctuator	5	11
int	Keyword	6	6
,	Punctuator	6	12
_l	Identifier	6	13
;	Punctuator	6	11
_l	Identifier	7	13
=	Operator	7	14
15	Constant	7	15
;	Punctuator	7	11
=	Operator	8	14
10	Constant	8	9
;	Punctuator	8	11
printf	Identifier	9	16
(	Punctuator	9	3
"%d"	String	9	17
,	Punctuator	9	12
_l	Identifier	9	13
)	Punctuator	9	4
;	Punctuator	9	11
printf	Identifier	10	16
(	Punctuator	10	3
"hsbda \" asd \" sa"	String	10	18
)	Punctuator	10	4
;	Punctuator	10	11
}	Punctuator	11	19
ygvG	Identifier	12	20

test case 5.txt - Notepad

File Edit Format View Help

#include<stdio.h>

void main()

{

int a[10];

int 0b,\_l;

\_l=15;

0b=10;

printf("%d",\_l);

printf("hsbda \" asd \" sa");

}

/\* /\* These comments are wrong \*/ygvG\*/

/\* /\* These are valid comments \*/

Anaconda Prompt

(lex) G:\Coding files\lex>lex p3.1

(lex) G:\Coding files\lex>gcc lex.yy.c

(lex) G:\Coding files\lex>a.exe

0b Wrong language used

0b Wrong language used

Error: Encountered a \*/ before /\*

(lex) G:\Coding files\lex>