SRM INSTITUTION OF SCIENCE AND TECHNOLOGY
KATTANKULATHUR-603203

BONAFIDE CERTIFICATE

Certified that this Course Project Report titled **"DESIGNING A SCANNER FOR C LANGUAGE"** is the bonafide work done by **VADDU SRUJAN REDDY [RA2011026010352] AND SARAPU SETHU MADHAVA [RA2011026010365]** who carried out under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other work.

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DESIGNING A SCANNER FOR C LANGUAGE

Submitted by

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Under the Guidance of

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In partial satisfaction of the requirements for the degree of

BACHELORS OF TECHNOLOGY
in
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with specialization in Artificial Intelligence & Machine Learning

SCHOOL OF COMPUTING

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SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

KATTANKULATHUR - 603203

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Introduction

Compiler

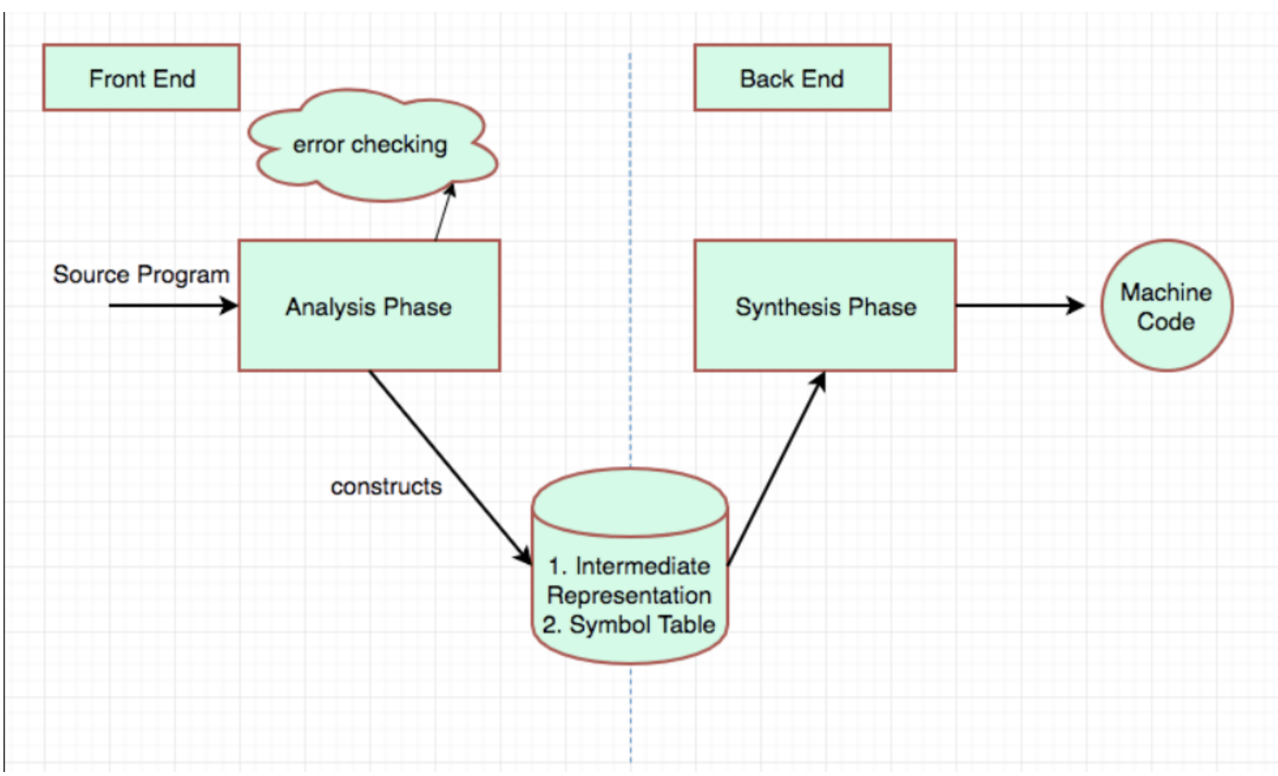
A compiler is a program that can read a program in one language - the source language - and translate it to an equivalent program in another language - the target language. An important role of the compiler is to detect any errors in the source program during the translation process.

Structure of a compiler

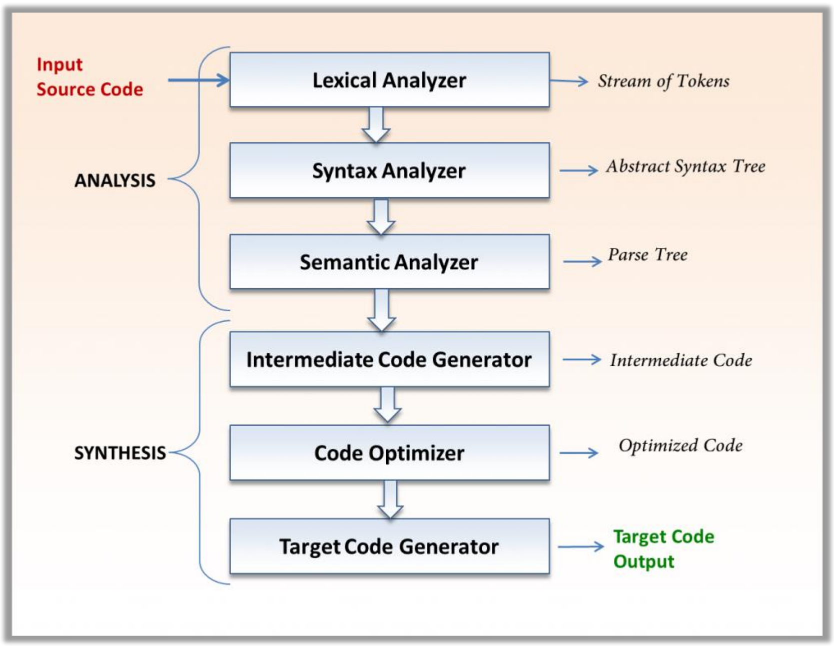
There are two parts involved in the translation of a program in the source language into a semantically equivalent target program: analysis and synthesis.

The analysis part breaks up the source program into constituent pieces and imposes a grammatical structure on them. It then uses this structure to create an intermediate representation of the source program. The analysis part also collects information about the source program and stores it in a data structure called a symbol table, which is passed along with the intermediate representation to the synthesis part.

The synthesis part constructs the desired target program from the intermediate representation and the information in the symbol table. The analysis part is often called the front end of the compiler and the synthesis part is called as the back end.



Phases of compilation



The compilation process operates as a sequence of phases each of which transforms one representation of the source program to another.

- The first phase of a compiler is called **lexical analysis or scanning.** The lexical analyzer reads the stream of characters making up the source program and groups the characters into meaningful sequences called lexemes For each lexeme, the lexical analyzer produces as output a token that it passes on to the subsequent phase, syntax analysis.
- The second phase of the compiler is **syntax analysis or parsing.** The parser uses the tokens produced by the lexical analyzer to create a tree-like intermediate representation that depicts the grammatical structure of the token stream.
- The third phase is the **semantic analysis**. The semantic analyzer uses the syntax tree and the information in the symbol table to check the source program for semantic consistency with the language definition. An important part of semantic analysis is type checking, where the compiler checks that each operator has matching operands.
- After syntax and semantic analysis of the source program, many compilers generate an explicit low-level or machine-like **intermediate code representation**.
- The machine-independent **code-optimization** phase attempts to improve the intermediate code so that better target code will result.
- The last phase is the **code generation**. The code generator takes as input an intermediate representation of the source program and maps it into the target language

Lexical Analysis

As the first phase of a compiler, the main task of the lexical analyzer is to read the input characters of the source program, group them into lexemes, and produce as output a sequence of tokens for each lexeme in the source program.

The lexical analyzer maintains a data structure called as the symbol table. When the lexical analyzer discovers a lexeme constituting an identifier, it enters that lexeme into the symbol table.

The lexical analyzer performs certain other tasks besides identification of lexemes. One such task is stripping out comments and whitespace. Another task is correlating error messages generated by the compiler with the source program

Designing a scanner for C language

We have used Flex to perform lexical analysis on a subset of the C programming language. Flex is a lexical analyzer generator that takes in a set of descriptions of possible tokens and produces a C file that performs lexical analysis and identifies the tokens.
Here we describe the functionality and construction of our scanner.

This document is divided into the following sections:

- **Functionality:** Contains a description of our Flex program and the variety of tokens that it can identify and the error handling strategies.
- **Symbol table and Constants table:** Contains an overview of the architecture of the symbol and constants table which contain descriptions of the lexemes identified during lexical analysis.
- **Code Organisation:** Contains a description of the files used for lexical analysis
- **Source Code:** Contains the source code used for lexical analysis

Functionality

Below is a list containing the different tokens that are identified by our Flex program. It also gives a detailed description of how the different tokens are identified and how errors are detected if any.

Keywords

The keywords identified are: **int, long, short, long long, signed, unsigned, for, break, continue, if, else, return.**

Identifiers

- Identifiers are identified and added to the symbol table. The rule followed is represented by the regular expression **(_|{letter})({letter}|{digit}|_){0,31}**.
- The rule only identifies those lexemes as identifiers which either begin with a letter or an underscore and is followed by either a letter, digit or an underscore with a maximum length of 32.
- The first part of the regular expression **(_|{letter})** ensures that the identifiers begin with an underscore or a letter and the second part**({letter}|{digit}|_){0,31}** matches a combination of letters, digits and underscore and ensures that the maximum length does not exceed 32. The definitions of **{letter}** and **{digit}** can be seen in the code at the end.
- Any identifier that begins with a digit is marked as a lexical error and the same is displayed on the output. The regex used for this is **{digit}+({letter}|_)+**

Comments

Single and multi line comments are identified. Single line comments are identified by **//.*** regular expression. The multiline regex is identified as follows:

- We make use of an exclusive state called **<CMNT>**. When a **/*** pattern is found, we note down the line number and enter the **<CMNT>** exclusive state. When the ***/** is found, we go back to the **INITIAL** state, the default state in Flex, signifying the end of the comment.
- Then we define patterns that are to be matched only when the lexer is in the **<CMNT>** state. Since, it is an exclusive state, only the patterns that are defined for this state (the ones prepended with **<CMNT>** in the lex file are matched, rest of the patterns are inactive.
- We also identify nested comments. If we find another **/*** while still in the **<CMNT>** state, we print an error message saying that nested comments are invalid.
- If the comment does not terminate until **EOF**, and error message is displayed along with the line number where the comment begins. This is implemented by checking if the lexer matches **<<EOF>>** pattern while still in the **<CMNT>** state, which means that a ***/** has not been found until the end of file and therefore the comment has not been terminated.

Strings

The lexer can identify strings in any C program. It can also handle double quotes that are escaped using a **`\`** inside a string. Further, error messages are displayed for unterminated strings. We use the following strategy.

- We first match patterns that are within double quotes.
- But if the string is something like **“This is \” a string”,** it will only match **“This is \”**. So as soon as a match is found we first check if the last double quote is escaped using a backslash.
- If the last quote is not escaped with a backslash we have found the string we are looking for and we add it to the constants table.
- But in case the last double quote is escaped with a backslash we push the last double quote back for scanning. This can be achieved in lex using the command **`yyless(yyleng - 1).`**
- **`yyless(n)`** [1] tells lex to “push back” all but the first n characters of the matched token. **`yyleng`** [1] holds the length of the matched token.
- And hence **`yyless(yyleng -1)`** will push back the last character i.e the double quote back for scanning and lex will continue scanning from **“ is a string”**.
- We use another built-in lex function called **`yymore()`** [1] which tells lex to append the next matched token to the currently matched one.
- Now the lexer continues and matches **“is a string”** and since we had called **`yymore()`** earlier it appends it to the earlier token **“This is ** giving us the entire string **“This is \” a string”**. Notice that since we had called **`yyless(yyleng - 1)`** the last double quote is left out from the first matched token giving us the entire string as required.
- The following lines of code accomplish the above described process.

```
\"[^\"\n]*\"   {

  if(yytext[yyleng-2]=='\\') /* check if it was an escaped quote */
  {
       yyless(yyleng-1);     /* push the quote back if it was escaped */
       yymore();            /* Append next token to this one */
  }
  else{
  insert( constant_table, yytext, STRING);
 }
```

- We use the regular expression **`\"[^\"\n]*$`** to check for strings that don’t terminate. This regular expression checks for a sequence of a double quote followed by zero or more occurrences of characters excluding double quotes and new line and this sequence should not have a close quote. This is specified by the **`$`** character which tests for the end of line. Thus, the regular expression checks for strings that do not terminate till end of line and it prints an error message on the screen.

Integer Constants

- The Flex program can identify two types of numeric constants: decimal and hexadecimal. The regular expressions for these are **`[+-]?{digit}+[lLuU]?`** and **`[+-]?0[xX]{hex}+[lLuU]?`** respectively.
- The sign is considered as optional and a constant without a sign is by default positive. All hexadecimal constants should begin with **`0x`** or **`0X`**.
- The definition of **`{digit}`** is all the decimal digits **`0-9`**. The definition of **`{hex}`** consists of the hexadecimal digits **`0-9`** and characters **`a-f`**.
- Some constants which are assigned to long or unsigned variables may suffix **`l`** or **`L`** and **`u`** or **`U`** or a combination of these characters with the constant. All of these conditions are taken care of by the regular expression.

Preprocessor Directives

The filenames that come after the **`#include`** are selectively identified through the exclusive state **`<PREPROC>`** since the regular expressions for treating the filenames must be kept different from other regexes.

Upon encountering a **`#include`** at the beginning of a line, the lexer switches to the state **`<PREPROC>`** where it can tokenize filenames of the form **`"stdio.h"`** or **`<stdio.h>`**. Filenames of any other format are considered as illegal and an error message regarding the same is printed.

Symbol Table & Constants table

We implement a generic hash table with chaining than can be used to declare both a symbol table and a constant table. Every entry in the hash table is a struct of the following form.

```
/* struct to hold each entry */
struct entry_s
{
    char* lexeme;
    int token_name;
    struct entry_s* successor;
};

typedef struct entry_s entry_t;
```

The struct consists of a character pointer to the lexeme that is matched by the lexer, an integer token that is associated with each type of token as defined in "**tokens.h**" and a pointer to the next node in the case of chaining in the hash table.

A symbol table or a constant table can be created using the **`create_table()`** function. The function returns a pointer to a new created hash table which is basically an array of pointers of the type **`entry_t*`**. This is achieved by the following lines:

```
/* declare pointers and assign hash tables */
entry_t** symbol_table;
entry_t** constant_table;
symbol_table = create_table();
constant_table = create_table();
```

Every time the lexer matches a pattern, the text that matches the pattern (lexeme) is entered into the associated hash table using an **`insert()`** function. There are two hash tables maintained: the symbol table and the constants table. Depending on whether the lexeme is a constant or a symbol, an appropriate parameter is passed to the insert function. For example, **`insert(symbol_table, yytext, INT)`** inserts the keyword **`INT`** into the symbol table and **`insert(constant_table, yytext, HEX_CONSTANT)`** inserts a hexadecimal constant into the constants table. The values associated with **`INT, HEX_CONSTANT`** and other tokens are defined in the tokens.h file.
A hash is generated using the matched pattern string as input. We use the Jenkins hash function[2]. The hash table has a fixed size as defined by the user using **`HASH_TABLE_SIZE`**. The generated hash value is mapped to a value in the range **`[0, HASH_TABLE_SIZE)`** through the operation **`hash_value % HASH_TABLE_SIZE`**. This is the index in the hash table for this particular entry. In case the indices clash, a linked list is created and the multiple clashing entries are chained together at that index.

Code Organisation

The entire code for lexical analysis is broken down into 3 files: lexer.l, tokens.h and symboltable.h

File	Contents
lexer.l	A lex file containing the lex specification of regular expressions
tokens.h	Contains enumerated constants for keywords, operator, special symbols, constants and identifiers.
symboltable.h	Contains the definition of the symbol table and the constants table and also defines functions for inserting into the hash table and displaying its contents.

Source Code

lexer.l

```
%{

#include <stdlib.h>
#include <stdio.h>
#include "symboltable.h"
#include "tokens.h"

entry_t** symbol_table;
entry_t** constant_table;
int cmnt_strt = 0;

%}

letter [a-zA-Z]
digit [0-9]
ws  [ \t\r\f\v]+
identifier (_|{letter})({letter}|{digit}|_){0,31}
hex [0-9a-f]

 /* Exclusive states */
%x CMNT
%x PREPROC

%%
  /* Keywords*/
"int"                                {printf("\t%-30s : %3d\n",yytext,INT);}
"long"                               {printf("\t%-30s : %3d\n",yytext,LONG);}
"long long"                          {printf("\t%-30s : %3d\n",yytext,LONG_LONG);}
"short"                              {printf("\t%-30s : %3d\n",yytext,SHORT);}
"signed"                             {printf("\t%-30s : %3d\n",yytext,SIGNED);}
"unsigned"                           {printf("\t%-30s : %3d\n",yytext,UNSIGNED);}
"for"                                {printf("\t%-30s : %3d\n",yytext,FOR);}
"break"                              {printf("\t%-30s : %3d\n",yytext,BREAK);}
"continue"                           {printf("\t%-30s : %3d\n",yytext,CONTINUE);}
"if"                                 {printf("\t%-30s : %3d\n",yytext,IF);}
"else"                               {printf("\t%-30s : %3d\n",yytext,ELSE);}
"return"                             {printf("\t%-30s : %3d\n",yytext,RETURN);}

{identifier}                         {printf("\t%-30s : %3d\n", yytext,IDENTIFIER);
                                     insert( symbol_table,yytext,IDENTIFIER );}
{ws}                                 ;
```

```
[+\-]?[0][x|X]{hex}+[lLuU]?         {printf("\t%-30s : %3d\n", yytext,HEX_CONSTANT);
                                    insert( constant_table,yytext,HEX_CONSTANT);}

[+\-]?{digit}+[lLuU]?               {printf("\t%-30s : %3d\n", yytext,DEC_CONSTANT);
                                    insert( constant_table,yytext,DEC_CONSTANT);}

"/*"                                {cmnt_strt = yylineno; BEGIN CMNT;}
<CMNT>.|{ws}                        ;
<CMNT>\n                            {yylineno++;}
<CMNT>"*/"                          {BEGIN INITIAL;}
<CMNT>"/*"                          {printf("Line %3d: Nested comments are not
valid!\n",yylineno);}
<CMNT><<EOF>>                       {printf("Line %3d: Unterminated comment\n", cmnt_strt);
yyterminate();}
^"#include"                         {BEGIN PREPROC;}
<PREPROC>"<"[^>\n]+">"              {printf("\t%-30s : %3d\n",yytext,HEADER_FILE);}
<PREPROC>{ws}                       ;
<PREPROC>\"[^"\n]+\"                {printf("\t%-30s : %3d\n",yytext,HEADER_FILE);}
<PREPROC>\n                         {yylineno++; BEGIN INITIAL;}
<PREPROC>.                          {printf("Line %3d: Illegal header file format
\n",yylineno); yyterminate();}
"//".*                              ;

\"[^\"\n]*\"   {

  if(yytext[yyleng-2]=='\\') /* check if it was an escaped quote */
  {
       yyless(yyleng-1);     /* push the quote back if it was escaped */
       yymore();
  }
  else
  insert( constant_table,yytext,STRING);
 }

\"[^\"\n]*$                  {printf("Line %3d: Unterminated string %s\n",yylineno,yytext);}
{digit}+({letter}|_)+        {printf("Line %3d: Illegal identifier name
%s\n",yylineno,yytext);}
\n                           {yylineno++;}
"--"                         {printf("\t%-30s : %3d\n",yytext,DECREMENT);}
"++"                         {printf("\t%-30s : %3d\n",yytext,INCREMENT);}
"->"                         {printf("\t%-30s : %3d\n",yytext,PTR_SELECT);}
"&&"                         {printf("\t%-30s : %3d\n",yytext,LOGICAL_AND);}
"||"                         {printf("\t%-30s : %3d\n",yytext,LOGICAL_OR);}
"<="                         {printf("\t%-30s : %3d\n",yytext,LS_THAN_EQ);}
">="                         {printf("\t%-30s : %3d\n",yytext,GR_THAN_EQ);}
"=="                         {printf("\t%-30s : %3d\n",yytext,EQ);}
"!="                         {printf("\t%-30s : %3d\n",yytext,NOT_EQ);}
";"                         {printf("\t%-30s : %3d\n",yytext,DELIMITER);}
"{"                          {printf("\t%-30s : %3d\n",yytext,OPEN_BRACES);}
"}"                          {printf("\t%-30s : %3d\n",yytext,CLOSE_BRACES);}
","                         {printf("\t%-30s : %3d\n",yytext,COMMA);}
```

```
"="                            {printf("\t%-30s : %3d\n",yytext,ASSIGN);}
"("                            {printf("\t%-30s : %3d\n",yytext,OPEN_PAR);}
")"                            {printf("\t%-30s : %3d\n",yytext,CLOSE_PAR);}
"["                             {printf("\t%-30s : %3d\n",yytext,OPEN_SQ_BRKT);}
"]"                             {printf("\t%-30s : %3d\n",yytext,CLOSE_SQ_BRKT);}
"-"                            {printf("\t%-30s : %3d\n",yytext,MINUS);}
"+"                            {printf("\t%-30s : %3d\n",yytext,PLUS);}
"*"                            {printf("\t%-30s : %3d\n",yytext,STAR);}
"/"                             {printf("\t%-30s : %3d\n",yytext,FW_SLASH);}
"%"                            {printf("\t%-30s : %3d\n",yytext,MODULO);}
"<"                            {printf("\t%-30s : %3d\n",yytext,LS_THAN);}
">"                            {printf("\t%-30s : %3d\n",yytext,GR_THAN);}
.                               {printf("Line %3d: Illegal character %s\n",yylineno,yytext);}

%%

int main()
{
  yyin=fopen("testcases/test-case-4.c","r");
  Symbol_table = create_table();
  Constant_table = create_table();
  yylex();
  printf("\n\tSymbol table\n");
  display(symbol_table);
  printf("\n\n\tConstants Table\n");
  display(constant_table);
}
```

symboltable.h

```
/*
* Compiler Design Project 1 : Lexical Analyser
*
* File          : symboltable.h
* Description : This file contains functions related to a hash organised symbol table.
*               The functions implemented are:
*               create_table(), insert(), search, display()
*
* Authors       : ARYANN , TAPAL JUNAID
* Date          : 17-1-2018
*/
#include <stdint.h>
```

```c
#include <stdlib.h>
#include <stdio.h>
#include <limits.h>
#include <string.h>

#define HASH_TABLE_SIZE 100

/* struct to hold each entry */
struct entry_s
{
    char* lexeme;
    int token_name;
    struct entry_s* successor;
};

typedef struct entry_s entry_t;

/* Create a new hash_table. */
entry_t** create_table()
{
    entry_t** hash_table_ptr = NULL; // declare a pointer

    /* Allocate memory for a hashtable array of size HASH_TABLE_SIZE */
    if( ( hash_table_ptr = malloc( sizeof( entry_t* ) * HASH_TABLE_SIZE ) ) == NULL )
        return NULL;

    int i;

    // Initialise all entries as NULL
       for( i = 0; i < HASH_TABLE_SIZE; i++ )
    {
        hash_table_ptr[i] = NULL;
    }

    return hash_table_ptr;
}

/* Generate hash from a string. Then generate an index in [0, HASH_TABLE_SIZE) */
uint32_t hash( char *lexeme )
{
    size_t i;
    uint32_t hash;

    /* Apply Jenkins hash function
     * https://en.wikipedia.org/wiki/Jenkins_hash_function#one-at-a-time
     */
    for ( hash = i = 0; i < strlen(lexeme); ++i ) {
       hash += lexeme[i];
       hash += ( hash << 10 );
```

```
        hash ^= ( hash >> 6 );
        }
    hash += ( hash << 3 );
    hash ^= ( hash >> 11 );
    hash += ( hash << 15 );

    return hash % HASH_TABLE_SIZE; // return an index in [0, HASH_TABLE_SIZE)
}

/* Create an entry for a lexeme, token pair. This will be called from the insert function */
entry_t *create_entry( char *lexeme, int token_name )
{
    entry_t *newentry;

    /* Allocate space for newentry */
    if( ( newentry = malloc( sizeof( entry_t ) ) ) == NULL ) {
        return NULL;
    }
    /* Copy lexeme to newentry location using strdup (string-duplicate). Return NULL if it
fails */
    if( ( newentry->lexeme = strdup( lexeme ) ) == NULL ) {
        return NULL;
    }

    newentry->token_name = token_name;
    newentry->successor = NULL;

    return newentry;
}

/* Search for an entry given a lexeme. Return a pointer to the entry of the lexeme exists,
else return NULL */
entry_t* search( entry_t** hash_table_ptr, char* lexeme )
{
    uint32_t idx = 0;
    entry_t* myentry;

        // get the index of this lexeme as per the hash function
    idx = hash( lexeme );

    /* Traverse the linked list at this idx and see if lexeme exists */
    myentry = hash_table_ptr[idx];

    while( myentry != NULL && strcmp( lexeme, myentry->lexeme ) != 0 )
    {
        myentry = myentry->successor;
    }

    if(myentry == NULL) // lexeme is not found
```

```
        return NULL;

    else // lexeme found
        return myentry;

}

/* Insert an entry into a hash table. */
void insert( entry_t** hash_table_ptr, char* lexeme, int token_name )
{
    if( search( hash_table_ptr, lexeme ) != NULL) // If lexeme already exists, don't insert,
return
       return;

    uint32_t idx;
    entry_t* newentry = NULL;
    entry_t* head = NULL;

    idx = hash( lexeme ); // Get the index for this lexeme based on the hash function
    newentry = create_entry( lexeme, token_name ); // Create an entry using the <lexeme,
token> pair

    if(newentry == NULL) // In case there was some error while executing create_entry()
    {
        printf("Insert failed. New entry could not be created.");
        exit(1);
    }

    head = hash_table_ptr[idx]; // get the head entry at this index

    if(head == NULL) // This is the first lexeme that matches this hash index
    {
        hash_table_ptr[idx] = newentry;
    }
    else // if not, add this entry to the head
    {
        newentry->successor = hash_table_ptr[idx];
        hash_table_ptr[idx] = newentry;
    }
}

// Traverse the hash table and print all the entries
void display(entry_t** hash_table_ptr)
{
    int i;
    entry_t* traverser;
       printf("\n==========================================\n");
       printf("\t < lexeme , token >\n");
       printf("==========================================\n");
```

```
    for( i=0; i < HASH_TABLE_SIZE; i++)
    {
        traverser = hash_table_ptr[i];

        while( traverser != NULL)
        {
                printf("< %-30s, %3d >\n", traverser->lexeme, traverser->token_name);
                traverser = traverser->successor;
        }
    }
      printf("==========================================\n");
      printf("NOTE: Please refer tokens.h for token meanings\n");
}
```

tokens.h

```
/*
* Compiler Design Project 1 : Lexical Analyser
*
* File          : tokens.h
* Description : This file defines tokens and the values associated to them.
*
* Authors       : ARYANN, JUNAID
* Date          : 27-04-2023
*/

enum keywords
{
  INT=100,
  LONG,
  LONG_LONG,
  SHORT,
  SIGNED,
  UNSIGNED,
  FOR,
  BREAK,
  CONTINUE,
  RETURN,
  CHAR,
  IF,
  ELSE
};
```

```
enum operators
{
  DECREMENT=200,
  INCREMENT,
  PTR_SELECT,
  LOGICAL_AND,
  LOGICAL_OR,
  LS_THAN_EQ,
  GR_THAN_EQ,
  EQ,
  NOT_EQ,
  ASSIGN,
  MINUS,
  PLUS,
  STAR,
  MODULO,
  LS_THAN,
  GR_THAN
};

enum special_symbols
{
  DELIMITER=300,
  OPEN_BRACES,
  CLOSE_BRACES,
  COMMA,
  OPEN_PAR,
  CLOSE_PAR,
  OPEN_SQ_BRKT,
  CLOSE_SQ_BRKT,
  FW_SLASH
};

enum constants
{
  HEX_CONSTANT=400,
  DEC_CONSTANT,
  HEADER_FILE,
  STRING
};

enum IDENTIFIER
{
  IDENTIFIER=500
};
```

Test-cases & Screenshots

```
 /*
ARYANN-18csc304j
JUNAID-18csc304j
Compiler Design Project

 Test Case 1
  - Test for single line comments
  - Test for multi-line comments
  - Test for single line nested comments
  - Test for multiline nested comments

 The output in lex should remove all the comments including this one
 */

 #include<stdio.h>

 void main(){
        // Single line comment

        /* Multi-line comment
        Like this */

        /* here */ int a; /* "int a" should be untouched */

     // This nested comment // This comment should be removed should be removed



     /* To make things /* nested multi-line comment */ interesting */

     return 0;
 }
```

```
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●  ./a.out
        <stdio.h>                       : 402
        void                            : 500
        main                            : 500
        (                               : 304
        )                               : 305
        {                               : 301
        int                             : 100
        a                               : 500
        ;                               : 300
Line  29: Nested comments are not valid!
        interesting                     : 500
        *                               : 212
        /                               : 308
        return                          : 109
        0                               : 401
        ;                               : 300
        }                               : 302

        Symbol table
==========================================
         < lexeme , token >
==========================================
< interesting                      , 500 >
< void                             , 500 >
< a                                , 500 >
< main                             , 500 >
==========================================

        Constants Table
==========================================
         < lexeme , token >
==========================================
< 0                                , 401 >
==========================================
NOTE: Please refer tokens.h for token meanings
```

test-case-1

```
/*

Compiler Design Project 1

Test Case 2
 - Test for multi-line comment that doesn't end till EOF

The output in lex should print as error message when the comment does not terminate
It should remove the comments that terminate
*/

#include<stdio.h>

void main(){

    // This is fine
    /* This as well
    like we know */

    /* This is not fine since
    this comment has to end somewhere

    return 0;
}
```

```
 ~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●  ./a.out
        <stdio.h>                      : 402
        void                           : 500
        main                           : 500
        (                              : 304
        )                              : 305
        {                              : 301
Line  21: Unterminated comment

        Symbol table
==========================================
         < lexeme , token >
==========================================
< void                          , 500 >
< main                          , 500 >
==========================================

        Constants Table
==========================================
         < lexeme , token >
==========================================
==========================================
NOTE: Please refer tokens.h for token meanings
 ~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ● 
```

test-case-2

```
/*
Compiler Design Project 1

Test Case 3
 - Test for string
 - Test for string that doesn't end till EOF
 - Test for invalid header name

The output in lex should identify the first string correct and display error message that
the second one does not terminate
*/

#include<stdio.h>
#include <<stdlib.h>
#include "custom.h"
#include ""wrong.h"

void main(){

    printf("This is a string");
    printf("This is a string that never terminates);
}
```

```
File  Edit  View  Search  Terminal  Help
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ● cc lex.yy.c -ll
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ● ./a.out
        <stdio.h>                      : 402
Line  15: Illegal header file format
        <stdlib.h>                     : 402
        "custom.h"                     : 402
Line  17: Illegal header file format
        "wrong.h"                      : 402
        void                           : 500
        main                           : 500
        (                              : 304
        )                              : 305
        {                              : 301
        printf                         : 500
        (                              : 304
        )                              : 305
        ;                              : 300
        printf                         : 500
        (                              : 304
Line  22: Unterminated string "This is a string that never terminates);

        Symbol table
==========================================
         < lexeme , token >
==========================================
< printf                         , 500 >
< void                           , 500 >
< main                           , 500 >
==========================================

        Constants Table
==========================================
         < lexeme , token >
==========================================
< "This is a string"             , 403 >
==========================================
NOTE: Please refer tokens.h for token meanings
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●
```

test-case-3

```c
/*
Compiler Design Project 1

Test Case 4

Following errors must be detected
 - Invalid identifiers: 9y, total$
 - Invalid operator: @
 - Escaped quoted should be part of the string that is identified
 - Stray characters: `, @, -

The output should display appropriate errors
*/

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

int main()
{
  `
  @ -
  short int b;
  int x, 9y, total$;
  total = x @ y;
  printf ("Total = %d \n \" ", total);
}
```

```
File  Edit  View  Search  Terminal  Help
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ● ./a.out
        <stdio.h>                       : 402
        <stdlib.h>                      : 402
        int                             : 100
        main                            : 500
        (                               : 304
        )                               : 305
        {                               : 301
Line  22: Illegal character `
Line  23: Illegal character @
        -                               : 210
        short                           : 103
        int                             : 100
        b                               : 500
        ;                               : 300
        int                             : 100
        x                               : 500
        ,                               : 303
Line  25: Illegal identifier name 9y
        ,                               : 303
        total                           : 500
Line  25: Illegal character $
        ;                               : 300
        total                           : 500
        =                               : 209
        x                               : 500
Line  26: Illegal character @
        y                               : 500
        ;                               : 300
        printf                          : 500
        (                               : 304
        ,                               : 303
        total                           : 500
        )                               : 305
        ;                               : 300
        }                               : 302

        Symbol table
```

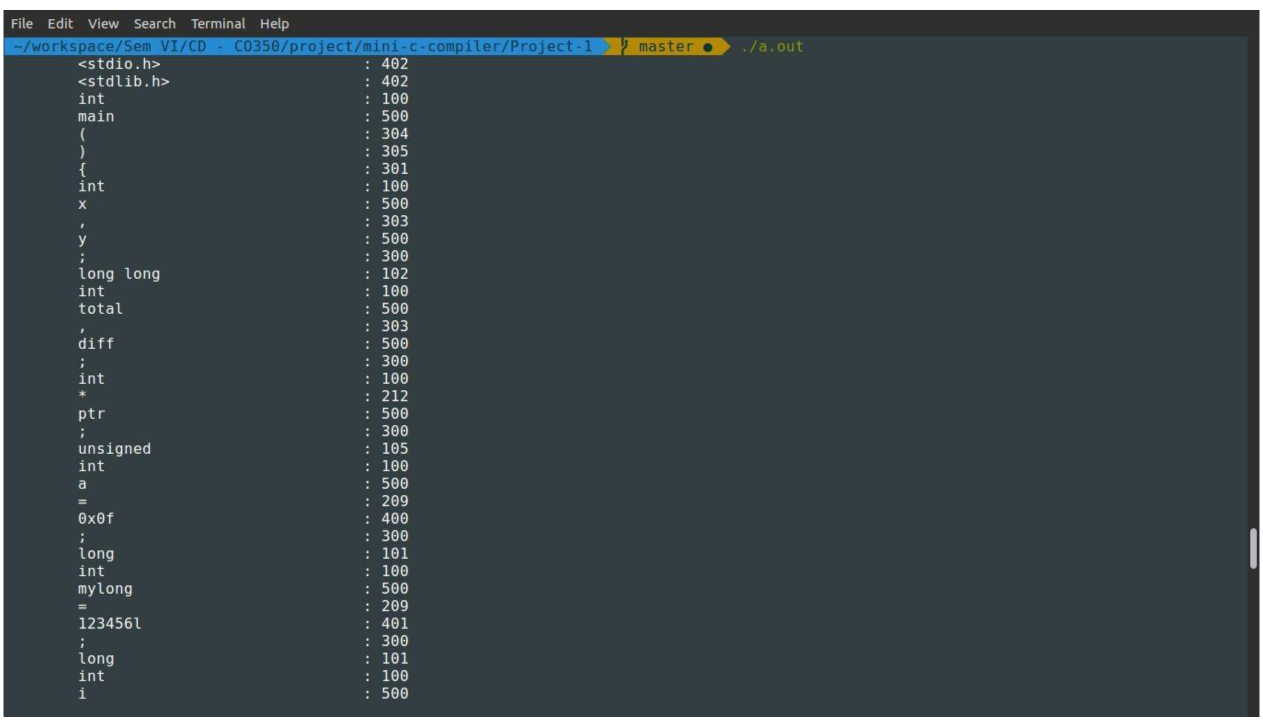
Test-case-4a

```
File  Edit  View  Search  Terminal  Help
        ,                               : 303
        total                           : 500
Line  25: Illegal character $
        ;                               : 300
        total                           : 500
        =                               : 209
        x                               : 500
Line  26: Illegal character @
        y                               : 500
        ;                               : 300
        printf                          : 500
        (                               : 304
        ,                               : 303
        total                           : 500
        )                               : 305
        ;                               : 300
        }                               : 302

        Symbol table
==========================================
         < lexeme , token >
==========================================
< total                        , 500 >
< printf                       , 500 >
< x                            , 500 >
< main                         , 500 >
< b                            , 500 >
< y                            , 500 >
==========================================

        Constants Table
==========================================
         < lexeme , token >
==========================================
< "Total = %d \n \" "          , 403 >
==========================================
NOTE: Please refer tokens.h for token meanings
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●
```

test-case-4b

```
/*
Test Case 5

Identifying tokens and displaying symbol and constants table

Following tokens must be detected
 - Keywords   (int, long int, long long int, main include)
```

```
 - Identifiers (main,total,x,y,printf),
 - Constants  (-10, 20, 0x0f, 123456l)
 - Strings ("Total = %d \n")
 - Special symbols and Brackets ( (), {}, ;, ,)
 - Operators (+,-,=,*,/,%,--,++)

The output should display appropriate tokens with their type and also the symbol and
constants table
*/
#include<stdio.h>
#include<stdlib.h>

int main()
{
  int x, y;
  long long int total, diff;
  int *ptr;
  unsigned int a = 0x0f;
  long int mylong = 123456l;
  long int i, j;
  for(i=0; i < 10; i++){
       for(j=10; j > 0; j--){
       printf("%d",i);
       }
  }
  x = -10, y = 20;
  x=x*3/2;
  total = x + y;
  diff = x - y;
  int rem = x % y;
  printf ("Total = %d \n", total);
}
```



```
File  Edit  View  Search  Terminal  Help
~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●  ./a.out
       <stdio.h>                     : 402
       <stdlib.h>                    : 402
       int                           : 100
       main                          : 500
       (                             : 304
       )                             : 305
       {                             : 301
       int                           : 100
       x                             : 500
       ,                             : 303
       y                             : 500
       ;                             : 300
       long long                     : 102
       int                           : 100
       total                         : 500
       ,                             : 303
       diff                          : 500
       ;                             : 300
       int                           : 100
       *                             : 212
       ptr                           : 500
       ;                             : 300
       unsigned                      : 105
       int                           : 100
       a                             : 500
       =                             : 209
       0x0f                          : 400
       ;                             : 300
       long                          : 101
       int                           : 100
       mylong                        : 500
       =                             : 209
       123456l                       : 401
       ;                             : 300
       long                          : 101
       int                           : 100
       i                             : 500
```

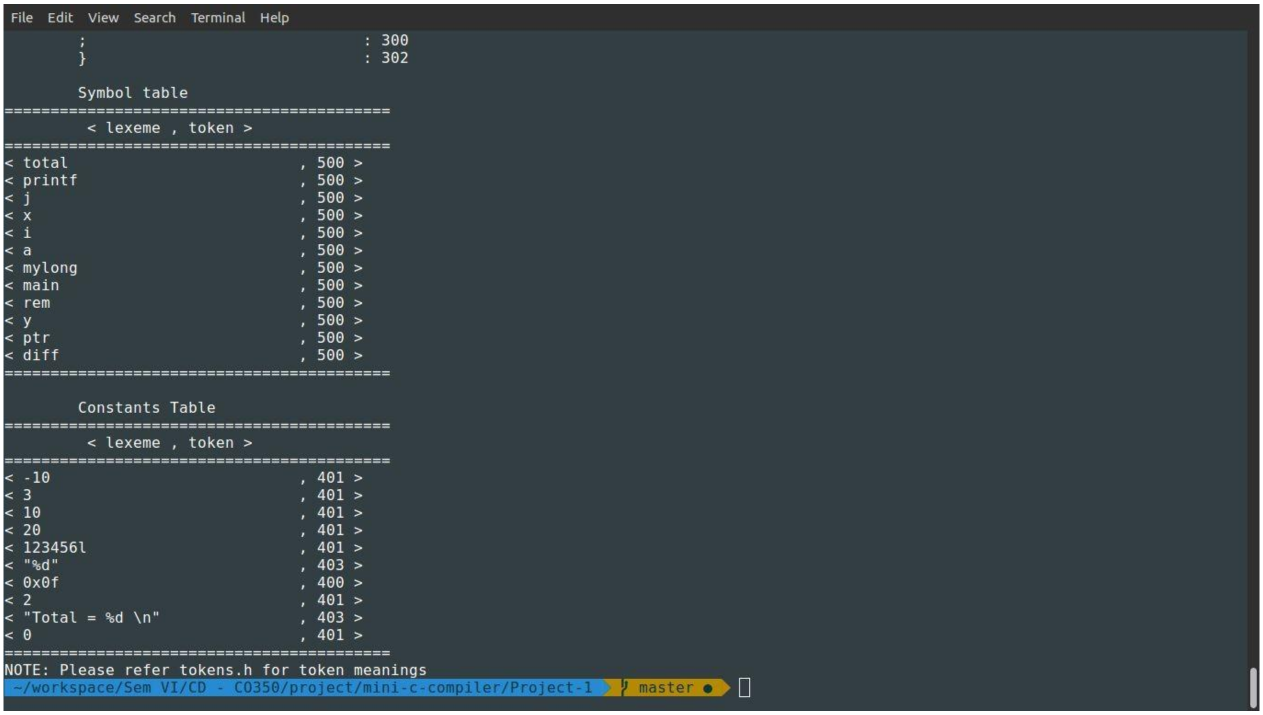
test-case-5a

```
File  Edit  View  Search  Terminal  Help
        int                             : 100
        i                               : 500
        ,                               : 303
        j                               : 500
        ;                               : 300
        for                             : 106
        (                               : 304
        i                               : 500
        =                               : 209
        0                               : 401
        ;                               : 300
        i                               : 500
        <                               : 214
        10                              : 401
        ;                               : 300
        i                               : 500
        ++                              : 201
        )                               : 305
        {                               : 301
        for                             : 106
        (                               : 304
        j                               : 500
        =                               : 209
        10                              : 401
        ;                               : 300
        j                               : 500
        >                               : 215
        0                               : 401
        ;                               : 300
        j                               : 500
        --                              : 200
        )                               : 305
        {                               : 301
        printf                          : 500
        (                               : 304
        ,                               : 303
        i                               : 500
        )                               : 305
```

test-case-5b

```
File  Edit  View  Search  Terminal  Help
        i                               : 500
        )                               : 305
        ;                               : 300
        }                               : 302
        }                               : 302
        x                               : 500
        =                               : 209
        -10                             : 401
        ,                               : 303
        y                               : 500
        =                               : 209
        20                              : 401
        ;                               : 300
        x                               : 500
        =                               : 209
        x                               : 500
        *                               : 212
        3                               : 401
        /                               : 308
        2                               : 401
        ;                               : 300
        total                           : 500
        =                               : 209
        x                               : 500
        +                               : 211
        y                               : 500
        ;                               : 300
        diff                            : 500
        =                               : 209
        x                               : 500
        -                               : 210
        y                               : 500
        ;                               : 300
        int                             : 100
        rem                             : 500
        =                               : 209
        x                               : 500
        %                               : 213
```

test-case-5c



```
File  Edit  View  Search  Terminal  Help
        ;                              : 300
        }                              : 302

        Symbol table
==========================================
         < lexeme , token >
==========================================
< total                         , 500 >
< printf                        , 500 >
< j                             , 500 >
< x                             , 500 >
< i                             , 500 >
< a                             , 500 >
< mylong                        , 500 >
< main                          , 500 >
< rem                           , 500 >
< y                             , 500 >
< ptr                           , 500 >
< diff                          , 500 >
==========================================

        Constants Table
==========================================
         < lexeme , token >
==========================================
< -10                           , 401 >
< 3                             , 401 >
< 10                            , 401 >
< 20                            , 401 >
< 123456l                       , 401 >
< "%d"                          , 403 >
< 0x0f                          , 400 >
< 2                             , 401 >
< "Total = %d \n"               , 403 >
< 0                             , 401 >
==========================================
NOTE: Please refer tokens.h for token meanings
 ~/workspace/Sem VI/CD - CO350/project/mini-c-compiler/Project-1  master ●
```

test-case-5d

What next?

The lexical analyzer that was created in this project helps us to break down a C source file into tokens as per the C language specifications. Each token (such as identifiers, keywords, special symbols, operators, etc.) has an integer value associated with it, as specified in the **tokens.h** file.

When we design the parser in the next phase, the parser will call upon the Flex program to give it tokens and the lexical analyzer will return to the parser the integer value associated with the tokens as and when required by the parser.

Together with the symbol, the parser will prepare a syntax tree with the help of a grammar that we provide it with. The parser can then logically group the tokens to form meaningful statements and can detect C programming constructs such as arrays, loops, and functions. The parser will also help us identify errors that could not be detected in the lexical analysis phase such as unbalanced parentheses, unterminated statements, missing operators, two operators in a row, etc.

References

1. Lex and YACC - 2nd Edition - Levine, Mason Brown.
2. Jenkins Hash Function on Wikipedia :
   https://en.wikipedia.org/wiki/Jenkins_hash_function#one-at-a-time