
# SRM Institute of Science and Technology

## College of Engineering and Technology

## School of Computing

## Department of Computing Technologies

## B.Tech – Computer Science and Engineering

## Regulations 2018

# 18CSC304J – Compiler Design

# LAB MANUAL

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**Department Vision**

- To become a world-class department in imparting high-quality knowledge and providing students with a unique learning and research experience in Computer Science and Engineering.

**Department Mission**

- To impart knowledge in cutting edge technologies in part with industrial standards.
- To collaborate with renowned academic institutions in research and development.
- To instill societal and ethical responsibilities in all professional activities.

## List of Experiments

| S. No. | Topic(s) | CO | PO |
|---|---|---|---|
| 1 | Write a simple calculator program in C/C++/JAVA | 1 | 1 |
| 2 | Write a program using FLEX. | 1 | 2,5 |
| 3 | Implementation of scanner by specifying Regular Expressions. | 1 | 2,5 |
| 4 | Write a program using BISON. | 2 | 2,5 |
| 5 | Write a program for Top-Down Parsing - predictive parsing table (Removal of Left recursion/Left factoring and Compute FIRST & FOLLOW). | 2 | 2 |
| 6 | Write a program for Bottom-Up Parsing - SLR Parsing | 3 | 2 |
| 7 | Introduction to basic Java - Programs in java | 3 | 2 |
| 8 | Write a program to traverse syntax trees and perform action arithmetic operations | 3 | 2 |
| 9 | Write an Intermediate code generation for If/While. | 4 | 3 |
| 10 | Code Generation Introduction to MIPS Assembly language- (Teach SPIM MIPS simulator). | 4 | 3 |
| 11 | Write a program to generate machine code for a simple statement | 5 | 3 |
| 12 | Write a program to generate machine code for an indexed assignment statement | 5 | 3 |

## Ex. 1: Write a simple calculator program in C/C++/JAVA

**Features of the calculator**:

- Take input from standard input.
- On each line an arithmetic expression can be given in the standard format and the calculator
- must print the o/p after that.
- The calculator should exit, when the user enters the Ctrl^D (eof) character.
- Supported operators: +, -, *, /, ^, and ().

**Procedure for simple calculator:**

1. Read a line of input
2. If input is Ctrl^D terminate the program
3. If the expression is not balanced for parenthesis report error and go to step 1
4. Convert the expression into post-fix notation
5. Scan through the post-fix expression and push the operands into the stack in the order they appear
6. When any operator is encountered pop the top two stack elements (operands) and execute the operation
7. Push the result on to the stack
8. Print the result and got to step 1

**Procedure for post-fix conversion**:

1. Scan the expression from left to right
2. If the scanned character is operand place it in postfix expression
3. If the scanned character is an operand

a. If the precedence and associativity of the scanned operator is larger than the one in the stack then push it onto the stack.

b. Else pop all the operators from the stack, which are greater than or equal to in precedence and place it in postfix expression and push the scanned operator into the stack. Popping should be stopped if a parenthesis is encountered.

4. If the scanned character is a '(' push it into the stack
5. If the scanned character is a ')', pop the stack and output it until a '(' is encountered, and discard both the parenthesis.
6. Repeat steps 2-5 until the infix expression is scanned.
7. Once the scanning is over, pop the stack and add the operators in the postfix expression until it is not empty.
8. Return the postfix expression.

**Procedure for Balancing Symbols:**

1. Traverse the expression from left to right.
   a. If the current character is a starting bracket, then push it to stack
   b. If the current character is a closing bracket, then pop from stack and if the poppedcharacter is not matching starting bracket, return “not balanced”.
2. If there is some starting bracket left in stack then return “not balanced”
3. Return balanced

**Example run of the program:**

Input: 2 + 3 * 5
Output: 17
Input 2: (2 + 3) * 5
Output 2: 25
Input 3: 30 / 5 / 2
Output 3: 3
Input 4: 2 ^ 3 ^ 2
Output 4: 64
Input 5: (2 ^ 3) ^ 2
Output 5: 36

## Ex. 2: Write a program Using FLEX

Flex is a scanner generator tool for lexical analysis, which is based on finite state machine (FSM). The input is a set of regular expressions, and the output is the code to implement the scanner according to the input rules.

To implement a scanner for calculator, we can write the file “cal1.l” as below:

```
/* this is only for scanner, not link with parser yet */
%{
int lineNum = 0;
%}
%%
"(" { printf("(\n"); }
")" { printf(")\n"); }
"+" { printf("+\n"); }
"*" { printf("*\n"); }
\n { lineNum++; }
[ \t]+ { }
[0-9]+ { printf("%s\n", yytext); }
%%
int yywrap() {
return 1;
}
int main () {
yylex();
return 0;
}
```

Here is the Makefile used to build the scanner:

```
p1: lex.yy.o
gcc -g -o p1 lex.yy.o
lex.yy.o: cal1.l
flex cal1.l; gcc -g -c lex.yy.c
clean:
rm -f p1 *.o lex.yy.c
```

Simple calculator program in bison

```
//yacc file
#include&lt;stdio.h&gt;
int regs[26];
int base;
%}
```

```
%start list
%union { int a; }

%token DIGIT LETTER
%left &#39;|&#39;
%left &#39;&amp;&#39;
%left &#39;+&#39; &#39;-&#39;
%left &#39;*&#39; &#39;/&#39; &#39;%&#39;
%left UMINUS /*supplies precedence for unary minus */
%% /* beginning of rules section */
list: /*empty */
|
list stat &#39;\n&#39;
|
list error &#39;\n&#39;
{
yyerrok;
}
;
stat: expr
{
printf(&quot;%d\n&quot;,$1);
}
|
LETTER &#39;=&#39; expr
{
regs[$1.a] = $3.a;
};
```

**Ex. 3 : Implementation of scanner by specifying Regular Expressions**

**Procedure:**

1. Place the following files in a folder minijava.html, P1.tab.h, P1.l and a sample input file
(Factorial.java).
2. flex P1.l
3. gcc lex.yy.c -o P1
4. P1
5. Give = if as input
Output: = number (number is symbol table id of =)
if number (number is symbol table id of if)
6. Fill in the code that you have been asked to include in P1.l
7. flex P1.l
8. gcc lex.yy.c -o P1
9. P1 < Factorial.java
10. All tokens generated by the parser will be placed in the output

**The content for minijava.html:**

Goal ::= MainClass ( TypeDeclaration )* <EOF>
MainClass ::= "class" Identifier "{" "public" "static" "void" "main" "(" "String" "[" "]" Identifier ")" "{" PrintStatement "}" "}"
TypeDeclaration ::= ClassDeclaration
| ClassExtendsDeclaration
ClassDeclaration ::= "class" Identifier "{" ( VarDeclaration )* ( MethodDeclaration )* "}"
ClassExtendsDeclaration ::= "class" Identifier "extends" Identifier "{" ( VarDeclaration )*
( MethodDeclaration )* "}"
VarDeclaration ::= Type Identifier ";"
MethodDeclaration ::= "public" Type Identifier "(" ( FormalParameterList )? ")" "{" ( VarDeclaration )*
( Statement )* "return" Expression ";" "}"
FormalParameterList ::= FormalParameter ( FormalParameterRest )*
FormalParameter ::= Type Identifier
FormalParameterRest ::= "," FormalParameter
Type ::= ArrayType
| BooleanType
| IntegerType
| Identifier
ArrayType ::= "int" "[" "]"
BooleanType ::= "boolean"
IntegerType ::= "int"
Statement ::= Block

| AssignmentStatement
| ArrayAssignmentStatement
| IfStatement
| WhileStatement
| PrintStatement
Block ::= "{" ( Statement )* "}"
AssignmentStatement ::= Identifier "=" Expression ";"
ArrayAssignmentStatement ::= Identifier "[" Expression "]" "=" Expression ";"
IfStatement ::= "if" "(" Expression ")" Statement "else" Statement
WhileStatement ::= "while" "(" Expression ")" Statement
PrintStatement ::= "System.out.println" "(" Expression ")" ";"
Expression ::= AndExpression
| CompareExpression
| PlusExpression
| MinusExpression
| TimesExpression
| ArrayLookup
| ArrayLength
| MessageSend
| PrimaryExpression
AndExpression ::= PrimaryExpression "&" PrimaryExpression
CompareExpression ::= PrimaryExpression "<" PrimaryExpression
PlusExpression ::= PrimaryExpression "+" PrimaryExpression
MinusExpression ::= PrimaryExpression "-" PrimaryExpression
TimesExpression ::= PrimaryExpression "*" PrimaryExpression
ArrayLookup ::= PrimaryExpression "[" PrimaryExpression "]"
ArrayLength ::= PrimaryExpression "." "length"
MessageSend ::= PrimaryExpression "." Identifier "(" ( ExpressionList )? ")"
ExpressionList ::= Expression ( ExpressionRest )*
ExpressionRest ::= "," Expression
PrimaryExpression ::= IntegerLiteral
| TrueLiteral
| FalseLiteral
| Identifier
| ThisExpression
| ArrayAllocationExpression
| AllocationExpression
| NotExpression
| BracketExpression
IntegerLiteral ::= <INTEGER_LITERAL>
TrueLiteral ::= "true"
FalseLiteral ::= "false"
Identifier ::= <IDENTIFIER>
ThisExpression ::= "this"

ArrayAllocationExpression ::= "new" "int" "[" Expression "]"
AllocationExpression ::= "new" Identifier "(" ")"
NotExpression ::= "!" Expression
BracketExpression ::= "(" Expression ")"

**The content for P1.tab.h**

/* A Bison parser, made by GNU Bison 2.5. */
/* Bison interface for Yacc-like parsers in C
Copyright (C) 1984, 1989-1990, 2000-2011 Free Software Foundation, Inc.
This program is free software: you can redistribute it and/or modify
it under the terms of the GNU General Public License as published by
the Free Software Foundation, either version 3 of the License, or
(at your option) any later version.
This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
GNU General Public License for more details.
You should have received a copy of the GNU General Public License
along with this program. If not, see <http://www.gnu.org/licenses/>. */
/* As a special exception, you may create a larger work that contains
part or all of the Bison parser skeleton and distribute that work
under terms of your choice, so long as that work isn't itself a
parser generator using the skeleton or a modified version thereof
as a parser skeleton. Alternatively, if you modify or redistribute
the parser skeleton itself, you may (at your option) remove this
special exception, which will cause the skeleton and the resulting
Bison output files to be licensed under the GNU General Public
License without this special exception.
This special exception was added by the Free Software Foundation in
version 2.2 of Bison. */

/* Tokens. */
#ifndef YYTOKENTYPE
# define YYTOKENTYPE
/* Put the tokens into the symbol table, so that GDB and other debuggers
know about them. */
enum yytokentype {
HASHDEFINE = 258,
NOT = 259,
CURLY_OPEN = 260,
CURLY_CLOSE = 261,
PAR_OPEN = 262,
PAR_CLOSE = 263,

```
SQR_CLOSE = 264,
IF = 265,
WHILE = 266,
CLASS = 267,
PUBLIC = 268,
STATIC = 269,
VOID = 270,
MAIN = 271,
STR = 272,
PRINTLN = 273,
EXTENDS = 274,
THIS = 275,
NEW = 276,
SEMI_COLON = 277,
COMMA = 278,
LENGTH = 279,
TRUE = 280,
FALSE = 281,
NUMBER = 282,
RET = 283,
BOOL = 285,
INT = 286,
IDENTIFIER = 287,
ADD = 288,
SUB = 289,
MUL = 290,
DIV = 291,
MOD = 292,
BIT_AND = 293,
LESSTHAN = 294,
SQR_OPEN = 295,
DOT = 296,
ASSIGNMENT = 297,
ELSE = 298,
lab1 = 299,
newlabel = 300,
label = 301
};
#endif
#if ! defined YYSTYPE && ! defined YYSTYPE_IS_DECLARED
typedef union YYSTYPE
{
/* Line 2068 of yacc.c */
#line 25 "P1.y"
```

```
char* str;
/* Line 2068 of yacc.c */
#line 102 "P1.tab.h"
} YYSTYPE;
# define YYSTYPE_IS_TRIVIAL 1
# define yystype YYSTYPE /* obsolescent; will be withdrawn */
# define YYSTYPE_IS_DECLARED 1
#endif
extern YYSTYPE yylval;
```

Template of the lex (P1.l) file with code for one operator and one keyword.

```
%{
#include "P1.tab.h"
#include<stdio.h>
#include<stdlib.h>
%}
%%
/* Write code to ignore empty spaces and newlines. */
/* Write code to ignore comments (single line and multiline). */
/* Write code to scan all the operators, paranthesis etc. Example shown for
assignment. */
"=" {char* str=yytext;printf ("%s %d\n", str, ASSIGNMENT);}
/* Write code to scan all the keywords. Example shown for if */
"if" {char* str=yytext;printf ("%s %d\n", str, IF);}

* Write code to scan all the punctuations. */
/* Write code to scan numbers and identifiers. */
/* Write code to throw error if you encounter any invalid token. */
%%
int main(){
yylex();
}
int yywrap(){}
```

The content for Factorial.java

```
class Factorial{
public static void main(String[] a){
System.out.println(new Fac().ComputeFac((10)));
}
}
class Fac { // Test
public int ComputeFac(int num){
int num_aux ;
if (num < 2)
num_aux = 1 ;
else
```

```
num_aux = num * (this.ComputeFac(num-1)) ;
return num_aux ;
}}
```

## Ex. 4: Write a program using BISON.Simple calculator program in bison

- **Features of the calculator:**
    - the calculator takes input from standard input.
    - As input, on each line an arithmetic expression can be given in the standard format and the calculator must print the o/p after that.
    - The calculator should exit, when the user enters the Ctrl^D (eof) character.
    - Supported operators: +, -, *, /, ^, and ().

**Procedure:**

1. Define Lexical Analysis Rules: Write lexical analysis rules using regular expressions to identify tokens like identifiers, numbers, operators, etc. Use the flex tool to generate the corresponding lexer code.
2. Define Syntax Rules: Write Bison grammar rules specifying the syntax of your language. Bison uses BNF-like notation for specifying grammar rules. These rules define how different parts of the language can be combined to form valid programs.
3. Handle Tokenization: In your Bison grammar file, specify how tokens generated by the lexer should be handled. This involves associating token types with grammar symbols and actions to take when certain combinations of tokens are recognized.
4. Implement Semantic Actions: Define semantic actions associated with grammar rules to specify what should happen when a certain rule is recognized during parsing. Semantic actions typically involve constructing abstract syntax trees (ASTs) or executing code.
5. Error Handling: Implement error handling mechanisms to detect and report syntax errors during parsing. Bison provides facilities for error recovery and reporting.
6. Generate Parser Code: Use the bison tool to generate C code for the parser based on your Bison grammar file.
7. Integrate Lexer and Parser: Integrate the lexer and parser code into a single program. The lexer provides tokens to the parser, which uses the Bison-generated parser code to parse the input according to the grammar rules.
8. Test the Parser: Test the parser with various inputs to ensure that it correctly recognizes valid programs and detects syntax errors in invalid ones.

**Bison program for a calculator:**

1. Lexical tokens are defined using %token.
2. Grammar rules are specified using the syntax lhs: rhs.
3. Semantic actions are written within curly braces {} and can include C code.
4. The %left directive specifies the associativity of operators.
5. The yylex() function is the lexer function that provides tokens to the parser.
6. The yyerror() function handles syntax errors.
7. The main() function calls yyparse() to start the parsing process.

```
//yacc file #include&lt;stdio.h&gt;int regs[26];
	int base;
	%}
	%start list
	%union { int a; }

	%token DIGIT LETTER
	%left &#39;|&#39;
	%left &#39;&amp;&#39;
	%left &#39;+&#39; &#39;-&#39;
	%left &#39;*&#39; &#39;/&#39; &#39;%&#39;
	%left UMINUS /*supplies precedence for unary minus */
	%% /* beginning of rules section */
	list: /*empty */
	|
	list stat &#39;\n&#39;
	|
	list error &#39;\n&#39;
	{
	yyerrok;
	}
	;
	stat: expr
	{
	printf(&quot;%d\n&quot;,$1);
	}
	|
	LETTER &#39;=&#39; expr
	{
	regs[$1.a] = $3.a;
	}
	;

	expr: &#39;(&#39; expr &#39;)&#39;
	{
	$$ = $2;
	}
	|
	expr &#39;*&#39; expr
	{
	$$.a = $1.a * $3.a;
	}
	|
	expr &#39;/&#39; expr
```

```
{
$$.a = $1.a / $3.a;
}
|
expr &#39;%&#39; expr
{
$$.a = $1.a % $3.a;
}
|
expr &#39;+&#39; expr
{
$$.a = $1.a + $3.a;
}
|
expr &#39;-&#39; expr
{
$$.a = $1.a - $3.a;
}
|
expr &#39;&amp;&#39; expr
{
$$.a = $1.a &amp; $3.a;
}
|
expr &#39;|&#39; expr
{
$$.a = $1.a | $3.a;
}
|
&#39;-&#39; expr %prec UMINUS
{
$$.a = -$2.a;
}

|
LETTER
{
$$.a = regs[$1.a];
}
|
number
;
number: DIGIT
{
```

```
$$ = $1;
base = ($1.a==0) ? 8 : 10;
} |
number DIGIT
{
$$.a = base * $1.a + $2.a;
}
;
%%
main()
{
return(yyparse());
}
yyerror(s)
char *s;
{
fprintf(stderr, &amp;quot;%s\n&amp;quot;,s);
}
yywrap()
{
return(1);
}
```

LEX FILE

```
#include &lt;stdio.h&gt;
#include &amp;quot;y.tab.h&amp;quot;
int c;
%}
%%
&amp;quot; &amp;quot; ;
[a-z] {
c = yytext[0];
yylval.a = c - &amp;#39;a&amp;#39;;
return(LETTER);
}
[0-9] {
c = yytext[0];
yylval.a = c - &amp;#39;0&amp;#39;;
return(DIGIT);
}
[^a-z0-9\b]  {
c = yytext[0];
return(c);
```

```
}
%%
```

1) Create the calc.yacc file
2) Create the calc.lex file
3) Run the following commands:

```
yacc -d calc.yacc
lex -d calc.lex
cc y.tab.c lex.yy.c
./a.out
```

**OUTPUT:**

```
5+4
9
```

## Ex. 5. Write a program for Top-Down Parsing - predictive parsing table (Removalof Left recursion/Left factoring and Compute FIRST & FOLLOW)

**Procedure**

Input: Grammar G
Output: Parsing table

**1. Remove left recursion from the grammar G.**

a. For each non-terminal A in G, do the following:

i. If there exists a production A -> Aα | β,
where β is not starting with A, split it into:
A -> βA'
A' -> αA' | ε (epsilon), where ε represents the empty string.

ii. If A -> β1 | β2 | ... | βn are the productions of A after step 1,
remove βi if βi starts with A.

**2. Compute FIRST sets for each non-terminal and terminal symbol in the grammarG.**

a. Initialize FIRST set for each terminal as itself.

b. For each non-terminal A in G, initialize FIRST(A) as an empty set.

c. Repeat until no changes in FIRST sets:

i. For each production A -> α, do the following:

- If α is terminal or ε, add α to FIRST(A).
- If α is non-terminal, add all symbols from FIRST(α) to FIRST(A), except ε.
- If ε is in FIRST(α), continue to the next symbol.

**3. Compute FOLLOW sets for each non-terminal in the grammar G.**

a. Initialize FOLLOW set for the start symbol S as { $ }, where $ is the end marker.

b. Repeat until no changes in FOLLOW sets:

i. For each production A -> αBβ, where B is a non-terminal:

- Add all symbols from FIRST(β) to FOLLOW(B), except ε.
- If β is ε or the symbols in β derive ε, add all symbols from FOLLOW(A) to FOLLOW (B)

**4. Construct the parsing table.**

a. Initialize parsing table M with empty entries.

b. For each production A -> α in G, do the following:

i. For each terminal a in FIRST(α), add A -> α to M[A, a].

- If α derives ε, add A -> α to M[A, b] for each terminal b in FOLLOW(A).

ii. If ε is in FIRST(α), for each terminal b in FOLLOW(A),
add A -> α to M[A, b].

**5. Return the parsing table M.**

**Example:**

**Remove left recursion from the grammar G**

```
public static List<String> removeLeftRecursion(List<String> grammar) {
        List<String> newGrammar = new ArrayList<>();

        // Iterate over each non-terminal in the grammar
        for (String production : grammar) {
            String[] parts = production.split("->");
            String nonTerminal = parts[0].trim();
            String[] alternatives = parts[1].trim().split("\\|");

            List<String> withRecursion = new ArrayList<>();
            List<String> withoutRecursion = new ArrayList<>();

            // Separate productions with and without left recursion
            for (String alt : alternatives) {
                if (alt.trim().startsWith(nonTerminal)) {
                    withRecursion.add(alt.trim().substring(nonTerminal.length()).trim() + "
" + nonTerminal + """);
                } else {
                    withoutRecursion.add(alt.trim() + " " + nonTerminal + """);
                }
            }
```

**Removal of left factoring**

```
public static List<String> leftFactor(List<String> grammar) {
        List<String> newGrammar = new ArrayList<>();

        // Iterate over each non-terminal in the grammar
        for (String production : grammar) {
            String[] parts = production.split("->");
            String nonTerminal = parts[0].trim();
```

```
            String[] alternatives = parts[1].trim().split("\\|");

            // Find the common prefix among alternatives
            String commonPrefix = findCommonPrefix(alternatives);

            // If there is a common prefix, perform left factoring
            if (!commonPrefix.isEmpty()) {
                StringBuilder sb = new StringBuilder();
                sb.append(nonTerminal).append(" -> ").append(commonPrefix).append("
").append(nonTerminal).append("'");
                newGrammar.add(sb.toString());

                StringBuilder sb2 = new StringBuilder();
                for (String alt : alternatives) {
                    if (alt.startsWith(commonPrefix)) {
                        sb2.append(alt.substring(commonPrefix.length()).trim());
                        sb2.append(" | ");
                    }
                }
                sb2.append("ε");
                newGrammar.add(nonTerminal + "' -> " + sb2.toString());
            } else {
                // If no common prefix, keep the production as is
                newGrammar.add(production);
            }
        }

        return newGrammar;
    }
```

**Parse table creation**

```
public class TopDownParser {
    public static void main(String[] args) {
        // Example grammar: S -> A, A -> aA | ε
        Map<String, Set<String>> firstSets = new HashMap<>();
        Map<String, Set<String>> followSets = new HashMap<>();

        // Construct FIRST sets
        firstSets.put("S", new HashSet<>());
        firstSets.put("A", new HashSet<>());

        firstSets.get("S").add("a");
        firstSets.get("A").add("a");
        firstSets.get("A").add("ε");
```

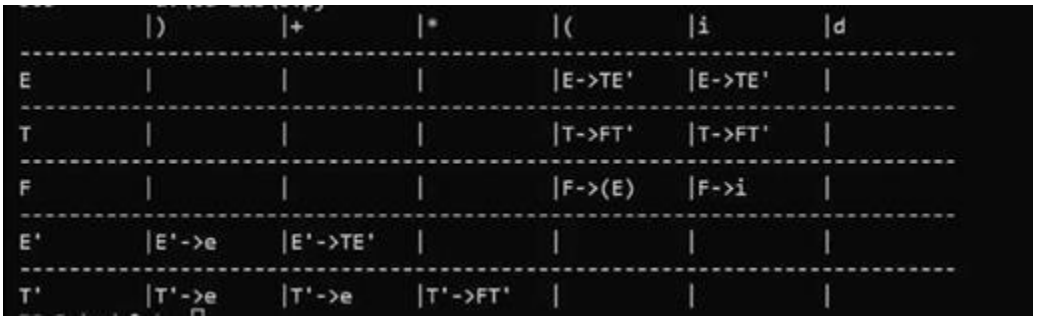
```
        // Construct FOLLOW sets
        followSets.put("S", new HashSet<>());
        followSets.put("A", new HashSet<>());
        followSets.get("S").add("$");

        followSets.get("A").add("$");
        followSets.get("A").add("a");

        // Construct parse table
        Map<String, Map<String, String>> parseTable = new HashMap<>();

        parseTable.put("S", new HashMap<>());
        parseTable.put("A", new HashMap<>());

        parseTable.get("S").put("a", "A");
        parseTable.get("A").put("a", "aA");
        parseTable.get("A").put("$", "ε");

        // Print FIRST sets
        System.out.println("FIRST sets:");
        for (Map.Entry<String, Set<String>> entry : firstSets.entrySet()) {
            System.out.println(entry.getKey() + ": " + entry.getValue());
        }

        // Print FOLLOW sets
        System.out.println("\nFOLLOW sets:");
        for (Map.Entry<String, Set<String>> entry : followSets.entrySet()) {
            System.out.println(entry.getKey() + ": " + entry.getValue());
        }

        // Print parse table
        System.out.println("\nParse Table:");
        for (Map.Entry<String, Map<String, String>> entry : parseTable.entrySet()) {
            String nonTerminal = entry.getKey();
            Map<String, String> actions = entry.getValue();
            System.out.println("Non-Terminal: " + nonTerminal);
            System.out.println("Actions: " + actions);
        }
    }
}
```

**EXPRESSION GRAMMAR**

E->E+T
E->T
T->T*F
T->F
F->( E)
F->id

**OUTPUT**

**PARSE TABLE**



| | ) | + | * | ( | i | d |
|---|---|---|---|---|---|---|
| E | | | | E->TE' | E->TE' | |
| T | | | | T->FT' | T->FT' | |
| F | | | | F->(E) | F->i | |
| E' | E'->e | E'->TE' | | | | |
| T' | T'->e | T'->e | T'->FT' | | | |

## Ex. 6: Write a program for Bottom-Up Parsing - SLR Parsing

**Procedure:**

- SLR is simple LR. It is the smallest class of grammar having few number of states. SLR is very easy to construct and is similar to LR parsing.
- The only difference between SLR parser and LR(0) parser is that in LR(0) parsing table, there's a chance of 'shift reduced' conflict because we are entering 'reduce' corresponding to all terminal states.
- We can solve this problem by entering 'reduce' corresponding to FOLLOW of LHS of production in the terminating state. This is called SLR(1) collection of items

**Steps for constructing the SLR parsing table :**

1. Writing augmented grammar
2. LR(0) collection of items to be found
3. Find FOLLOW of LHS of production
4. Defining 2 functions:goto[list of terminals] and action[list of non-terminals] in the parsing table

**Sample Code**

```
import java.util.*;
class SLRParser {
   private final List<String> grammar;
   private final Map<Integer, Map<String, String>> actionTable;
   private final Map<Integer, Map<String, Integer>> goToTable;
   private final Stack<Integer> stateStack;
   private final Stack<String> symbolStack;
   private final List<String> input;

   public SLRParser(List<String> grammar, Map<Integer, Map<String, String>>
actionTable, Map<Integer, Map<String, Integer>> goToTable, List<String> input)
{
      this.grammar = grammar;
      this.actionTable = actionTable;
      this.goToTable = goToTable;
      this.input =  input;
      this.stateStack = new Stack<>();
      this.symbolStack = new Stack<>();
   }

   public boolean parse() {
      stateStack.push(0);
      int inputIndex = 0;

      while (inputIndex < input.size()) {
         int currentState = stateStack.peek();
```

```
            String currentSymbol = input.get(inputIndex);

            if (actionTable.containsKey(currentState) &&
actionTable.get(currentState).containsKey(currentSymbol)) {
                String action = actionTable.get(currentState).get(currentSymbol);

                if (action.startsWith("s")) {
                    int nextState = Integer.parseInt(action.substring(1));
                    stateStack.push(nextState);
                    symbolStack.push(currentSymbol);
                    inputIndex++;
                } else if (action.startsWith("r")) {
                    int productionIndex = Integer.parseInt(action.substring(1));
                    String production = grammar.get(productionIndex);
                    String[] parts = production.split("->");
                    String leftPart = parts[0].trim();
                    String rightPart = parts[1].trim();
                    int len = rightPart.split(" ").length;
                    for (int i = 0; i < len; i++) {
                        stateStack.pop();
                        symbolStack.pop();
                    }
                    currentState = stateStack.peek();
                    String nonTerminal = leftPart;
                    stateStack.push(goToTable.get(currentState).get(nonTerminal));
                    symbolStack.push(nonTerminal);
                } else if (action.equals("accept")) {
                    return true;
                }
            } else {
                // No valid action in action table, parsing fails
                return false;
            }
        }

        // No more input symbols, parsing fails
        return false;
    }
}

public class Main {
    public static void main(String[] args) {
        // Example grammar
        List<String> grammar = Arrays.asList(
```

```
            "S -> E",
            "E -> E + T",
            "E -> T",
            "T -> id"
        );

        // Example action table
        Map<Integer, Map<String, String>> actionTable = new HashMap<>();
        Map<String, String> action0 = new HashMap<>();
        action0.put("id", "s3");
        actionTable.put(0, action0);
        Map<String, String> action1 = new HashMap<>();
        action1.put("+", "s4");
        actionTable.put(1, action1);
        Map<String, String> action3 = new HashMap<>();
        action3.put("$", "accept");
        actionTable.put(3, action3);
        Map<String, String> action4 = new HashMap<>();
        action4.put("id", "s3");
        actionTable.put(4, action4);
        // Example go-to table
        Map<Integer, Map<String, Integer>> goToTable = new HashMap<>();
        Map<String, Integer> goTo0 = new HashMap<>();
        goTo0.put("E", 1);
        goToTable.put(0, goTo0);
        Map<String, Integer> goTo1 = new HashMap<>();
        goTo1.put("T", 2);
        goToTable.put(1, goTo1);
        // Example input
        List<String> input = Arrays.asList("id", "+", "id", "$");
        SLRParser parser = new SLRParser(grammar, actionTable, goToTable, input);
        boolean result = parser.parse();
        if (result) {
            System.out.println("Input string accepted by grammar.");
        } else {
            System.out.println("Input string rejected by grammar.");
        }
    }
}
```

OUTPUT:

```
Enter input word: id*id

The string is accepted
```

## Ex. 7: Introduction to basic Java - Programs in java

### Introduction to JAVA-

- **JAVA** was developed by James Gosling at **Sun Microsystems** Inc in the year **1995** and later acquired by Oracle Corporation.
- It is a simple programming language. Java makes writing, compiling, and debugging programming easy.
- It helps to create reusable code and modular programs. Java is a class-based, object-oriented programming language and is designed to have as few implementation dependencies as possible.
- A general-purpose programming language made for developers to ***Write Once Run Anywhere*** (WORA) that is compiled Java code can run on all platforms that support Java.
- Java applications are compiled to byte code that can run on any ***Java Virtual Machine***. The syntax of Java is similar to c/c++.
- Java is known for its simplicity, robustness, and security features, making it a popular choice for enterprise-level applications.

### Implementation of a Java application program:

- It involves a following step. They include:
  1. Creating the program
  2. Compiling the program
  3. Running the program
- Remember that, before we begin creating the program, the Java Development Kit (JDK) must be properly installed on our system and also path will be set.

### Simple Java Program

```
public class Main {
  public static void main(String[] args) {
    System.out.println("Hello World");
  }
}
```

### Compiling the program

- Save the code in Notepad as "Main.java". Open Command Prompt (cmd.exe), navigate to the directory where you saved your file, and type "javac Main.java":
- To compile the program, we must run the Java compiler (javac), with the name of the source file on “command prompt” like as follows

  **C:\Users*Your Name*>javac Main.java**

- This will compile your code. If there are no errors in the code, the command prompt will take you to the next line. Now, type "java Main" to run the file:

  **C:\Users*Your Name*>java Main**

- **The output should read:**

  Hello World

**Sample Code**

```
import java.util.Scanner;
public class SimpleJavaProgram {
    public static void main(String[] args) {
        Scanner scanner = new Scanner(System.in);

        // Prompt the user to enter the first number
        System.out.print("Enter the first number: ");
        int num1 = scanner.nextInt();

        // Prompt the user to enter the second number
        System.out.print("Enter the second number: ");
        int num2 = scanner.nextInt();

        // Compute the sum of the two numbers
        int sum = num1 + num2;

        // Display the result
        System.out.println("The sum of " + num1 + " and " + num2 + " is: " + sum);

        // Close the scanner
        scanner.close();
    }
}
```

**Ex. 8: Write a program to traverse syntax trees and perform action arithmetic operations**

**Procedure:**

Input: Syntax tree T representing an arithmetic expression

1. Define a recursive function Traverse(node), where node is a node in the syntax tree:
   a. If node is a leaf node containing a number:
      i. Return the value of the number.
   b. If node is an interior node representing an operator:
      i. Let leftValue = Traverse(leftChild), where leftChild is the left child of node.
      ii. Let rightValue = Traverse(rightChild), where rightChild is the right child of node.
      iii. Perform the arithmetic operation indicated by the operator stored in node, using leftValue and rightValue.
      iv. Return the result of the operation.

2. Call Traverse(root), where root is the root node of the syntax tree.

## Sample Code

```
class TreeNode {
    String value;
    TreeNode left;
    TreeNode right;

    TreeNode(String value) {
        this.value = value;
        this.left = null;
        this.right = null;
    }
}

public class SyntaxTreeTraversal {
    public static int traverseAndCalculate(TreeNode node) {
        if (node == null) {
            return 0;
        }
```

```
        if (node.left == null && node.right == null) {
            return Integer.parseInt(node.value);
        }

        int leftValue = traverseAndCalculate(node.left);
        int rightValue = traverseAndCalculate(node.right);

        switch (node.value) {
            case "+":
                return leftValue + rightValue;
            case "-":
                return leftValue - rightValue;
            case "*":
                return leftValue * rightValue;
            case "/":
                if (rightValue == 0) {
                    throw new ArithmeticException("Division by zero");
                }
                return leftValue / rightValue;
            default:
                throw new IllegalArgumentException("Invalid operator: " + node.value);
        }
    }

    public static void main(String[] args) {
        // Example syntax tree: 3 + (5 * 2)
        TreeNode root = new TreeNode("+");
        root.left = new TreeNode("3");
        root.right = new TreeNode("*");
        root.right.left = new TreeNode("5");
        root.right.right = new TreeNode("2");

        // Perform traversal and calculation
        int result = traverseAndCalculate(root);
        System.out.println("Result: " + result);
    }
}
```

Implemented a method traverse and calculate to recursively traverse the syntax tree and perform arithmetic operations. In the main method, created an example syntax tree representing the expression 3 + (5 * 2), reverse the tree, and print the result.

**Ex. 9: Write an Intermediate code generation for If/While**

**Procedure**

- Create a method takes two strings as input: condition represents the condition of the if statement, and action represents the action to be performed if the condition is true.
- Inside the generate if Code method, a StringBuilder is used to construct the code.
- The condition and action strings are concatenated to form the if statement block.
- Finally, the generated code is returned as a string.

Can customize this code by providing different conditions and actions to generate code for different if statements. Additionally, can extend this algorithm to handle more complex if-else or nested if statements as needed.

## Sample Code

```
import java.util.*;

public class CodeGenerationForIf {
   public static void main(String[] args) {
      // Example input: if (x > 5) { y = x * 2; }
      String condition = "x > 5";
      String action = "y = x * 2;";

      // Generate code for the if statement

      String generatedCode = generateIfCode(condition, action);
      System.out.println("Generated code:");
      System.out.println(generatedCode);
   }

   public static String generateIfCode(String condition, String action) {
      StringBuilder codeBuilder = new StringBuilder();
      // Add the if statement
```

```
        codeBuilder.append("if (").append(condition).append(") {\n");

        // Add the action inside the if block
        codeBuilder.append("\t").append(action).append("\n");
        // Close the if block
        codeBuilder.append("}");
        return codeBuilder.toString();
    }

}
```

**OUTPUT:**

```
Generated code:
if (x > 5) {
    y = x * 2;
}
```

## Ex. 10: Code Generation Introduction to MIPS Assembly language

To learn the basics of MIPS Assembly Language

**Introduction:**

- MIPS (Million Instructions Per Second) is a RISC (Reduced Instruction Set Computer)instruction set architecture developed by MIPS Technologies in the late 1980s.
- It is a loadstore architecture, meaning that data must be loaded into registers before it can be processed. MIPS is known for its simplicity, efficiency, and high performance.
- It has been widely used in embedded systems, networking equipment, andother applications where performance and power consumption are critical.

**Procedure:**

Step 1: get value for register $a0

Step 2: get value for register $a1

Step 3: add values in $a0 and $a1

Step 4: store result in register $v0

Step 5: print value in register $v0

**Sample Code:**

```
.data
num1: .word 10
num2: .word 5
.text
main:
   # load num1 into $a0
   lw $a0, num1
   # load num2 into $a1
   lw $a1, num2
   # add num1 and num2
   add $v0, $a0, $a1
   # print result
   li $v0, 1 # syscall code for print_int
   syscall
   # exit program
   li $v0, 10 # syscall code for exit
syscall
```

**Output:** 15

**How To Run:**

- Open MARS MIPS Simulator.
- Click "File" -> "Open" and select your MIPS assembly file.
- Click "Assemble" to assemble the file.
- Click "Run" to execute the program.

## Ex. 11: Write a program to generate machine code for a simple statement

To implement a java program to convert an assembly language statement to machine

**Procedure**

- Create a byte array to store the machine code
- Set the opcode for the MIPS instruction in the byte array
- Set the source register for the first operand in the byte array
- Set the source register for the second operand in the byte array
- Set the destination register in the byte array
- Set the function code for the MIPS instruction in the byte array
- Write the machine code to a file

**Sample Code**:

```
import java.io.FileOutputStream;
import java.io.IOException;
public class GenerateMachineCode {
   public static void main(String[] args) throws IOException {
      // Create a byte array to store the machine code
      byte[] machineCode = new byte[4];
      // Set the opcode for the MIPS instruction in the byte array
      machineCode[0] = (byte) 0x0;
      // Set the source register for the first operand in the byte array
      machineCode[1] = (byte) 0x0;
      // Set the source register for the second operand in the byte array
      machineCode[2] = (byte) 0x80;
      // Set the destination register in the byte array
      machineCode[3] = (byte) 0x21;
      // Write the machine code to a file
      try (FileOutputStream fos = new FileOutputStream("machine_code.bin")){
         fos.write(machineCode);
      }
catch (IOException e) {
         e.printStackTrace();
      }
   }
}
```

**Explanation:**

The machine code instructions for MIPS are 32 bits long. Each instruction is divided into fields, which specify the opcode, source registers, destination register, and function code.

- The opcode for the add instruction is 000000. This is stored in the first byte of the machine code instruction, which is machineCode[0].
- The source registers for the add instruction are $a0 and $a1. These are stored in the second and third bytes of the machine code instruction, which are machineCode[1] and machineCode[2].
- The destination register for the add instruction is $v0. This is stored in the fourth byte of themachine code instruction, which is machineCode[3].
- The function code for the add instruction is 000001. This is also stored in the fourth byte of the machine code instruction, which is machineCode[3].
- Therefore, the machine code instruction 00000000000000010000001 translates to the MIPS assembly instruction add $v0, $a0, $a1.

Here is a breakdown of the machine code instruction:

**000000: Opcode for the add instruction**
**00000: Source register for the first operand ($a0)**
**00001: Source register for the second operand ($a1)**
**10000: Destination register ($v0)**
**000001: Function code for the add instruction**
Assembly Statement: add $v0, $a0, $a1
Machine Statement: 00000000000000000000000010000001

**How to run:**

javac GenerateMachineCode.java
java GenerateMachineCode

**Ex. 12: Write a program to generate machine code for an indexed assignment statement**

**Procedure:**

Step 1: create a byte array to store the machine code

Step 2: set the opcode for the MIPS instruction in the byte array

Step 3: set the source register in the byte array

Step 4: set the base register in the byte array

Step 5: set the offset in the byte array

Step 6: write the machine code to a file

**Sample Code:**

```
import java.io.FileOutputStream;
import java.io.IOException;
public class GenerateMachineCodeIndexedAssignment {
   public static void main(String[] args) throws IOException {
      // Create a byte array to store the machine code
      byte[] machineCode = new byte[6];
      // Set the opcode for the MIPS instruction in the byte array
      machineCode[0] = (byte) 0x2b;
      // Set the source register in the byte array
      machineCode[1] = (byte) 0x04;
      // Set the base register in the byte array
      machineCode[2] = (byte) 0x00;
      // Set the offset in the byte array
      machineCode[3] = (byte) 0x00;
      machineCode[4] = (byte) 0x00;
      machineCode[5] = (byte) 0x18;
      // Write the machine code to a file
      try (FileOutputStream fos = new FileOutputStream("machine_code.bin")) {
         fos.write(machineCode);
      } catch (IOException e) {
         e.printStackTrace();
      }
   }
}
```

**Explanation:**

The first 6 bits (101011) are the opcode for the sw instruction.
The next 5 bits (00000) are the source register ($v0).
The next 5 bits (01000) are the base register ($a0).
The next 16 bits (0000000000000100) are the offset (4).
Assembly Statement: sw $v0, 4($a0)
Machine Statement: 10101101000001000000000000011000