Instruction Hours / week: L: 4 T: 0 P: 0   **Marks:** Int : **40** Ext : **60**   Total: **100**

SCOPE

This course enables for good understanding of the role of system programming and the scope of duties and tasks of a system programmer. This course enables to learn the concepts and principles of developing system-level software (e.g., compiler, and networking software)

OBJECTIVES

- To introduce students the concepts and principles of system programming
- To provide students the knowledge about both theoretical and practical aspects of system programming, teaching them the methods and techniques for designing and implementing system-level programs.
- To train students in developing skills for writing system software with the aid of sophisticated OS services, programming languages and utility tools.

UNIT-I

Assemblers & Loaders, Linkers: One pass and two pass assembler design of an assembler, Absolute loader, relocation and linking concepts, relocating loader and Dynamic Linking., overview of compilation, Phases of a compiler.

UNIT-II

Lexical Analysis:

Role of a Lexical analyzer, Specification and recognition of tokens, Symbol table, lexical

UNIT-III

Parsing:

Bottom up parsing- LR parser, yaITU. **Intermediate representations: Three** address code generation, syntax directed translation, translation of types, control Statements.

UNIT-IV

Storage organization: Activation records stack allocation.

UNIT-V

Code Generation: Object code generation

Suggested Readings
1. Santanu Chattopadhyaya. (2011). Systems Programming. New Delhi: PHI.
2. Alfred, V. Aho., Monica, S. Lam., Ravi Sethi.,& Jeffrey, D. Ullman. (2006). Compilers: Principles, Techniques, and Tools (2nd ed.). New Delhi: Prentice Hall.
3. Dhamdhere, D. M. (2011). Systems Programming. New Delhi: Tata McGraw Hill.

4. Leland Beck., & Manjula, D. (2008). System Software: An Introduction to System Programming (3rd ed.). New Delhi: Pearson Education.

Grune, D., Van Reeuwijk, K., Bal, H. E., Jacobs, C. J. H., & Langendoen, K.(2012). Modern Compiler Design (2nd ed.). Springer.

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)

(Established Under Section 3 of UGC Act 1956)

COIMBATORE – 641 021.

LECTURE PLAN
DEPARTMENT OF COMPUTER SCIENCE

STAFF NAME: Dr. B.Firdaus Begam

SUBJECT NAME: **SYSTEM PROGRAMMING**   SUB.CODE: **16ITU603B**

SEMESTER: VI   CLASS: III B. Sc -IT

Sl.No	Lecture Duration (Periods)	Topics to be covered	Support Materials
UNIT- I			
1	1	**Assemblers & Loaders, Linkers:** One pass and two pass assembler design of an assembler	T2: 71-118
2	1	Absolute loader	T2:161-162
3	1	relocation and linking concepts	T2 : 162-169
4	1	relocating loader and Dynamic Linking	T2:170-183
5	1	overview of compilation	T2: 183-185
6	1	Phases of a compiler	T2: 185-192
7	1	Recapitulation and Discussion of Possible Questions	
		Total No. Of Hours Planned for unit I	**07**
Sl.No	Lecture Duration (Periods)	Topics to be covered	Support Materials
UNIT- II			
1	1	Role of a Lexical analyzer	T1: 109-113

2	1	Contd... Role of a Lexical analyzer	T1: 116-135
3	1	Contd… Specification and recognition of tokens	T1: 116-135
4	1	Contd…Specification and recognition of tokens	T1: 116-135
5	1	Contd…Specification and recognition of tokens	T1: 116-135
6	1	Symbol table	T1: 85-99
7	1	Contd…Symbol table	T1: 85-99
8	1	Contd…Symbol table	T1: 85-99
9	1	Recapitulation and Discussion of Possible Questions	
		Total No. Of Hours Planned for unit II:	**09**
Sl.No	**Lecture Duration (Periods)**	**Topics to be covered**	**Support Materials**
		UNIT- III	
1	1	Bottom up parsing- LR parser	T1: 233-253
2	1	yaCSU	W1
3	1	Intermediate representations: Three address code generation	T1: 363-369
4	1	syntax directed translation	T1: 303-306
5	1	translation of types	T1: 370-378
6	1	control Statements.	T1: 399-408
7	1	Recapitulation and Discussion of Possible Questions	
8	1	Recapitulation and Discussion of Possible Questions	
		Total No. Of Hours Planned for unit III:	**08**
Sl.No	**Lecture Duration (Periods)**	**Topics to be covered**	**Support Materials**
		UNIT- IV	

1	1	**Storage organization**	T2: 435-459
2	1	Contd… **Storage organization**	T2: 435-459
3	1	Contd… **Storage organization**	T2: 435-459
4	1	Contd…Activation records stack allocation	T2: 463-481
5	1	Contd…Activation records stack allocation	T2: 463-481
6	1	Contd…Activation records stack allocation	T2: 463-481
7	1	Recapitulation and Discussion of Possible Questions	
8	1	Recapitulation and Discussion of Possible Questions	
		Total No. Of Hours Planned for unit IV:	**08**

Sl.No	Lecture Duration (Periods)	Topics to be covered	Support Materials
		UNIT- V	
1	1	**Code Generation**	T1:505-520,W2
2	1	**Contd… Code Generation**	T1:505-520,W2
3	1	Object code generation	T1:520-530
4	1	**Contd…** Object code generation	T1:520-530
5	1	Recapitulation and Discussion of Possible Questions	
6	1	Recapitulation and Discussion of Possible Questions	
7	1	Discussion of Previous ESE Question Paper	
8	1	Discussion of Previous ESE Question Paper	
		Total No. Of Hours Planned for unit V:	**08**
		Overall Planned Hours　　:　　40	

SUGGESTED READINGS

T1 - Alfred, V. Aho., Monica, S. Lam., Ravi Sethi.,& Jeffrey, D. Ullman. (2006). Compilers: Principles, Techniques, and Tools (2nd ed.). New Delhi: Prentice Hall.

T2- Dhamdhere, D. M.,(2011). Systems Programming, Tata McGraw Hill.

<u>**WEBSITES**</u>

W1 -cs.lmv.edu\~ray\notes\sysprog

W2 – www.tutorialspoint.com

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established under section 3 of UGC Act,1956

CLASS : II B.SC IT	COURSE NAME: System Programming
COURSE CODE: 16ITU603B	BATCH: 2016-2019
UNIT I: ASSEMBLERS, LOADERS AND LINKERS	

UNIT I

SYLLABUS

Assemblers & Loaders, Linkers: One pass and two pass assembler design of an assembler, Absolute loader, relocation and linking concepts, relocating loader and Dynamic Linking., overview of compilation, Phases of a compiler.

Assemblers & Loaders, Linkers:

Assembly language is a low-level programming language for a computer or other programmable device specific to particular computer architecture in contrast to most high-level programming languages, which are generally portable across multiple systems. Assembly language is converted into executable machine code by a utility program referred to as an assembler like NASM, MASM, etc.

Linker and Loader are the utility programs that plays a major role in the execution of a program. The Source code of a program passes through compiler, assembler, linker, loader in the respective order, before execution. On the one hand, where the **linker** intakes the object codes generated by the assembler and combine them to generate the executable module. On the other hands, the **loader** loads this executable module to the main memory for execution.

Linker

- Tool that merges the object files produced by *separate compilation* or assembly and creates an executable file

- Three tasks
  - Searches the program to find library routines used by program, e.g. printf(), math routines,…
  - Determines the memory locations that code from each module will occupy and relocates its instructions by adjusting absolute references
  - Resolves references among files

Translation Hierarchy

- Compiler
  - Translates high-level language program into assembly language (CS 440)
- Assembler
  - Converts assembly language programs into *object* files
    - Object files contain a combination of machine instructions, data, and information needed to place instructions properly in memory
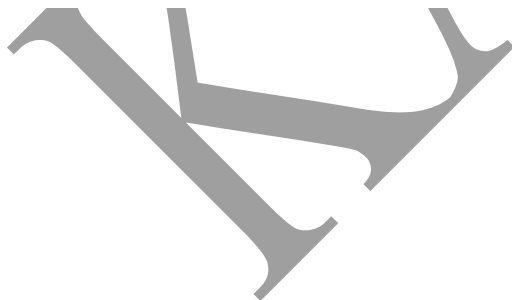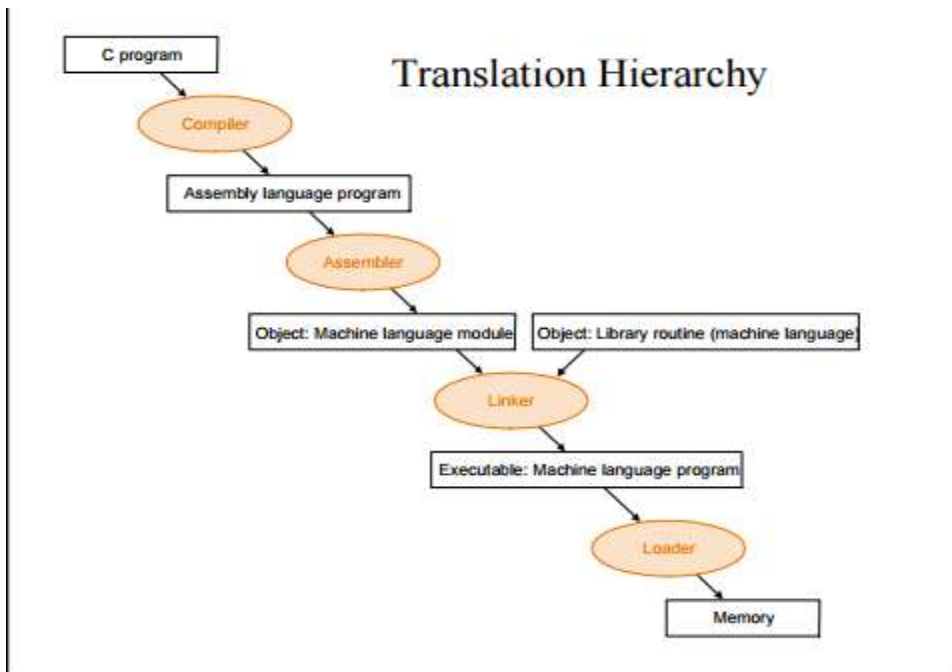
Assemblers

- Assemblers need to
  - translate assembly instructions and pseudo-instructions into machine instructions
  - Convert decimal numbers, etc. specified by programmer into binary
- Typically, assemblers make two passes over the assembly file
  - First pass: reads each line and records *labels* in a *symbol table*
  - Second pass: use info in symbol table to produce actual machine code for each line

Differences between Linkers and Loaders

BASIS FOR COMPARISON	LINKER	LOADER
Basic	It generates the executable module of a source program.	It loads the executable module to the main memory.

BASIS FOR COMPARISON	LINKER	LOADER
Input	It takes as input, the object code generated by an assembler.	It takes executable module generated by a linker.
Function	It combines all the object modules of a source code to generate an executable module.	It allocates the addresses to an executable module in main memory for execution.
Type/Approach	Linkage Editor, Dynamic linker.	Absolute loading, Relocatable loading and Dynamic Run-time loading.

Object file format

Object file header	Text segment	Data segment	Relocation information	Symbol table	Debugging information

- Object file header describes the size and position of the other pieces of the file
- Text segment contains the machine instructions
- Data segment contains binary representation of data in assembly file
- Relocation info identifies instructions and data that depend on absolute addresses
- Symbol table associates addresses with external labels and lists unresolved references
- Debugging info

One pass and two pass assembler design of an assembler

One pass assemblers perform single scan over the source code. If it encounters any undefined label, it puts it into symbol table along with the address so that the label can be replaced later when its value is encountered. On the other hand two pass assembler performs two sequential scans over the source code.

An assembler program creates object code by translating combinations of mnemonics and syntax for operations and addressing modes into their numerical equivalents. This representation typically includes an *operation code* ("opcode") as well as other control bits and data. The assembler also calculates constant expressions and resolves symbolic names for memory locations and other entities. The use of symbolic references is a key feature of assemblers, saving tedious calculations and manual address updates after program modifications. Most assemblers also include macro facilities for performing textual substitution – e.g., to generate common short sequences of instructions as inline, instead of *called* subroutines.

Some assemblers may also be able to perform some simple types of instruction set-specific optimizations. One concrete example of this may be the ubiquitous x86 assemblers from various vendors. Most of them are able to perform jump-instruction replacements (long jumps replaced by short or relative jumps) in any number of passes, on request. Others may even do simple rearrangement or insertion of instructions, such as some assemblers for RISC architectures that can help optimize a sensible instruction scheduling to exploit the CPU pipeline as efficiently as possible.

Like early programming languages such as Fortran, Algol, Cobol and Lisp, assemblers have been available since the 1950s and the first generations of text based computer interfaces. However, assemblers came first as they are far simpler to write than compilers for high-level languages. This is because each mnemonic along with the addressing modes and operands of an instruction translates rather directly into the numeric representations of that particular instruction, without much context or analysis. There have also been several classes of translators and semi automatic code generators with properties similar to both assembly and high level languages, with speedcode as perhaps one of the better known examples.

There may be several assemblers with different syntax for a particular CPU or instruction set architecture. For instance, an instruction to add memory data to a register in a x86-family processor might be add eax,[ebx], in original *Intel syntax*, whereas this would be written addl (%ebx),%eax in the *AT&T syntax* used by the GNU Assembler. Despite different appearances, different syntactic forms generally generate the same numeric machine code, see further below. A single assembler may also have different modes in order to support variations in syntactic forms as well as their exact semantic interpretations (such as FASM-syntax, TASM-syntax, ideal mode etc., in the special case of x86 assembly programming).

Number of passes

There are two types of assemblers based on how many passes through the source are needed (how many times the assembler reads the source) to produce the object file.

- **One-pass assemblers** go through the source code once. Any symbol used before it is defined will require "errata" at the end of the object code (or, at least, no earlier than the point where the symbol is defined) telling the linker or the loader to "go back" and overwrite a placeholder which had been left where the as yet undefined symbol was used.
- **Multi-pass assemblers** create a table with all symbols and their values in the first passes, then use the table in later passes to generate code.

In both cases, the assembler must be able to determine the size of each instruction on the initial passes in order to calculate the addresses of subsequent symbols. This means that if the size of an operation referring to an operand defined later depends on the type or distance of the operand, the assembler will make a pessimistic estimate when first encountering the operation, and if necessary pad it with one or more "no-operation" instructions in a later pass or the errata. In an assembler with peephole optimization, addresses may be recalculated between passes to allow replacing pessimistic code with code tailored to the exact distance from the target.

The original reason for the use of one-pass assemblers was speed of assembly – often a second pass would require rewinding and rereading the program source on tape or rereading a deck of cards or punched paper tape. Later computers with much larger memories (especially disc storage), had the space to perform all necessary processing without such re-reading. The advantage of the multi-pass assembler is that the absence of errata makes the linking process (or the program load if the assembler directly produces executable code) faster.[10]

Example: in the following code snippet a one-pass assembler would be able to determine the address of the backward reference *BKWD* when assembling statement *S2*, but would not be able to determine the address of the forward reference *FWD* when assembling the branch statement *S1*; indeed *FWD* may be undefined. A two-pass assembler would determine both addresses in pass 1, so they would be known when generating code in pass 2,

```
S1   B   FWD
 ...
FWD  EQU *
 ...
```

```
BKWD  EQU *
 ...
S2   B  BKWD
```

High-level assemblers

More sophisticated high-level assemblers provide language abstractions such as:

- High-level procedure/function declarations and invocations
- Advanced control structures (IF/THEN/ELSE, SWITCH)
- High-level abstract data types, including structures/records, unions, classes, and sets
- Sophisticated macro processing (although available on ordinary assemblers since the late 1950s for IBM 700 series and since the 1960s for IBM/360, amongst other machines)
- Object-oriented programming features such as classes, objects, abstraction, polymorphism, and inheritance

A program written in assembly language consists of a series of mnemonic processor instructions and meta-statements (known variously as directives, pseudo-instructions and pseudo-ops), comments and data. Assembly language instructions usually consist of an opcode mnemonic followed by a list of data, arguments or parameters.[12] These are translated by anassembler into machine language instructions that can be loaded into memory and executed.

For example, the instruction below tells an x86/IA-32 processor to move an immediate 8-bit value into a register. The binary code for this instruction is 10110 followed by a 3-bit identifier for which register to use. The identifier for the *AL* register is 000, so the following machine code loads the *AL* register with the data 01100001.[13]

```
10110000 01100001
```

This binary computer code can be made more human-readable by expressing it in hexadecimal as follows.

```
B0 61
```

Here, B0 means 'Move a copy of the following value into *AL'*, and 61 is a hexadecimal representation of the value 01100001, which is 97 in decimal. Assembly language for the

8086 family provides the mnemonic MOV (an abbreviation of *move*) for instructions such as this, so the machine code above can be written as follows in assembly language, complete with an explanatory comment if required, after the semicolon. This is much easier to read and to remember.

MOV AL, 61h   *; Load AL with 97 decimal (61 hex)*

In some assembly languages the same mnemonic such as MOV may be used for a family of related instructions for loading, copying and moving data, whether these are immediate values, values in registers, or memory locations pointed to by values in registers. Other assemblers may use separate opcode mnemonics such as L for "move memory to register", ST for "move register to memory", LR for "move register to register", MVI for "move immediate operand to memory", etc.

The x86 opcode 10110000 (B0) copies an 8-bit value into the *AL* register, while 10110001 (B1) moves it into *CL* and 10110010 (B2) does so into *DL*. Assembly language examples for these follow.[13]

MOV AL, 1h   *; Load AL with immediate value 1*
MOV CL, 2h   *; Load CL with immediate value 2*
MOV DL, 3h   *; Load DL with immediate value 3*

The syntax of MOV can also be more complex as the following examples show.[14]

MOV EAX, [EBX]   *; Move the 4 bytes in memory at the address contained in EBX into EAX*
MOV [ESI+EAX], CL *; Move the contents of CL into the byte at address ESI+EAX*

In each case, the MOV mnemonic is translated directly into an opcode in the ranges 88-8E, A0-A3, B0-B8, C6 or C7 by an assembler

Algorithm for Pass-1 Assembler

```
read first input line
if OPCODE='START' then
    begin
        save #[OPERAND] as starting address
        initialize LOCCTR to starting address
        write line to intermediate file
        read next input line
    end
else
    initialize LOCCTR to 0
while OPCODE≠'END' do
    begin
        if this is not a comment line then
        begin
            if there is a symbol in the LABEL field then

begin
            search SYMTAB for LABEL
            if found then
              set error flag (duplicate symbol)
            else
              insert (LABEL, LOCCTR) into SYMTAB
        end {if symbol}
         search OPTAB for OPCODE
         if found then
         add 3 {instruction length} to LOCCTR
          else if OPCODE='WORD' then
         add 3 to LOCCTR
          else if OPCODE='RESW' then
         add 3 * #[OPERAND] to LOCCTR

    else if OPCODE='RESB' then
            add #[OPERAND] to LOCCTR
             else if OPCODE='BYTE' then
            begin
                find length of constant in bytes
                add length to LOCCTR
            end {if BYTE}
             else
            set error flag (invalid operation code)
        end  {if not a comment}
        write line to intermediate file
        read next input line
    end {while not END}
Write last line to intermediate file
Save (LOCCTR-starting address) as program length
```

Two-pass assembler

Uses of two-pass assembler

- A two-pass assembler reads through the source code twice. Each read-through is called a pass.

  On pass one the assembler doesn't write any code. It builds up a table of symbolic names against values or addresses.

  On pass two, the assembler generates the output code, using the table to resolve symbolic names, enabling it to enter the correct values.

  The advantage of a two-pass assember is that it allows forward referencing in the source code because when the assembler is generating code it has already found all references.
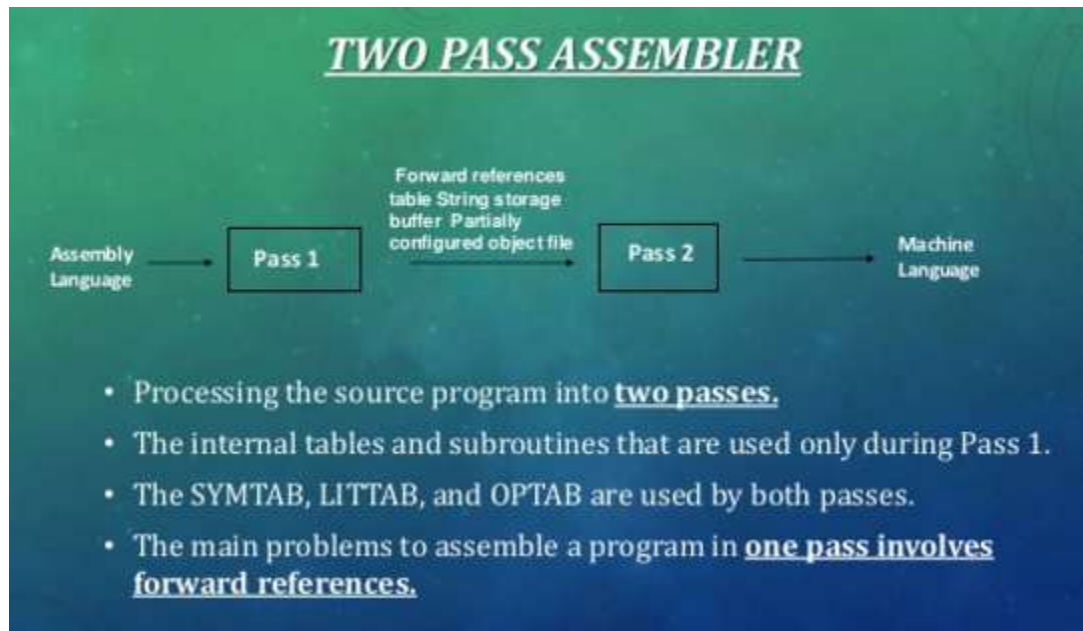
Algorithm for Pass-2 Assembler

```
read first input line (from intermediate file)
If OPCODE='START' then
  begin
    write listing line
    read next input line
  end {if START}
Write Header record to object program
Initialize first Text record
While OPCODE≠ 'END' do
  begin
    if this is not a comment line then
      begin
        search OPTAB for OPCODE
        if found then
          begin

          if there is a symbol in OPERAND field then
                  begin
                search SYMTAB for OPERAND
                if found then
                  store symbol value as operand address
                else
                  begin
                      store 0 as operand address
                      set error flag (undefined symbol)
                  end
                  end {if symbol}
                else
                  store 0 as operand address
                assemble the object code instruction
          end {if opcode found}

          else if OPCODE='BYTE' or 'WORD' then
            convert constant to object code
          if object code will not fit into the current Text record then
            begin
                write Text record to object program
                initialize new Text record
            end
          add object code to Text record
      end {if not comment}
    write listing line
    read next input line
  end {while not END}
write last Text record to object program
Write End record to object program
Write last listing line
```


Absolute loader

In computer **systems** a **loader** is the part of an operating **system** that is responsible for loading programs and libraries. It is one of the essential stages in the process of starting a **program**, as it places programs into memory and prepares them for execution.

An **absolute** loader is the simplest type of **loading scheme** that **loads** the file into memory at the location specified by the beginning portion (header) of the file, then it passes control to the program.

There are two types of loaders, relocating and absolute. The absolute loader is the simplest and quickest of the two. The loader loads the file into memory at the location specified by the beginning portion (header) of the file, then passes control to the program. If the memory space specified by the header is currently in use, execution cannot proceed, and the user must wait until the requested memory becomes free.

- The absolute loader is a kind of loader in which relocated object files are created, loader accepts these files and places them at a specified location in the memory.
- This type of loader is called absolute loader because no relocating information is needed, rather it is obtained from the programmer or assembler.
- The starting address of every module is known to the programmer, this corresponding starting address is stored in the object file then the task of loader becomes very simple that is to simply place the executable form of the machine instructions at the locations mentioned in the object file.
- In this scheme, the programmer or assembler should have knowledge of memory management. The programmer should take care of two things:
  - Specification of starting address of each module to be used. If some modification is done in some module then the length of that module may vary. This causes a change in the starting address of immediate next modules, it's then the programmer's duty to make necessary changes in the starting address of respective modules.
  - While branching from one segment to another the absolute starting address of respective module is to be known by the programmer so that such address can be specified at respective JMP instruction.
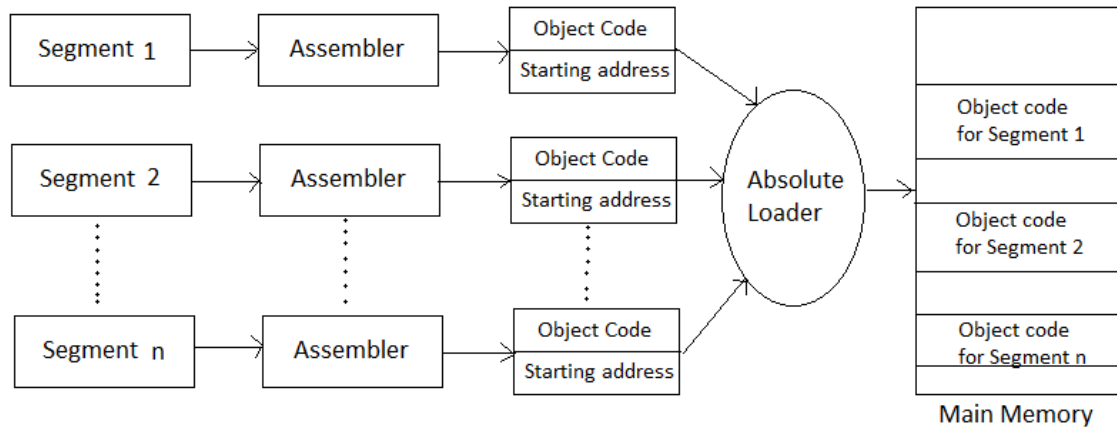
Advantages:

1. It is simple to implement.
2. This scheme allows multiple programs or the source programs written in different languages. If there are multiple programs written in different languages then the respective language assembler will convert it to the language and common object file can be prepared with all the ad resolution.
3. The task of loader becomes simpler as it simply obeys the instruction regarding where to place the object code to the main memory.
4. The process of execution is efficient.

Disadvantages:

1. In this scheme, it's the programmer's duty to adjust all the inter-segment addresses and manually do the linking activity. For that, it is necessary for a programmer to know the memory management.
2. If at all any modification is done to some segment the starting address of immediate next segments may get changed the programmer has to take care of this issue and he/she needs to update the corresponding starting address on any modification in the source.

The relocating loader

The relocating loader will load the program anywhere in memory, altering the various addresses as required to ensure correct referencing. The decision as to where in memory the program is placed is done by the Operating System, not the programs header file. This is obviously more efficient, but introduces a slight overhead in terms of a small delay whilst all the relative offsets are calculated. The relocating loader can only relocate code that has been produced by a linker capable of producing relative code.

Types of Loaders:

Absolute Loader.
Bootstrap Loader.
Relocating Loader (Relative Loader)
Linking Loader.

Two methods for specifying relocation as part of the object program:

The first method:

- A Modification is used to describe each part of the object code that must be changed when the program is relocated.

Consider the program

Line	Loc	Source statement			Object code
5	0000	COPY	START	0	
10	0000	FIRST	STL	RETADR	17202D
12	0003		LDB	#LENGTH	69202D
13		BASE		LENGTH	
15	0006	CLOOP	+JSUB	RDREC	4B101036
20	000A		LDA	LENGTH	032026
25	000D		COMP	#0	290000
30	0010		JEQ	ENDFIL	332007
35	0013		+JSUB	WRREC	4B10105D
40	0017		J	CLOOP	3F2FEC
45	001A	ENDFIL	LDA	EOF	032010
50	001D		STA	BUFFER	0F2016
55	0020		LDA	#3	010003
60	0023		STA	LENGTH	0F200D
65	0026		+JSUB	WRREC	4B10105D
70	002A		J	@RETADR	3E2003
80	002D	EOF	BYTE	C'EOF'	454F46
95	0030	RETADR	RESW	1	
100	0033	LENGTH	RESW	1	
105	0036	BUFFER	RESB	4096	
110		.			
115		.	SUBROUTINE TO READ RECORD INTO BUFFER		
120		.			
125	1036	RDREC	CLEAR	X	B410
130	1038		CLEAR	A	B400
132	103A		CLEAR	S	B440
133	103C		+LDT	#4096	75101000
135	1040	RLOOP	TD	INPUT	E32019
140	1043		JEQ	RLOOP	332FFA
145	1046		RD	INPUT	DB2013
150	1049		COMPR	A,S	A004
155	104B		JEQ	EXIT	332008
160	104E		STCH	BUFFER,X	57C003
165	1051		TIXR	T	B850
170	1053		JLT	RLOOP	3B2FEA
175	1056	EXIT	STX	LENGTH	134000
180	1059		RSUB		4F0000
185	105C	INPUT	BYTE	X'F1'	F1
195		.			
200		.	SUBROUTINE TO WRITE RECORD FROM BUFFER		
205		.			
210	105D	WRREC	CLEAR	X	B410
212	105F		LDT	LENGTH	774000
215	1062	WLOOP	TD	OUTPUT	E32011
220	1065		JEQ	WLOOP	332FFA
225	1068		LDCH	BUFFER,X	53C003
230	106B		WD	OUTPUT	DF2008
235	106E		TIXR	T	B850
240	1070		JLT	WLOOP	3B2FEF
245	1073		RSUB		4F0000
250	1076	OUTPUT	BYTE	X'05'	05
255			END	FIRST	

- Most of the instructions in this program use relative or immediate addressing.
- The only portions of the assembled program that contain actual addresses are the extended format instructions on lines 15, 35, and 65. Thus these are the only items whose values are affected by relocation.

Object program

```
HCOPY  000000001077
T0000001D17202D69202D4B101036032026290000332007AB10105D3F2FEC032010
T00001D130F20160100030F200D4B10105D3E2003454F46
T0010361DB410B400B440751010000E320193332FFADB2013A00433200857C003B850
T00105310D3B2FEA1340004F00000F1B410774000E320113332FFA53C003DF2008B850
T001070073B2FEF4F0000005
M00000705+COPY
M00001405+COPY
M00002705+COPY
E000000
```

- Each Modification record specifies the starting address and length of the field whose value is to be altered.
- It then describes the modification to be performed.
- In this example, all modifications add the value of the symbol COPY, which represents the starting address of the program.

The second method:

- There are no Modification records.
- The Text records are the same as before except that there is a *relocation bit* associated with each word of object code.
- Since all SIC instructions occupy one word, this means that there is one relocation bit for each possible instruction.

Object program with relocation by bit mask

```
HCOPY  00000000107A
T0000001EFFC1400334810390000362800303000154810613C000300002A0C003900002D
T00001E15E000C003648106108003334C0000454F46000000000000
T0010391BFFC040030000030E0105D30103FD8105D28003030105755480392C105E38103F
T0010570A8001000364C00000F1001000
T0010611 9FE0040030E010793010645080393DC10792C003638105D44C000005
E000000
```

Dynamic Linking

An application that depends on **dynamic linking** calls the external files as needed during execution. The subroutines are typically part of the operating system, but may be auxiliary files that came with the application.

Dynamic linking has the following advantages: Saves **memory** and reduces swapping. Many processes can use a single DLL simultaneously, sharing a single copy of the DLL in **memory**. In contrast, Windows must load a copy of the library code into **memory** for each application that is built with a static link library.

A dynamic link library (DLL) is a collection of small programs that can be loaded when needed by larger programs and used at the same time. The small program lets the larger program communicate with a specific device, such as a printer or scanner. It is often packaged as a DLL program, which is usually referred to as a DLL file. DLL files that support specific device operation are known as device drivers.

Link editors are commonly known as linkers. The compiler automatically invokes the linker as the last step in compiling a program. The linker inserts code (or maps in shared libraries) to resolve program library references, and/or combines object modules into an executable image suitable for loading into memory. On Unix-like systems, the linker is typically invoked with the ld command.

Static linking is the result of the linker copying all library routines used in the program into the executable image. This may require more disk space and memory than dynamic linking, but is both faster and more portable, since it does not require the presence of the library on the system where it is run.

Dynamic linking is accomplished by placing the name of a sharable library in the executable image. Actual linking with the library routines does not occur until the image is run, when both the executable and the library are placed in memory. An advantage of dynamic linking is that multiple programs can share a single copy of the library.

Linking is often referred to as a process that is performed when the executable is compiled, while a dynamic linker is a special part of an operating system that loads external shared libraries into a running process and then binds those shared libraries dynamically to the running process. This approach is also called dynamic linking or late linking.

Overview of compilation:

The process of compiling a set of source files into a corresponding set of class files is not a simple one, but can be generally divided into three stages. Different parts of source files may proceed through the process at different rates, on an "as needed" basis.
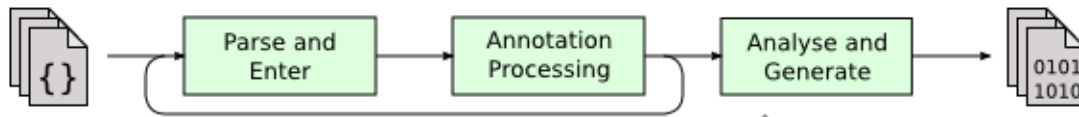
This process is handled by the JavaCompiler class.

1. All the source files specified on the command line are read, parsed into syntax trees, and then all externally visible definitions are entered into the compiler's symbol tables.
2. All appropriate annotation processors are called. If any annotation processors generate any new source or class files, the compilation is restarted, until no new files are created.
3. Finally, the syntax trees created by the parser are analyzed and translated into class files. During the course of the analysis, references to additional classes may be found. The compiler will check the source and class path for these classes; if they are found on the source path, those files will be compiled as well, although they will not be subject to annotation processing.

Parse and Enter

Source files are processed for Unicode escapes and converted into a stream of tokens by the Scanner.

The token stream is read by the Parser, to create syntax trees, using a TreeMaker. Syntax trees are built from subtypes of JCTree which implementcom.sun.source.Tree and its subtypes.

Each tree is passed to Enter, which enters symbols for all the definitions encountered into the symbols. This has to done before analysis of trees which might reference those symbols. The output from this phase is a *To Do* list, containing trees that need to be analyzed and have class files generated.

Enter consists of phases; classes migrate from one phase to the next via queues.

class enter	→	Enter.uncompleted	→	MemberEnter (1)
	→	MemberEnter.halfcompleted	→	MemberEnter (2)
	→	To Do	→	(Attribute and Generate)

1. In the first phase, all class symbols are entered into their enclosing scope, descending recursively down the tree for classes which are members of other classes. The class symbols are given a MemberEnter object as completer.

   In addition, if any package-info.java files are found, containing package annotations, then the top level tree node for the file is put on the *To Do* list as well.

2. In the second phase, classes are completed using MemberEnter.complete(). Completion might occur on demand, but any classes that are not completed that way will be eventually completed by processing the *uncompleted* queue. Completion entails

   - (1) determination of a class's parameters, supertype and interfaces.
   - (2) entering all symbols defined in the class into its scope, with the exception of class symbols which have been entered in phase

3. After all symbols have been entered, any annotations that were encountered on those symbols will be analyzed and validated.

Whereas the first phase is organized as a sweep through all compiled syntax trees, the second phase is on demand. Members of a class are entered when the contents of a class are first accessed. This is accomplished by installing completer objects in class symbols for compiled classes which invoke the MemberEnter phase for the corresponding class tree.

Annotation Processing

This part of the process is handled by JavacProcessingEnvironment.

Conceptually, annotation processing is a preliminary step before compilation. This preliminary step consists of a series of rounds, each to parse and enter source files, and then to determine and invoke any appropriate annotation processors. After an initial round, subsequent rounds will be performed if any of the annotation processors that are called generate any new source files or class files that need to be part of the eventual compilation. Finally, when all necessary rounds have been completed, the actual compilation is performed.

Analyse and Generate

Once all the files specified on the command line have been parsed and entered into the compiler's symbol tables, and after any annotation processing has occurred, JavaCompiler can proceed to analyse the syntax trees that were parsed with a view to generating the corresponding class files.

Attr

The top level classes are "attributed", using Attr, meaning that names, expressions and other elements within the syntax tree are resolved and associated with the corresponding types and symbols. Many semantic errors may be detected here, either by Attr, or by Check.

Flow

If there are no errors so far, flow analysis will be done for the class, using Flow. Flow analysis is used to check for definite assignment to variables, and unreachable statements, which may result in additional errors.

TransTypes

Code involving generic types is translated to code without generic types, usingTransTypes.

Phases of a compiler:

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. Let us understand the phases of a compiler.
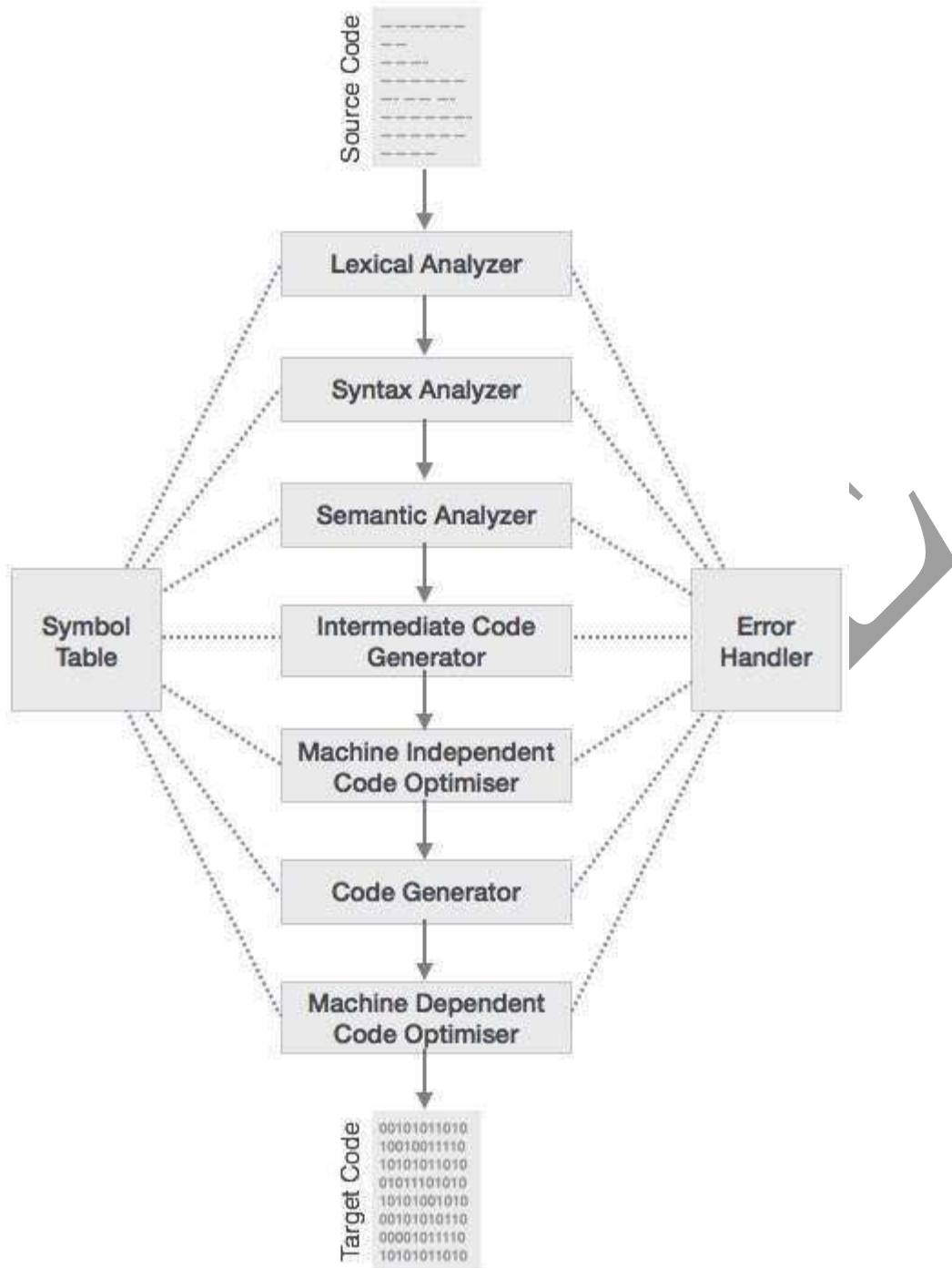
Lexical Analysis

The first phase of scanner works as a text scanner. This phase scans the source code as a stream of characters and converts it into meaningful lexemes. Lexical analyzer represents these lexemes in the form of tokens as:

<token-name, attribute-value>

Syntax Analysis

The next phase is called the syntax analysis or **parsing**. It takes the token produced by lexical analysis as input and generates a parse tree (or syntax tree). 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.

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 analyzer keeps track of identifiers, their types and expressions; whether identifiers are declared before use or not etc. The semantic analyzer produces an annotated syntax tree as an output.
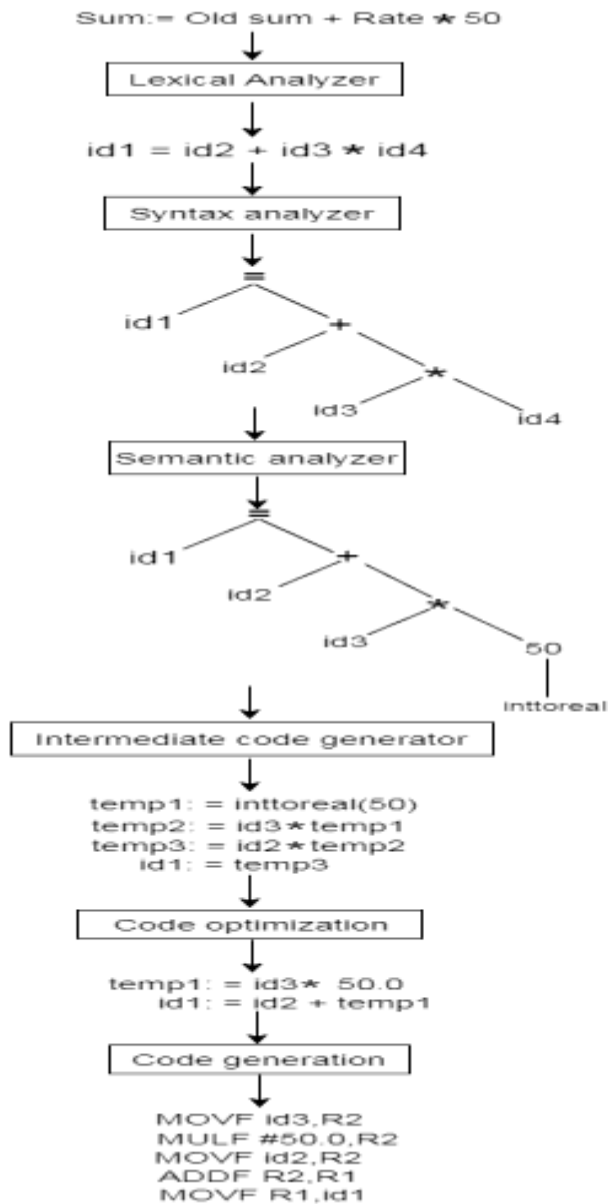
Intermediate Code Generation

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. It is in between the high-level language and the machine language. This intermediate code should be generated in such a way that it makes it easier to be translated into the target machine code.

Code Optimization

The next phase does code optimization of the intermediate code. Optimization can be assumed as something that removes unnecessary code lines, and arranges the sequence of statements in order to speed up the program execution without wasting resources (CPU, memory).

Code Generation

In this phase, the code generator takes the optimized representation of the intermediate code and maps it to the target machine language. The code generator translates the intermediate code into a sequence of (generally) re-locatable machine code. Sequence of instructions of machine code performs the task as the intermediate code would do.

Sum:= Old sum + Rate ★ 50

Lexical Analyzer

id1 = id2 + id3 ★ id4

Syntax analyzer

Semantic analyzer

Intermediate code generator

temp1: = inttoreal(50)
temp2: = id3 ★ temp1
temp3: = id2 ★ temp2
id1: = temp3

Code optimization

temp1: = id3★ 50.0
id1: = id2 + temp1

Code generation

MOVF id3,R2
MULF #50.0,R2
MOVF id2,R2
ADDF R2,R1
MOVF R1,id1

Symbol Table

It is a data-structure maintained throughout all the phases of a compiler. All the identifier's names along with their types are stored here. The symbol table makes it easier for the compiler to quickly search the identifier record and retrieve it. The symbol table is also used for scope management.

UNIT -I

S.No	Questions	Opt1	Opt2	Opt3	opt4	Answer
1	In a two pass assembler the object code generation is done during the ?	Second pass	First pass	Zeroeth pass	Not done by assembler	Second pass
2	Which of the following is not a type of assembler ?	one pass	two pass	three pass	load and go	three pass
3	In a two pass assembler, adding literals to literal table and address resolution of local symbols are done using ?	First pass and second respectively	Both second pass	Second pass and first respectively	Both first pass	Both first pass
4	In a two pass assembler the pseudo code EQU is to be evaluated during ?	Pass 1	Pass 2	not evaluated by the assembler	None of above	Pass 1
5	system program foregoes the production of object code to generate absolute machine code and load it into the physical main storage location from which it will be executed immediately upon	Macro processor	Load and go assembler	Two pass assembler	Compiler	Load and go assembler
6	Translator for low level programming language were termed as	Assembler	Compiler	Linker	Loader	Assembler
7	An assembler is	programming language dependent	syntax dependant	machine dependant	data dependant	machine dependant
8	An imperative statement	Reserves areas of memory and associates names with them	Indicates an action to be performed during execution of assembled program	Indicates an action to be performed during optimization	None of the above	Indicates an action to be performed during execution of assembled program
9	In a two-pass assembler, the task of the Pass II is to	separate the symbol, mnemonic opcode and operand fields.	build the symbol table.	construct intermediate code.	synthesize the target program.	synthesize the target program.

#	Question	A	B	C	D	Answer
10	TII stands for	Table of incomplete instructions	Table of information instructions	Translation of instructions information	Translation of information instruction	Table of incomplete instructions
11	Which of the following system software resides in main memory always ?	Text editor	Assembler	Linker	Loader	Loader
12	Daisy chain is a device for ?	Interconnecting a number of devices to number of controllers	Connecting a number of devices to a controller	Connecting a number of controller to devices	All of above	Connecting a number of devices to a controller
13	type of software should be used if you need to create,edit and print document ?	Word processing	Spreadsheet	Desktop publishing	UNIX	Word processing
14	problem can be solved using ?	semaphores	event counters	monitors	all of above	all of above
15	What is bootstraping?	A language interpreting other language program	A language compiling other language program	A language compile itself	All of above	A language compile itself
16	Shell is the exclusive feature of	UNIX	DOS	System software	Application software	UNIX
17	called	Process	Instruction	Procedure	Function	Process
18	A UNIX device driver is	Structured into two halves called top half and bottom half	Three equal partitions	Unstructured	None of the above	Structured into two halves called top half and
19	Memory	is an device that performs a sequence of operations specified by instructions in memory	is the device where information is stored	is a sequence of instructions	is a computational unit to perform specific functions	is the device where information is stored
20	mode, the operand is given explicitly in the instruction itself	absolute mode	immediate mode	indirect mode	index mode	immediate mode
21	the effective address of the operand is generated by adding a constant value to the context of	absolute mode	immediate mode	indirect mode	index mode	indirect mode

22	A garbage is _____	un-allocated storage	allocated storage with all across path to it destroyed	allocated storage	uninitialized storage	allocated storage with all across path to it destroyed
23	Which of the following program is not a utility?	Debugger	Editor	Spooler	All of the above	Spooler
24	whereby the executive control modules of a system are coded and tested first, is known as	Bottom-up development	Top-down development	Left-Right development	All of the above	Top-down development
25	systems software does the job of merging the records from two flies into one?	Documentation system	Utility program	Networking software	Security software	Utility program
26	A computer can not boot if it does not have the	compiler	loader	operating system	assembler	loader
27	The Process Manager has to keep track of:_____	the status of each program	the priority of each program	the information management support to a programmer using the system	both a and b	both a and b
28	instructions, in a computer language, to get the desired result, is	Algorithm	Decision Table	Program	All of the above	Program
29	Action implementing instruction's meaning are a actually carried out by	Instruction fetch	Instruction decode	Instruction execution	Instruction program	Instruction execution
30	A bottom up parser generates	Right most derivation	Right most derivation in reverse	Left most derivation	Left most derivation in reverse	Right most derivation in reverse
31	Object program is a	Program written in machine language	Program to be translated into machine language	Translation of high-level language into machine language	None of the mentioned	Translation of high-level language into machine language
32	Software that allows your computer to interact with the user, applications, and hardware is called	application software	word processor	system software	database software	system software

33	computer resources, provide an interface between users and the computer,	utilities	operating systems	device drivers	language translators	operating systems
34	allow particular input or output devices to communicate with the rest of the computer system	operating systems	utilities	device drivers	language translators	device drivers
35	program, this type of program performs specific tasks related to managing computer resources.	utility	operating system	language translator	device driver	utility
36	In order for a computer to understand a program, it must be converted into machine language by	operating system	utility	device driver	language translator	language translator
37	Which of the following is not a function of the operating system?	Manage resources	Internet access	Provide a user interface	Load and run applications	Internet access
38	The items that a computer can use in its functioning are collectively called its	resources	stuff	capital	properties	resources
39	all of the computer's resources including memory, processing, storage, and devices such as printers are collectively referred to as	language translators	resources	applications	interfaces	resources
40	tool that translates _____ that the computer can understand.	Algorithm into data	Source code into data	Computer language into data	None of the above	Source code into data
41	passed through a program called a _____ which turns it into an executable program.	Integer	Source code	Linker	None of the above	Linker
42	turned on or restarted, a special type of absolute loader is executed, called a	Compile and Go loader	Boot loader	Bootstrap loader	Relating loader	Bootstrap loader

#	Question					
43	What is memory in Computer ?	is a sequence of instructions	is the device where information is stored	is an device that performs a sequence of operations specified by instructions in memory	none of these	is the device where information is stored
44	A program -	is a sequence of instructions	is the device where information is stored	is a device that performs a sequence of operations specified by instructions in memory	none of these	is a sequence of instructions
45	includes the program s or instructions.	icon	software	hardware	information	software
46	documents are represented on the Windows desktop by __.	icons	labels	graphs	symbols	icons
47	processor operation in CPU is controled by	CU	ALU	Registers	All of the above	CU
48	The name of the first microprocessor chip was	Intel1004	Intel2004	Intel3004	Intel4004	Intel4004
49	Intel introduced first 32 bit processor in	1985	1987	1989	1993	1985
50	are 120 instructions, how many bits needed to implement this	5	6	7	8	7
51	understand the difference data and programs?	ALU	Registers	Motherboard	Microprocessor	Microprocessor
52	A memory bus is used for communication between	ALU and Register	Processor and Memory	Input and Output devices	All of the above	Processor and Memory
53	The fourth generation computer was made up of	chips	transistor	vaccume tubes	microprocessor chips	microprocessor chips
54	cycles necessary to complete 1 fetch cycle in 8085 is	3 or 4	4 or 5	4 or 6	6 or 7	4 or 6

CLASS : II B.SC IT	COURSE NAME: System Programming
COURSE CODE: 16ITU603B	BATCH: 2016-2019

UNIT II: LEXICAL ANALYSIS

UNIT -2

SYLLABUS

Lexical Anlysis: Role of Lexical Analyzer, Specification and recognition of tokens, symbol table, lexical analysis
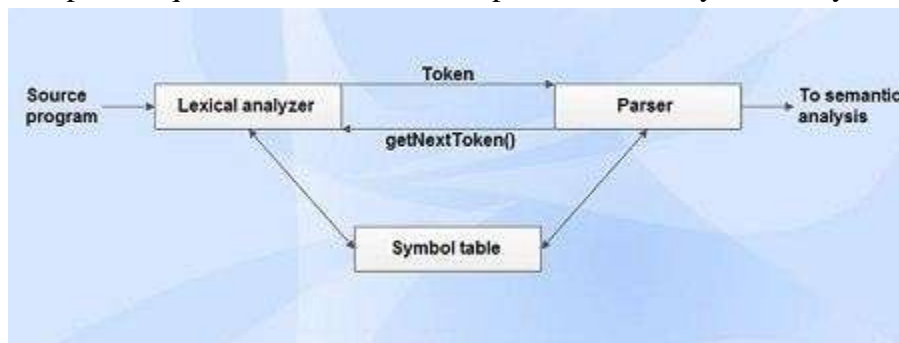
OVER VIEW OF LEXICAL ANALYSIS

To identify the tokens we need some method of describing the possible tokensthat can appear in the input stream. For this purpose we introduce regular expression, anotation that can be used to describe essentially all the tokens of programminglanguage.

Secondly , having decided what the tokens are, we need some mechanism torecognize these in the input stream. This is done by the token recognizers, which aredesigned using transition diagrams and finite automata.

ROLE OF LEXICAL ANALYZER

The LA is the first phase of a compiler. It main task is to read the input characterand produce as output a sequence of tokens that the parser uses for syntax analysis.

Upon receiving a 'get next token' command form the parser, the lexical analyzer reads the input character until it can identify the next token. The LA return to the parser representation for the token it has found. The representation will be an integer code, if the token is a simple construct such as parenthesis, comma or colon.

LA may also perform certain secondary tasks as the user interface. One such task is striping out from the source program the commands and white spaces in the form of blank, tab and new line characters. Another is correlating error message from the compiler with the source program.

LEXICAL ANALYSIS VS PARSING

Lexical analysis	Parsing
A Scanner simply turns an input String (say a file) into a list of tokens. These tokens represent things like identifiers, parentheses, operators etc.	A parser converts this list of tokens into a Tree-like object to represent how the tokens fit together to form a cohesive whole (sometimes referred to as a sentence).
The lexical analyzer (the "lexer") parses individual symbols from the source code file into tokens. From there, the "parser" proper turns those whole tokens into sentences of your grammar	A parser does not give the nodes any meaning beyond structural cohesion. The next thing to do is extract meaning from this structure (sometimes called contextual analysis).

TOKEN, LEXEME, PATTERN:

Token: Token is a sequence of characters that can be treated as a single logical entity.

Typical tokens are, 1) Identifiers 2) keywords 3) operators 4) special symbols 5)constants

Pattern: A set of strings in the input for which the same token is produced as output. This set of strings is described by a rule called a pattern associated with the token.

Lexeme: A lexeme is a sequence of characters in the source program that is matched by the pattern for a token. **Example**:

Token	lexeme	pattern
const	const	const
if	if	if
relation	<,<=,= ,<>,>=,>	< or <= or = or <> or >= or letter followed by letters & digit
i	pi	any numeric constant
nun	3.14	any character b/w "and "except"
literal	"core"	pattern

A patter is a rule describing the set of lexemes that can represent a particular token in source program.

DIFFERENCE BETWEEN COMPILER AND INTERPRETER

- ✓ A compiler converts the high level instruction into machine language while aninterpreter converts the high level instruction into an intermediate form.
- ✓ Before execution, entire program is executed by the compiler whereas aftertranslating the first line, an interpreter then executes it and so on.
- ✓ List of errors is created by the compiler after the compilation process while aninterpreter stops translating after the first error.
- ✓ An independent executable file is created by the compiler whereas interpreter isrequired by an interpreted program each time.
- ✓ The compiler produce object code whereas interpreter does not produce object code.
- ✓ In the process of compilation the program is analyzed only once and then the code isgenerated whereas source program is interpreted every time it is to be executed andevery time the source program is analyzed. hence interpreter is less efficient thancompiler.
- ✓ Examples of interpreter: A UPS Debugger is basically a graphical source leveldebugger but it contains built in C interpreter which can handle multiple source files.example of compiler: Borland c compiler or Turbo C compiler compiles the programswritten in C or C++.

Need of Lexical Analyzer

- ✓ *Simplicity of design of compiler* The removal of white spaces and comments enables the syntax analyzer for efficient syntactic constructs.
- ✓ *Compiler efficiency is improved* Specialized buffering techniques for reading characters speed up the compiler process.
- ✓ *Compiler portability is enhanced*

Issues in Lexical Analysis

Lexical analysis is the process of producing tokens from the source program. It has the following issues:

• Lookahead

• Ambiguities

Lookahead

Lookahead is required to decide when one token will end and the next token will begin. The simple example which has lookahead issues are i *vs. if, = vs. ==.* Therefore a way to describe the lexemes of each token is required.

A way needed to resolve ambiguities

• Is if it is two variables *i* and *f* or if?

• Is == is two equal signs =, = or ==?

• arr(5, 4) vs. fn(5, 4) *II* in Ada (as array reference syntax and function call syntax are similar.

Hence, the number of lookahead to be considered and a way to describe the lexemes of each token is also needed.

Regular expressions are one of the most popular ways of representing tokens.

Ambiguities

The lexical analysis programs written with lex accept ambiguous specifications and choose the longest match possible at each input point. Lex can handle ambiguous specifications. When more than one expression can match the current input, lex chooses as follows:

• The longest match is preferred.

• Among rules which matched the same number of characters, the rule given first is preferred.

LEXICAL ERRORS

Lexical errors are the errors thrown by your lexer when unable to continue. This means that there's no way to recognize a lexeme as a valid token for you lexer. Syntax errors, on the other side, will be thrown by your scanner when a given set of already recognised valid tokens don't match any of the right sides of your grammar rules. simple panic-mode error handling system requires that we return to a high-level parsing function when a parsing or lexical error is detected.

- Error-recovery actions are:
- Delete one character from the remaining input.
- Insert a missing character in to the remaining input.
- Replace a character by another character.
- Transpose two adjacent characters.

Lexical error handling approaches

Lexical errors can be handled by the following actions:

- ✓ Deleting one character from the remaining input.
- ✓ Inserting a missing character into the remaining input.
- ✓ Replacing a character by another character.
- ✓ Transposing two adjacent characters.

Specification of tokens

There are 3 specifications of tokens:

1) Strings

2) Language

3) Regular expression

Strings and Languages

An alphabet or character class is a finite set of symbols.

A string over an alphabet is a finite sequence of symbols drawn from that alphabet.

A language is any countable set of strings over some fixed alphabet. In language theory, the terms "sentence" and "word" are often used as synonyms for "string."

The length of a string s, usually written |s|, is the number of occurrences of symbols in s. For example, banana is a string of length six. The empty string, denoted ε, is the string of length zero

Operations on strings

The following string-related terms are commonly used:

1. A prefix of string s is any string obtained by removing zero or more symbols from the end of string s.

For example, ban is a prefix of banana.

2. A suffix of string s is any string obtained by removing zero or more symbols from the beginning of s.

For example, nana is a suffix of banana.

3. A substring of s is obtained by deleting any prefix and any suffix from s.

For example, nan is a substring of banana.

4. The proper prefixes, suffixes, and substrings of a string s are those prefixes, suffixes, and substrings, respectively of s that are not ε or not equal to s itself.

5. A subsequence of s is any string formed by deleting zero or more not necessarily consecutive positions of s.

For example, ban is a subsequence of banana.

Operations on languages:

The following are the operations that can be applied to languages:

1.Union

2.Concatenation

3.Kleene closure

4.Positive closure

The following example shows the operations on strings:

Let L={0,1} and S={a,b,c}

1. Union : L U S={0,1,a,b,c}

2. Concatenation : L.S={0a,1a,0b,1b,0c,1c}

3. Kleene closure : L*={ ε,0,1,00….}

4. Positive closure : L+ ={0,1,00….}

REGULAR EXPRESSIONS

s Each regular expression r denotes a language L(r).

- ✓ Regular expressions are notation for specifying patterns.
- ✓ Each pattern matches a set of strings.
- ✓ Regular expressions will serve as names for sets of strings.

Here are the rules that define the regular expressions over some alphabet Σ and the languages that

those expressions denote:

1. ε is a regular expression, and L(ε) is { ε }, that is, the language whose sole member is the empty string.

2. If 'a' is a symbol in Σ, then 'a' is a regular expression, and L(a) = {a}, that is, the language with

one string, of length one, with 'a' in its one position.

3. Suppose r and s are regular expressions denoting the languages L(r) and L(s). Then,

   a) (r)|(s) is a regular expression denoting the language L(r) U L(s).

   b) (r)(s) is a regular expression denoting the language L(r)L(s). c)

   (r)* is a regular expression denoting (L(r))*.

   d) (r) is a regular expression denoting L(r).

4. The unary operator * has highest precedence and is left associative.

5. Concatenation has second highest precedence and is left associative.

6. | has lowest precedence and is left associative.

Regular set

A language that can be defined by a regular expression is called a regular set. If two regular expressions r and s denote the same regular set, we say they are equivalent and write r = s.

There are a number of algebraic laws for regular expressions that can be used to manipulate into equivalent forms.

For instance, r|s = s|r is commutative; r|(s|t)=(r|s)|t is associative.

Regular Definitions

Giving names to regular expressions is referred to as a Regular definition. If Σ is an

alphabet of basic symbols, then a regular definition is a sequence of definitions of the form

dl → r 1

d2 → r2

………

dn → rn

1. Each di is a distinct name.

2. Each ri is a regular expression over the alphabet Σ U {dl

, d2,. . . , di-l}.

Example: Identifiers is the set of strings of letters and digits beginning with a letter. Regular

definition for this set:

letter → A | B | …. | Z | a | b | …. | z |

digit → 0 | 1 | …. | 9

id → letter (letter | digit) *

Shorthands

Certain constructs occur so frequently in regular expressions that it is convenient to introduce notational shorthands for them.

1. **One or more instances (+):**

- The unary postfix operator + means " one or more instances of" .

- If r is a regular expression that denotes the language L(r), then (r)+ is a regular expression that denotes the language (L (r))+

- Thus the regular expression a+ denotes the set of all strings of one or more a's.

- The operator + has the same precedence and associativity as the operator *

. **2. Zero or one instance (?):**

- The unary postfix operator ? means "zero or one instance of". -

The notation r? is a shorthand for r | ε.

- If 'r' is a regular expression, then (r)? is a regular expression that denotes the language L(r) U { ε }.

3. Character Classes:

- The notation [abc] where a, b and c are alphabet symbols denotes the regular expression a | b |c.

- Character class such as [a - z] denotes the regular expression a | b | c | d | ….|z.

- We can describe identifiers as being strings generated by the regular expression, [AZa-z][A-Za-z0-9]*

Non-regular Set A language which cannot be described by any regular expression is a non-regular set.

Example: The set of all strings of balanced parentheses and repeating strings cannot be described by a

regular expression. This set can be specified by a context-free grammar.

RECOGNITION OF TOKENS

Consider the following grammar fragment:

stmt → if expr then stmt
        | if expr then stmt else stmt
        | ε
expr → term relop term
        | term
term → id
        | num

where the terminals if , then, else, relop, id and num generate sets of strings given by the following regular definitions:

if → if

then → then

else → else

relop → <|<=|=|<>|>|>=

id → letter(letter|digit)*
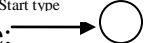
num → digit+(.digit+)?(E(+|-)?digit+)?

For this language fragment the lexical analyzer will recognize the keywords if, then, else, as well as the lexemes denoted by relop, id, and num. To simplify matters, we assume keywords are reserved; that is, they cannot be used as identifiers.

Transition Diagrams (TD)

As an intermediate step in the construction of a lexical analyzer, we first produce flowchart, called a Transition diagram. Transition diagrams depict the actions that take place when a lexical analyzer is called by the parser to get the next token.

The TD uses to keep track of information about characters that are seen as the forward pointer scans the input. it dose that by moving from position to position in the diagram as characters are read.

Components of Transition Diagram

One state is labeled the **Start State**; Start type   it is the initial state of the transition diagram where control resides whenwe begin to recognize a token
Positions in a transition diagram are drawn as circles and are called stat
The states are connected by **Arrows,** called edges. Labels on edges are indicating the input characters
The **Accepting** states in which the tokens has been found.
Retract one character use * to indicate states on which this input retraction

.

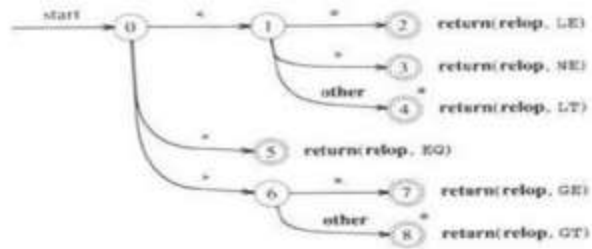**Transition diagram for relational operators**

Fig. 3.12. Transition diagram for relational operators.

Transition diagram for identifiers and keywords
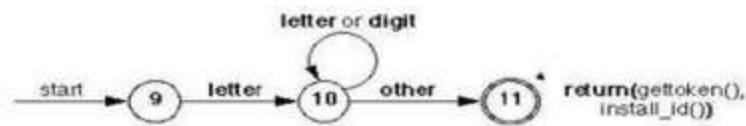
FINITE AUTOMATA

Finite Automata is one of the mathematical models that consist of a number of states and

edges. It is a transition diagram that recognizes a regular expression or grammar.

Types of Finite Automata

There are two types of Finite Automata :

- ✓ Deterministic Finite Automata (DFA)
- ✓ -Non-deterministic Finite Automata (NFA)

Non-deterministic Finite Automata

NFA is a mathematical model that consists of five tuples denoted by M = {Qn, Σ, δ, q0, fn}

Qn - finite set of states
Σ - finite set of input symbols
δ - transition function that maps state-symbol pairs to set of states
q0 - starting state
fn - final state

Deterministic Finite Automata

DFA is a special case of a NFA in which

i) no state has an ε-transition.

ii) there is at most one transition from each state on any input.

DFA has five tuples denoted by M = {Qd, Σ, δ , q0, fd}

Qd - finite set of states
Σ - finite set of input symbols
δ - transition function that maps state-symbol pairs to set of states
q0 - starting state
fd - final state

SYMBOL TABLE

Symbol table is an important data structure created and maintained by compilers in order to store information about the occurrence of various entities such as variable names, function names, objects, classes, interfaces, etc. Symbol table is used by both the analysis and the synthesis parts of a compiler.

- ✓ A symbol table may serve the following purposes depending upon the language in hand:
- ✓ To store the names of all entities in a structured form at one place.
- ✓ To verify if a variable has been declared.
- ✓ To implement type checking, by verifying assignments and expressions in the source code are semantically correct.
- ✓ To determine the scope of a name (scope resolution).

A symbol table is simply a table which can be either linear or a hash table. It maintains an entry for each name in the following format:

      <symbol name, type, attribute>

For example, if a symbol table has to store information about the following variable declaration:

      static int interest;

then it should store the entry such as:

<interest, int, static>

The attribute clause contains the entries related to the name.

Implementation

If a compiler is to handle a small amount of data, then the symbol table can be implemented as an unordered list, which is easy to code, but it is only suitable for small tables only. A symbol table can be implemented in one of the following ways:

- ✓ Linear (sorted or unsorted) list
- ✓ Binary Search Tree
- ✓ Hash table

Among all, symbol tables are mostly implemented as hash tables, where the source code symbol itself is treated as a key for the hash function and the return value is the information about the symbol.

Operations

A symbol table, either linear or hash, should provide the following operations.

insert()

This operation is more frequently used by analysis phase, i.e., the first half of the compiler where tokens are identified and names are stored in the table. This operation is used to add information in the symbol table about unique names occurring in the source code. The format or structure in which the names are stored depends upon the compiler in hand.

An attribute for a symbol in the source code is the information associated with that symbol. This information contains the value, state, scope, and type about the symbol. The insert() function takes the symbol and its attributes as arguments and stores the information in the symbol table.

For example:

int a;

should be processed by the compiler as:

insert(a, int);

lookup()

lookup() operation is used to search a name in the symbol table to determine:

- ✓ if the symbol exists in the table.
- ✓ if it is declared before it is being used.
- ✓ if the name is used in the scope.
- ✓ if the symbol is initialized.
- ✓ if the symbol declared multiple times.

The format of lookup() function varies according to the programming language. The basic format should match the following:

lookup(symbol)

This method returns 0 (zero) if the symbol does not exist in the symbol table. If the symbol exists in the symbol table, it returns its attributes stored in the table.

Scope Management

A compiler maintains two types of symbol tables: a **global symbol table** which can be accessed by all the procedures and **scope symbol tables** that are created for each scope in the program.

To determine the scope of a name, symbol tables are arranged in hierarchical structure as shown in the example below:

```
. . .
int value=10;

void pro_one()
   {
   int one_1;
   int one_2;

      {                \
      int one_3;       |_  inner scope 1
      int one_4;       |
      }                /

   int one_5;

      {                \
      int one_6;       |_  inner scope 2
      int one_7;       |
      }                /
   }

void pro_two()
   {
   int two_1;
   int two_2;

      {                \
      int two_3;       |_  inner scope 3
      int two_4;       |
      }                /

   int two_5;
   }
. . .
```

The above program can be represented in a hierarchical structure of symbol

tables:

The global symbol table contains names for one global variable (int value) and two procedure names, which should be available to all the child nodes shown above. The names mentioned in the pro_one symbol table (and all its child tables) are not available for pro_two symbols and its child tables.

This symbol table data structure hierarchy is stored in the semantic analyzer and whenever a name needs to be searched in a symbol table, it is searched using the following algorithm:

   ✓   first a symbol will be searched in the current scope, i.e. current symbol table.

   ✓   if a name is found, then search is completed, else it will be searched in the parent symbol table until,

   ✓   either the name is found or global symbol table has been searched for the name.

UNIT II

Sno	Questions	Opt1	Opt2	Opt3	Opt4	Answer
1	Which of the following electronic component are not found in ordinary ICs?	Diodes	Resistors	Inductors	Transistors	Inductors
2	Intel 486 is___ bit microprocessor.	8 Bit	16 Bit	32 Bit	64 Bit	32 Bit
3	The graph that shows basic blocks and their successor relationship is called	DAG	Flow graph	Control graph	Hamiltonion graph	Flow graph
4	When a computer is first turned on or resrarted, a special type of absolute loader is executed called	Boot loader	Relating loader	Boot strap loader	" Compile and GO " loader	Boot strap loader
5	Sotware that measures, monitors, analyzes and controls real world events is called	System software	Business software	Scientific software	Real time software	Real time software
6	The root directory of a disk should be placed	at a fixed address in main memory	at a fixed location on the disk	anywhere on the disk	none of these	at a fixed location on the disk
7	Linker and Loader are the _____.	Utility programs	Sub-Task	Sub-problems	Process	Utility programs
8	Dividing a project into segments and smaller units in order to simplify analysis, design and programming efforts is called	Left right approach	Modular approach	Top down approach	Bottom up approach	Modular approach
9	System generation	is always quite simple	is always very difficult	varies in difficulty between systems	requires extensive tools to be understandable	requires extensive tools to be understandable

10	While running DOS on a PC, command which can be used to duplicate the entire diskette is	COPY	DISKCOPY	CHKDSK	TYPE	DISKCOPY
11	A system program which sets up an executable program in main memory ready for execution, is	assembler	linker	loader	compiler	loader
12	Operating system for the laptop computer called MacLite is	windows	DOS	MS-DOS	OZ	OZ
13	Computer general-purpose software is basically a	system software	data base software	package software	application software	system software
14	Special purpose software are	application softwares	system softwares	utility softwares	Bespoke softwares	application softwares
15	In computers, operating system and utility programs are examples of	system software	device drivers	application software	customized software	system software
16	Control, usage and allocation of different hardware components of computer is done by	address bus	system software	application software	data bus	system software
17	Computer software which is designed only for the use of particular customer or organization is called	program	application	customized software	system software	customized software
18	Computer software designed for the use of sale to general public is called	package software	application software	system software	customized software	package software
19	The linker ?	is same as the loader	is required to create a load module	is always used before programs are executed	None of above	is required to create a load module

20	A system program that combines the separately compiled modules of a program into a form suitable for execution ?	Assembler	Linking loader	Cross compiler	Load and Go	Linking loader
21	Loading process can be divided into two separate programs, to solve some problems. The first is binder the other is ?	Linkage editor	Module Loader	Relocator	None of these	Module Loader
22	Load address for the first word of the program is called	Linker address origin	Load address origin	Phase library	Absolute library	Load address origin
23	A linker program	places the program in the memory for the purpose of execution.	relocates the program to execute from the specific memory area allocated to it.	links the program with other programs needed for its execution.	interfaces the program with the entities generating its input data.	links the program with other programs needed for its execution.
24	Resolution of externally defined symbols is performed by	Linker	Loader	Compiler	Editor	Linker
25	Relocatable programs	cannot be used with fixed partitions	can be loaded almost anywhere in memory	do not need a linker	can be loaded only at one specific location	can be loaded almost anywhere in memory
26	Static memory allocation is typically performed during _____.	compilation	execution	loading	linking	compilation
27	Dynamic memory allocation is typically performed during _____.	loading of the program	compilation of the program	execution of the program	None of the above	execution of the program
28	Dynamic memory allocation is implementing using _____.	queue and stacks	trees	stack and heaps	graphs	stack and heaps

29	_____ are used for reduce the main memory requirements of program.	Heaps	Overlays	Graphs	None of the above	Overlays
30	_____is used for reducing relocation requirements.	Relocation register	Track register	Binding register	Segment Register	Segment Register
31	Linking is process of binding	Internal part of a program	external functional call	External reference to the correct link time address	None of the above	External reference to the correct link time address
32	If load origin is not equal to linked origin then relocation is performed by	Loader	Linker	By program itself	Relocation not performed	Loader
33	If linked origin is not equal to translated address then relocation is performed by_____.	Absolute Loader	Loader	Linker	None of the above	Linker
34	Which is not a funciton of a loader	allocation	translation	relocation	loading	translation
35	A system program that set up an executable program in main memory ready for execution is	assembler	linker	loader	text-editor	loader
36	Linker and Loader are the	Utility programs	Sub-Task	Sub-problems	Process	Utility programs
37	_____ converts assembly language programs into object files	Compiler	Assembler	Linker	Loader	Assembler
38	_____ loads the executable module to the main memory.	Interpreter	Linker	Compiler		Loader
39	_____ is the type of linker.	Informal	Linkage Editor	Assembler	Loader	Linkage Editor
40	_____ header describes the size and position of the other pieces of the file.	Object file	Donald Knuth	Source file	Obj file	Object file

41	_____ assemblers perform single scan over the source code.	Two pass	One pass	Three pass	All of these	One pass
42	"opcode" is otherwise called as _____.	operation code	operable code	ope code	Obj code	operation code
43	The mnemonic used to move data from "register to register" is _____.	L	R	LRU	LR	LR
44	Relocating Loader is otherwise called as _____ loader.	Relative	Relational	Redo	Recursive	Relative
45	DLL files that support specific device operation are known as _____.	Bootstrap	device drivers	Parsing	Scheduling	device drivers
46	Source files are converted into a stream of tokens by _____.	Scanner	Memory	Register	Unicode	Scanner
47	_____ is a sequence of characters that can be treated as a single logical entity.	Function	Method	Definition	Token	Token
48	A _____ is a sequence of characters in the source program that is matched by the Pattern.	lexagon	lexeme	Analyser	combine	lexeme
49	A _____ converts the high level instruction into machine language.	Loader	Assembler	Interpreter	compiler	compiler
50	NASM, MASM are the examples for _____.	Analyser	Assembler	Compiler	Linker	Assembler
51	Resolving references among files is done by _____.	Linker	Unicode	Source file	All of these	Linker
52	_____ files contain a combination of machine instructions, data, and information.	Source	Register	Object	Obj code	Object

53	_____ pass reads each line and records labels in a symbol table.	First	Second	Third	First & Second	First
54	_____ takes executable module generated by a linker.	Assembler	Linker editor	Loader	Compiler	Loader
55	_____ segment contains binary representation of data in assembly file.	Data	Text	Object file	Header	Data

Unit III

S.No	Quesiton	Option A	Option B	OPtionC	Option D	Answer
1	_____ is considered as a	Texeme	Pattern	Lexeme	Mexeme	Lexeme
2	What is the name of the process that determining	Analysing	Recognizing	Translating	Parsing	Parsing
3	A _____ is a software utility that translates	Converter	Compiler	Text editor	Code optimizer	Compiler
4	Which of the following derivations does a top-down parser use while parsing an input string?	Leftmost derivation	Leftmost derivation in reverse	Rightmost derivation	Rightmost derivation in reverse	Leftmost derivation
5	The process of assigning load addresses to the various parts of the program and adjusting the code and data in the program to reflect the assigned addresses is called _____	Assembly	Parsing	Relocation	Symbol resolute	Relocation
6	. Which of the following statements is false?	Left as well as right most derivations can be in Unambiguous grammar	An LL (1) parser is a top-down parser	LALR is more powerful than SLR	Ambiguous grammar can't be LR (k)	Left as well as right most derivations can be in Unambiguous grammar

7	Given the following expression grammar:E -> E * F | F+E | F F -> F-F | id which of the following is true?	* has higher precedence than +	– has higher precedence than *	+ and — have same precedence	+ has higher precedence than *	– has higher precedence than *
8	Which of the following grammers are not phase-structured?	regular	context free grammer	context senstive	none	none
9	LR stands for _____	left to right	left to right reduction	right to left	left to right and right most derivation in reverse	left to right and right most derivation in reverse
10	Which of thefoloowing parsersare more powefull	linear list	search tree	hash table	self-organizing list	self-organizing list
11	Which of the following cannot be used as intermediate form?	Postfix notation	Three address code	Syntax trees	qudraples	qudraples
12	Which of the following symbol table implementation is based on ptoperty of locality of reference		search tree	hash table	self-organizing list	self-organizing list
13	Synthenized attribute can be easily simulated by _____	LL grammer	ambiguious grammer	LR grammer	RR grammer	LR grammer

14	A pictorial representation of value computed by each statement in basic block is _____	tree	DAG	Graph	none	DAG
15	Three address code involves _____	excatly 3 address	at the most 3 address	no unary operators	none	at the most 3 address
16	When is type checking is done ?	during syntax directed translation	during lexical analysis	during syntax analysis	during code optimizatio n	during syntax directed translation
17	Which of the following is/are grouped together into sematic structures?	Syntax analyzer	Semantic analyzer	Lexical analyzer	Intermediat e code generation	Lexical analyzer
18	Which of the following describes a handle (as applicable to LR-parsing) appropriately?	It is the position in a sentential form where the next shift or reduce operation will occur	It is non-terminal whose production will be used for reduction in the next step	It is a production that may be used for reduction in a future step along with a position in the sentential form where the next shift or reduce operation will occur	It is the production p that will be used for reduction in the next step along with a position in the sentential form where the right hand side of the production may be found	It is the production p that will be used for reduction in the next step along with a position in the sentential form where the right hand side of the production may be found
19	Which one of the following is a top-down parser?	Recursive descent parser	Operator precedence parse	An LR(k) parser	An LALR(k) parser	Recursive descent parser

20	Which of the following suffices to convert an arbitrary CFG to an LL(1) grammar?	Removing left recursion alone	Factoring the grammar alone	Removing left recursion and factoring the grammar	None of these	None of these
21	In a bottom-up evaluation of a syntax directed definition, inherited attributes can	always be evaluated	be evaluated only if the definition is L--attributed	be evaluated only if the definition has synthesized attributes	never be evaluated	be evaluated only if the definition is L--attributed
22	Consider the grammar shown below. S → C C C → c C | d The grammar is	LL(1)	SLR(1) but not LL(1)	LALR(1) but not SLR(1)	LR(1) but not LALR(1)	LL(1)
23	Which of the following statements is false?	An unambiguous grammar has same leftmost and rightmost derivation	An LL(1) parser is a top-down parser	LALR is more powerful than SLR	An ambiguous grammar can never be LR(k) for any k	An unambiguous grammar has same leftmost and rightmost derivation
24	Which one of the following is True at any valid state in shift-reduce parsing?	Viable prefixes appear only at the bottom of the stack and not inside	Viable prefixes appear only at the top of the stack and not inside	The stack contains only a set of viable prefixes	The stack never contains viable prefixes	The stack contains only a set of viable prefixes

25	In the context of abstract-syntax-tree (AST) and control-flow-graph (CFG), which one of the following is True?	In both AST and CFG, let node N2 be the successor of node N1. In the input program, the code corresponding to N2 is present after the code corresponding to N1	For any input program, neither AST nor CFG will contain a cycle	The maximum number of successors of a node in an AST and a CFG depends on the input program	Each node in AST and CFG corresponds to at most one statement in the input program	The maximum number of successors of a node in an AST and a CFG depends on the input program
26	Some code optimizations are carried out on the intermediate code because _____	they enhance the portability of the compiler to other target processors	program analysis is more accurate on intermediate code than on machine code	the information from dataflow analysis cannot otherwise be used for optimization	the information from the front end cannot otherwise be used for optimization	they enhance the portability of the compiler to other target processors
27	One of the purposes of using intermediate code in compilers is to _____	make parsing and semantic analysis simpler	improve error recovery and error reporting	increase the chances of reusing the machine-independent code optimizer in other compilers	improve the register allocation	increase the chances of reusing the machine-independent code optimizer in other compilers

28	What is the maximum number of reduce moves that can be taken by a bottom-up parser for a grammar with no epsilon- and unit-production (i.e., of type A -> ε and A -> a) to parse a string with n tokens?	n/2	n-1	2n-1	2n	n-1
29	The grammar S → aSa | bS | c is	LL(1) but not LR(1)	LR(1)but not LL(1)	Both LL(1)and LR(1)	Neither LL(1)nor LR(1	Both LL(1)and LR(1)
30	For predictive parsing the grammar A->AA I (A) I ε is not suitable because	The grammar is right recursive	The grammar is left recursive	The grammar is ambiguous	The grammar is an operator grammar	The grammar is left recursive
31	How many tokens are there in the following C statement? printf ("j=%d, &j=%x", j&j)	4	5	9	10	10
32	In a compiler, the data structure responsible for the management of information about variables and their attributes is	Semantic stack	Parser table	Symbol table	Abstract syntax-tree	Symbol table

33	One of the purposes of using intermediate code in compilers is to	make parsing and semantic analysis simpler.	improve error recovery and error reporting	increase the chances of reusing the machine-independent code optimizer in other compilers.	improve the register allocation.	increase the chances of reusing the machine-independent code optimizer in other compilers.
34	Syntax directed translation scheme is desirable because	It is based on the syntax	Its description is independent of any implementation	It is easy to modify	All of these	It is easy to modify
35	A top down parser generates	Right most derivation	Right most derivation in reverse	Left most derivation	Left most derivation in reverse	Left most derivation
36	Intermediate code generation phase gets input from	Lexical analyzer	Syntax analyzer	Semantic analyzer	Error handling	Semantic analyzer
37	An intermediate code form is	Postfix notation	Syntax trees	Three address code	All of these	All of these
38	Input to code generator	Source code	Intermediate code	Target code	All of the above	Intermediate code
39	A grammar is meaningless	If terminal set and non terminal set are not disjoint	If left hand side of a production is a single terminal	If left hand side of a production has no non terminal	All of these	If terminal set and non terminal set are not disjoint
40	Pee hole optimization	Loop optimization	Local optimization	Constant folding	Data flow analysis	Constant folding
41	Which is not true about syntax and semantic parts of a computer language	syntax is generally checked by the programmer	semantics is the responsibility of the programmer	semantics is checeked mechanically by a computer	both (b) and (c)	both (b) and (c)

42	Which of the following grammers are not phase structured ?	regular	context free gramm	context sensitive	none of these	none of these
43	Any syntactic constrct that can be described by a regular expression can also be described by a _____	context sensitive grammar	non-context free grammar	context free grammar	none of these	context free grammar
44	In which addressing mode, the operand is given explicitly in the instruction itself?	absolute mode	immediate mode	.indirect mode	index mode	immediate mode
45	CC stands for _____ __	yet accept compiler constructs	.yet accept compiler compiler	yet another compiler constructs	yet another compiler compiler	yet another compiler compiler
46	An ideal computer should a) be small in size b) produce object code that is smaller in size and executes into tokens in a compiler	parser	cose optimize	.code generator	.scanner	.scanner
47	A lex program consists of _____	declarations	.auxillary procedure	.translation rules	.all of these	.all of these
48	Which of the following pairs is the most powerful?	SLR, LALR	Canonical LR ,LALR	SLR canonical LR	LALR canonical LR	SLR canonical LR
49	Which phase of compiler is Syntax Analysis?	First	Second	Third	Fourth	Second

| 50	What is Syntax Analyser also known as ?	Hierarchical Analysis	Hierarchical Parsing	None of the mentioned	Hierarchical Analysis & Parsing	Hierarchical Analysis & Parsing
51	Syntax Analyser takes Groups Tokens of source Program into Grammatical Production	TRUE	FALSE	NULL	None	TRUE
52	Parsers are expected to parse the whole code	TRUE	FALSE	NULL	None	TRUE
53	A grammar for a programming language is a formal description of _____	Syntax	Semantics	Structure	Library	Structure
54	An LR-parser can detect a syntactic error as soon as _____	The parsing starts	It is possible to do so a left-to-right scan of the input.	It is possible to do so a right-to-left scan of the input.	Parsing ends	It is possible to do so a left-to-right scan of the input.
55	Which of the following is incorrect for the actions of A LR-Parser I) shift s ii) reduce A->ß iii) Accept iv) reject?	Only I)	I) and ii)	I), ii) and iii)	I), ii) , iii) and iv)	I), ii) and iii)
56	If a state does not know whether it will make a shift operation or reduction for a terminal is called	Shift/reduce conflict	Reduce /shift conflict	Shift conflict	Reduce conflict	Shift/reduce conflict

57	When there is a reduce/reduce conflict?	If a state does not know whether it will make a shift operation	If a state does not know whether it will make a shift or reduction operation	If a state does not know whether it will make a reduction operation	None of the mentioned	If a state does not know whether it will make a reduction operation using the
58	Which of these is also known as look-head LR parser?	SLR	LR	LLR	None	LLR
59	What is the similarity between LR, LALR and SLR?	Use same algorithm, but different parsing table	Same parsing table, but different algorithm.	Their Parsing tables and algorithm are similar but uses top down approach.	Both Parsing tables and algorithm are different.	Use same algorithm, but different parsing table

KARPAGAM ACADEMY OF HIGHER EDUCATION

CLASS : II B.SC CS	**COURSE NAME: System Programming**
COURSE CODE: 16CSU601B	**BATCH: 2016-2019**
UNIT III: PARSING	

UNIT III

SYLLABUS

Bottom up parsing- LR parser, YACC. **Intermediate representations: Three** address code generation, syntax directed translation, translation of types, control Statements.

Syntax Analyzer

A syntax analyzer or parser takes the input from a lexical analyzer in the form of token streams. The parser analyzes the source code (token stream) against the production rules to detect any errors in the code. The output of this phase is a parse tree.
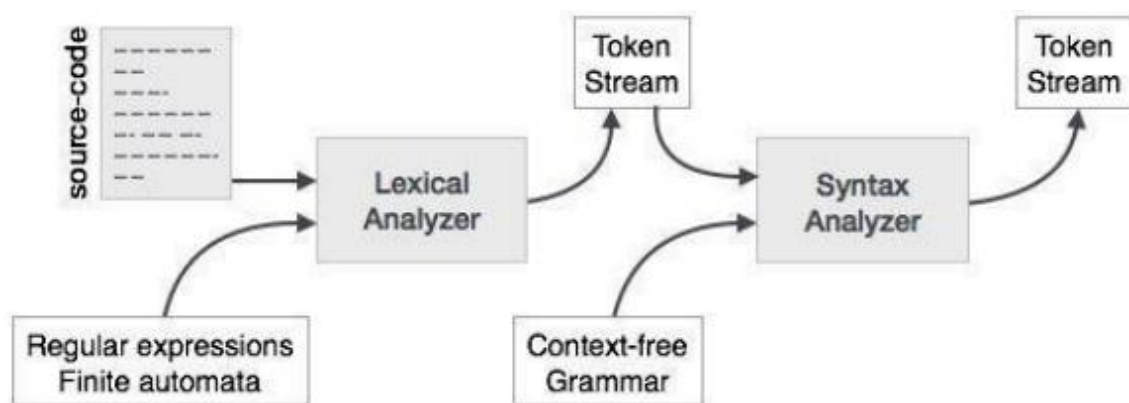
Working principle Syntax Analyzer

In this way, the parser accomplishes two tasks, i.e., parsing the code and looking forerrors. Finally a parse tree is generated as the output of this phase. Parsers are expected to parse the whole code even if some errors exist in the program.Parsers use error recovering strategies.

**Limitations of Syntax Analyzers**

Syntax analyzers receive their inputs, in the form of tokens, from lexical analyzers. Lexical analyzers are responsible for the validity of a token supplied by the syntax analyzer. Syntax analyzers have the following drawbacks:

- it cannot determine if a token is valid,
- it cannot determine if a token is declared before it is being used,
- it cannot determine if a token is initialized before it is being used,
- It cannot determine if an operation performed on a token type is valid or not.

These tasks are accomplished by the semantic analyzer, which we shall study inSemantic Analysis.

Types of Parsing

Syntax analyzers follow production rules defined by means of context-free grammar.The way the production rules are implemented (derivation) divides parsing into two types:top-down parsing and bottom-up parsing.
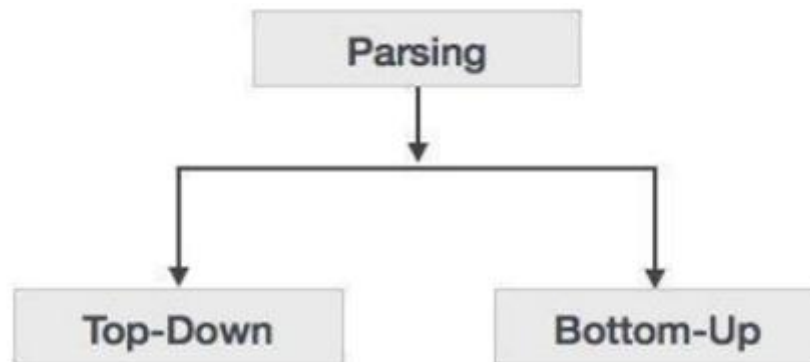
Top-down Parsing

When the parser starts constructing the parse tree from the start symbol and thentries to transform the start symbol to the input, it is called top-down parsing.

Recursive descent parsing: It is a common form of top-down parsing. It is calledrecursive, as it uses recursive procedures to process the input. Recursive descentparsing suffers from backtracking.

Backtracking: It means, if one derivation of a production fails, the syntax analyser restarts the process using different rules of same production. This technique mayprocess the input string more than once to determine the right production.
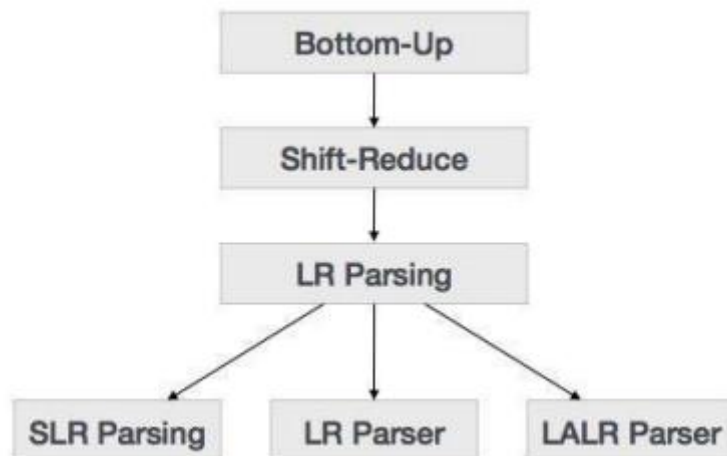
Bottom-up Parsing

As the name suggests, bottom-up parsing starts with the input symbols and tries toconstruct the parse tree up to the start symbol.

Note:

In both the cases the input to the parser is being scanned from left to right, onesymbol at a time.The bottom-up parsing method is called "Shift Reduce" parsing. The top-down parsingis called "Recursive Decent" parsing.

Bottom-up parsing starts from the leaf nodes of a tree and works in upward directiontill it reaches the root node. Here, we start from a sentence and then apply productionrules in reverse manner in order to reach the start symbol. The image given below depictsthe bottom-up parsers available

An operator-precedence parser is one kind of shift reduce parser and predictive parseris one kind of recursive descent parser.

Shift reduce parsing methods

It is called as bottom up style of parsing. Shift-reduce parsing uses two unique steps for bottom-up parsing. These steps are known as shift-step and reduce-step.

Shift step

The shift step refers to the advancement of the input pointer to the next input symbol, which is called the shifted symbol. This symbol is pushed onto the stack. The shifted symbol is treated as a single node of the parse tree.

Reduce step

When the parser finds a complete grammar rule (RHS) and replaces it to (LHS), it is known as reduce-step. This occurs when the top of the stack contains a handle. To reduce, a POP function is performed on the stack which pops off the handle and replaces it with LHS non-terminal symbol.

Reducing a string W to the start symbol S of a grammar.

At each step a string matching the right side of a production is replaced by the symbol on the left.

Example:

```
S→ aAcBe; A→Ab; A→ b; B→d and the string is abbcde, we have to reduce it to S.
   Abbcde → abbcBe
          → aAbcBe
          → aAcBe
          →S
```

Each replacement of the right side of the production the left side in the process above is called reduction .by reverse of a right most derivation is called Handle

$S^* \rightarrow \alpha A w \rightarrow \alpha \beta w, then\ A \rightarrow \beta$ in partition following is a handle of αβw. The string w to the right of the handle contains only terminal symbol.

A rightmost derivation in reverse often called a canonical reduction sequence, is obtained by "Handle Pruning".

Example:
$$E \rightarrow E+E$$
$$E \rightarrow E*E$$
$$E \rightarrow (E)$$
$$E \rightarrow id$$
Input: $id_1+id_2*id_3 \rightarrow E$

Right Sentential Form	Handle	Reducing production
$id_1+id_2*id_3$	id_1	$E \rightarrow id$
$E+id_2*id_3$	id_2	$E \rightarrow id$
$E+E*id_3$	id_3	$E \rightarrow id$
$E+E*E$	$E*E$	$E \rightarrow E*E$
$E+E$	$E+E$	$E \rightarrow E+E$
E		

LR Parser

The LR parser is a non-recursive, shift-reduce, bottom-up parser. It uses a wide classof context-free grammar which makes it the most efficient syntax analysis technique. LR parsers are also known as LR(k) parsers, where L stands for left-to-right scanning of the input stream; R stands for the construction of right-most derivation in reverse, and k denotes the number of look ahead symbols to make decisions.

An LL Parser accepts LL grammar. LL grammar is a subset of context-free grammar but with some restrictions to get the simplified version, in order to achieve easy implementation. LL grammar can be implemented by means of both algorithms, namely, recursive-descent or table-driven.

LL parser is denoted as LL(k). The first L in LL(k) is parsing the input from left to right, the second L in LL(k) stands for left-most derivation and k itself represents the number of look aheads. Generally k = 1, so LL(k) may also be written as LL(1).

LL	LR
Does a leftmost derivation.	Does a rightmost derivation in reverse.
Starts with the root nonterminal on the stack	Ends with the root nonterminal on the stack.
Ends when the stack is empty	Starts with an empty stack.
Uses thestack for designating what is still to be expected.	Uses the stack for designating what is already seen
Builds the parse tree top-down.	Builds the parse tree bottom-up.
Continuously pops a nonterminal off the stack, and pushes the corresponding right hand side.	Tries to recognize a right hand side on thestack, pops it, and pushes the corresponding nonterminal.

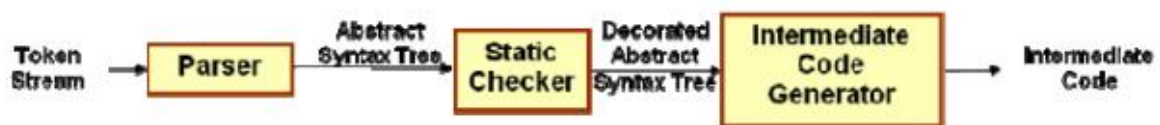|	
Expands the non-terminals	Reduces the non-terminals.
Reads the terminals when it pops one off the stack.	Reads the terminalswhile itpushes them on the stack.
Pre-order traversal of the parse tree.	Post-order traversal of the parse tree

INTERMEDIATE CODE GENERATION

Intermediate code forms:

An intermediate code form of source program is an internal form of a program created by the compiler while translating the program created by the compiler while translating the program from a high –level language to assembly code(or)object code(machine code).an intermediate source form represents a more attractive form of target code than does assembly. An optimizing Compiler performs optimizations on the intermediate source form and produces an object module.

Analysis + syntheses=translation

Creates an generate   target code

Intermediate code

Logical Structure of a Compiler Front End

In the analysis –synthesis model of a compiler, the front-end translates a source program into anintermediate representation from which the back-end generates target code, in many compilers thesource code is translated into a language which is intermediate in complexity between a HLL andmachine code .the usual intermediate code introduces symbols to stand for various temporaryquantities.

Intermediate representations span the gap between the source and target languages.

• High Level Representations

- closer to the source language
- easy to generate from an input program
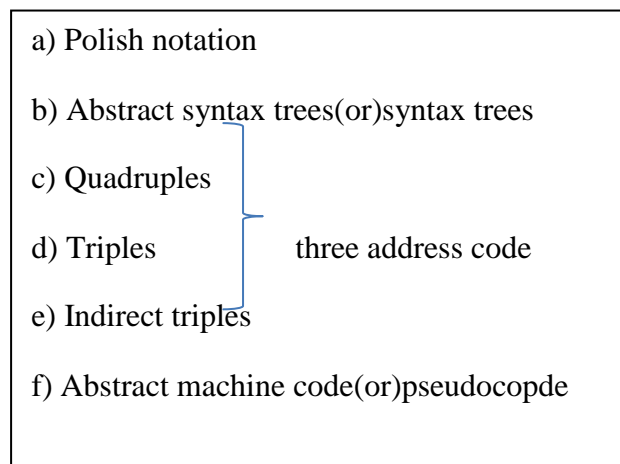- code optimizations may not be straightforward

• Low Level Representations

- closer to the target machine
- Suitable for register allocation and instruction selection
- easier for optimizations, final code generation

There are several options for intermediate code. They can be either Specific to the language being implemented

- P-code for Pascal
- Byte code for Java

We assume that the source program has already been parsed and statically checked.. the variousintermediate code forms are:

a) Polish notation

b) Abstract syntax trees(or)syntax trees

c) Quadruples

d) Triples   three address code

e) Indirect triples

f) Abstract machine code(or)pseudocopde

Postfix

The ordinary (infix) way of writing the sum of a and b is with the operator in the middle: a+b. thepostfix (or postfix polish)notation for the same expression places the operator at the right end, as ab+.In general, if e1 and e2 are any postfix expressions, and Ø to the values denoted by e1 and e2 isindicated in postfix notation nby e1e2Ø.no parentheses are needed in postfix notation because theposition and priority (number of arguments) of the operators permits only one way to decode apostfix expression.

Example:

1. (a+b)*c in postfix notation is ab+c*,sinceab+ represents the infix expression(a+b).

2. a*(b+c)is abc+* in postfix.

3. (a+b)*(c+d) is ab+cd+* in postfix.

Postfix notation can be generalized to k-ary operators for any k>=1.if k-ary operator Ø is applied topostfix expression e1,e2,……….ek, then the result is denoted by e1e2…….ek Ø. if we know thepriority of each operator then we can uniquely decipher any postfix expression by scanning it fromeither end.

Example:

Consider the postfix string ab+c*.

The right hand * says that there are two arguments to its left. since the next –to-rightmost symbol isc, simple operand, we know c must be the second operand of *.continuing to the left, we encounterthe operator +.we know the sub expression ending in + makes up the first operand of
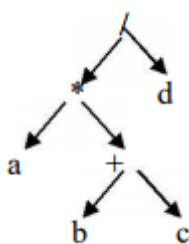
.continuing in this way ,we deduce that ab+c is "parsed" as (((a,b)+),c)*.

b. **syntax tree**:

The parse tree itself is a useful intermediate-language representation for a source program,especially in optimizing compilers where the intermediate code needs to extensively restructure.
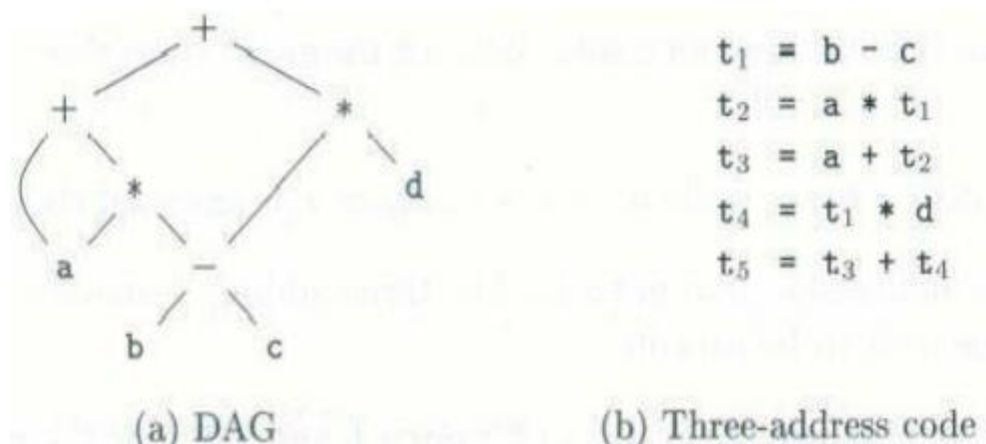
A parse tree, however, often contains redundant information which can be eliminated, Thusproducing a more economical representation of the source program. One such variant of a parse treeis what is called an (abstract) syntax tree, a tree in which each leaf represents an operand and eachinterior node an operator.

Exmples: 1) Syntax tree for the expression a*(b+c)/d

c.Three-Address Code: • In three-address code, there is at most one operator on the right side of aninstruction; that is, no built-up arithmetic expressions are permitted.

x+y*z t1 = y * z t2 = x + t1 • Example

$$t_1 = b - c$$
$$t_2 = a * t_1$$
$$t_3 = a + t_2$$
$$t_4 = t_1 * d$$
$$t_5 = t_3 + t_4$$

(a) DAG   (b) Three-address code

LANGUAGE INDEPENDENT 3-ADDRESS CODE

IR can be either an actual language or a group of internal data structures that are shared by the phases of the compiler. C used as intermediate language as it is flexible, compiles into efficient machine code and its compilers are widely available.In all cases, the intermediate code is a linearization of the syntax tree produced during syntax and semantic analysis. It is formed by breaking down the tree structure into sequential instructions, each of which is equivalent to a single, or small number of machine instructions.

Machine code can then be generated (access might be required to symbol tables etc). TAC can range from high- to low-level, depending on the choice of operators. In general, it is a statement containing at most 3 addresses or operands. The general form is x := y op z, where "op" is an operator, x is the result, and y and z are operands. x, y, z are variables, constants, or "temporaries". A three-address instruction consists of at most 3 addresses for each statement.

It is a linear zed representation of a binary syntax tree. Explicit names correspond to interiornodes of the graph. E.g. for a looping statement , syntax tree represents components of thestatement, whereas three-address code contains labels and jump instructions to represent theflow-of-control as in machine language. A TAC instruction has at most one operator on theRHS of an instruction; no built-up arithmetic expressions are permitted.

e.g. x + y * z can be translated as

t1 = y * z

t2 = x + t1

Where t1 & t2 are compiler–generated temporary names.

Since it unravels multi-operator arithmetic expressions and nested control-flow statements,it is useful for target code generation and optimization.

Addresses and Instructions

• TAC consists of a sequence of instructions, each instruction may have up to threeaddresses, prototypically t1 = t2 op t3

• Addresses may be one of:

o A name. Each name is a symbol table index. For convenience, we writethe namesas the identifier.

o A constant.

o A compiler-generated temporary. Each time a temporary address is needed, thecompiler generates another name from the stream t1, t2, t3, etc.

> • Temporary names allow for code optimization to easily move Instructions

> • At target-code generation time, these names will be allocated to registers or to memory.

> • TAC Instructions

o Symbolic labels will be used by instructions that alter the flow of control.

The instruction addresses of labels will be filled in later.

L: t1 = t2 op t3

o Assignment instructions: x = y op z

> • Includes binary arithmetic and logical operations

o Unary assignments: x = op y

Includes unary arithmetic op (-) and logical op (!) and typeconversion

o Copy instructions: x = y

o Unconditional jump: goto L

• L is a symbolic label of an instruction

o Conditional jumps:

if x goto L If x is true, execute instruction L next

ifFalse x goto L If x is false, execute instruction L next

o Conditional jumps:

if x relop y goto L

– **Procedure** calls. For a procedure call p(x1, …,xn)

param x1

…

paramxn

call p, n

– **Function**calls : y= p(x1, …, xn) y = call p,n , return y

Types of three address code

There are different types of statements in source program to which three address code has to

be generated. Along with operands and operators, three address code also use labels to

provide flow of control for statements like if-then-else, for and while. The different types of

three address code statements are:

Assignment statement

a = b op c

In the above case b and c are operands, while op is binary or logical operator. The result of

applying op on b and c is stored in a.

Unary operation

a = op b This is used for unary minus or logical negation.

Example: a = b * (- c) + d

Three address code for the above example will be

t1 = -c

t2 = t1 * b

t3 = t2 + d

a = t3

Copy Statement

a=b

The value of b is stored in variable a.

Unconditional jump

goto L

Creates label L and generates three-address code 'goto L'

v. Creates label L, generate code for expression exp, If the exp returns value true then go to

the statement labelled L. exp returns a value false go to the statement immediately following

the if statement.

Function call

For a function fun with n arguments a1,a2,a3….an ie.,

fun(a1, a2, a3,…an),

the three address code will be

Param a1

Param a2

…

Param an

Call fun, n

Where param defines the arguments to function.

Array indexing

In order to access the elements of array either single dimension ormultidimension, three address code requires base address and offset value. Base addressconsists of the address of first element in an array. Other elements of the array can beaccessed using the base address and offset value.

Example: x = y[i]

Memory location m = Base address of y + Displacement i

x = contents of memory location m

similarly x[i] = y

Memory location m = Base address of x + Displacement i

The value of y is stored in memory location m

Pointer assignment

x = &y x stores the address of memory location y

x = *y y is a pointer whose r-value is location

*x = y sets r-value of the object pointed by x to the r-value of y

Intermediate representation should have an operator set which is rich to implement. Theoperations of source language. It should also help in mapping to restricted instruction set oftarget machine.

QUADRUPLES-

Quadruples consists of four fields in the record structure. One field to store operator op, twofields to store operands or arguments arg1and arg2 and one field to store result res. res = arg1op arg2

Example: a = b + c

b is represented as arg1, c is represented as arg2, + as op and a as res.

Unary operators like '-'do not use agr2. Operators like param do not use agr2 nor result. Forconditional and unconditional statements res is label. Arg1, arg2 and res are pointers tosymbol table or literal table for the names.

Example: a = -b * d + c + (-b) * d

Three address code for the above statement is as follows

t1 = - b

t2 = t1 * d

t3 = t2 + c

t4 = - b

t5 = t4 * d

t6 = t3 + t5

a = t6

Quadruples for the above example is as follows

Op	Arg1	Arg2	Res
-	B		t1
*	t1	d	t2
+	t2	c	t3
-	B		t4
*	t4	d	t5
+	t3	t5	t6
=	t6		a

TRIPLES

Triples uses only three fields in the record structure. One field for operator, two fields foroperands named as arg1 and arg2. Value of temporary variable can be accessed by theposition of the statement the computes it and not by location as in quadruples.

Example: a = -b * d + c + (-b) * d

Triples for the above example is as follows

Stmt no	Op	Arg1	Arg2
(0)	-	b	
(1)	*	d	(0)
(2)	+	c	(1)
(3)	-	b	
(4)	*	d	(3)
(5)	+	(2)	(4)
(6)	=	a	(5)

Arg1 and arg2 may be pointers to symbol table for program variables or literal table forconstant or pointers into triple structure for intermediate results.Example: Triples for statement x[i] = y which generates two records is as follows

Stmt no	Op	Arg1	Arg2
(0)	[]=	x	i
(1)	=	(0)	y

INDIRECT TRIPLES

Indirect triples are used to achieve indirection in listing of pointers. That is, it uses pointers totriples than listing of triples themselves.

Example: a = -b * d + c + (-b) * d

	Stmt no	Stmt no	Op	Arg1	Arg2
(0)	(10)	(10)	-	b	
(1)	(11)	(11)	*	d	(0)
(2)	(12)	(12)	+	c	(1)
(3)	(13)	(13)	-	b	
(4)	(14)	(14)	*	d	(3)
(5)	(15)	(15)	+	(2)	(4)
(6)	(16)	(16)	=	a	(5)

Conditional operator and operands. Representations include quadruples, triples and indirect triples

SYNTAX DIRECTED TRANSLATION

- The Principle of Syntax Directed Translation states that the meaning of an input sentence is related to its syntactic structure, i.e., to its Parse-Tree.
- By Syntax Directed Translations we indicate those formalisms for specifying translations for programming language constructs guided by context-free grammars.
    - We associate Attributes to the grammar symbols representing the language constructs.
    - Values for attributes are computed by Semantic Rules associated with grammar productions.
- Evaluation of Semantic Rules may:
    - Generate Code;
    - Insert information into the Symbol Table;

- o Perform Semantic Check;
- o Issue error messages;
- o etc.

There are two notations for attaching semantic rules:

1. *Syntax Directed Definitions*. High-level specification hiding many implementationdetails (also called Attribute Grammars).

2. *Translation Schemes*. More implementation oriented: Indicate the order in whichsemantic rules are to be evaluated.

Syntax Directed Definitions

• Syntax Directed Definitions are a generalization of context-free grammars in which:

1. Grammar symbols have an associated set of Attributes;

2. Productions are associated with Semantic Rules for computing the values of attributes.

- Such formalism generates Annotated Parse-Trees where each node of the tree is a record with a field for each attribute (e.g.,X.a indicates the attribute a of the grammarsymbol X).
- The value of an attribute of a grammar symbol at a given parse-tree node is defined bya semantic rule associated with the production used at that node.

We distinguish between two kinds of attributes:

1. Synthesized Attributes. They are computed from the values of the attributes of thechildren nodes.

2. Inherited Attributes. They are computed from the values of the attributes of both thesiblings and the parent nodes

Syntax Directed Definitions: An Example

• Example. Let us consider the Grammar for arithmetic expressions. TheSyntax Directed Definition associates to each non terminal a synthesizedattribute called val.

PRODUCTION	SEMANTIC RULE
$L \rightarrow En$	$print(E.val)$
$E \rightarrow E_1 + T$	$E.val := E_1.val + T.val$
$E \rightarrow T$	$E.val := T.val$
$T \rightarrow T_1 * F$	$T.val := T_1.val * F.val$
$T \rightarrow F$	$T.val := F.val$
$F \rightarrow (E)$	$F.val := E.val$
$F \rightarrow digit$	$F.val := digit.lexval$

S-ATTRIBUTED DEFINITIONS

Definition. An S-Attributed Definition is a Syntax Directed Definition that usesonly synthesized attributes.

• Evaluation Order. Semantic rules in a S-Attributed Definition can beevaluated by a bottom-up, or PostOrder, traversal of the parse-tree.

• Example. The above arithmetic grammar is an example of an S-AttributedDefinition. The annotated parse-tree for the input 3*5+4n is:
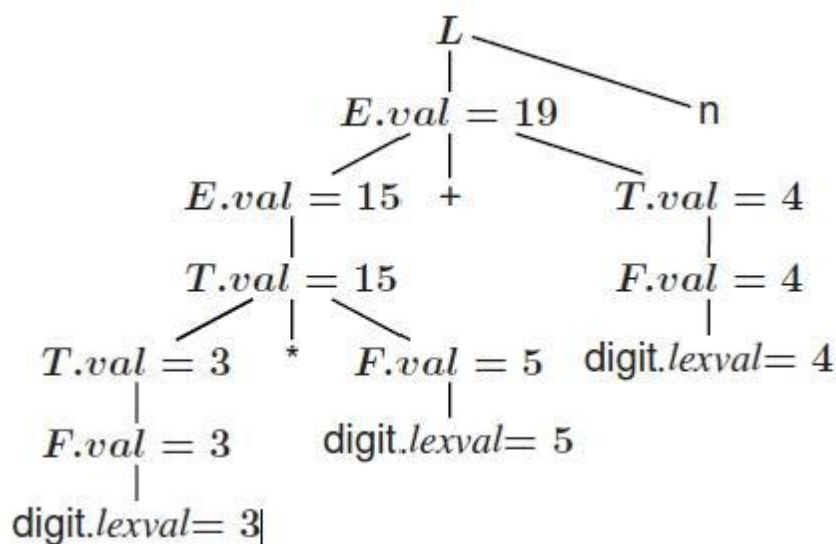
L-attributed definition

A SDD its L-attributed if each inherited attribute of Xi in the RHS of A !X1 :

:Xn depends only on

1. attributes of X1;X2; : : : ;Xi□1 (symbols to the left of Xi in the RHS)

---

2. inherited attributes of A.

Restrictions for translation schemes:

1. Inherited attribute of Xi must be computed by an action before Xi.

2. An action must not refer to synthesized attribute of any symbol to the right of that action.

3. Synthesized attribute for A can only be computed after all attributes it references have

been completed (usually at end of RHS).

Applications of Syntax-Directed Translation

• Construction of syntax Trees

− The nodes of the syntax tree are represented by objects with a suitable number of fields.

− Each object will have an op field that is the label of the node.

− The objects will have additional fields as follows

• If the node is a leaf, an additional field holds the lexical value for the leaf. A constructor function Leaf (op, val) creates a leaf object.

• If nodes are viewed as records, the Leaf returns a pointer to a new record for a leaf.

• If the node is an interior node, there are as many additional fields as the node has children in the syntax tree. A constructor function

Node takes two or more arguments:

Node (op , c1,c2,…..ck) creates an object with first field op and k additional fields for the k children c1,c2,…..ck

Syntax-Directed Translation Schemes

A SDT scheme is a context-free grammar with program fragments embedded within production bodies .The program fragments are called semantic actions and can appear at any position within the production body.

Any SDT can be implemented by first building a parse tree and then pre-forming the actions in a left-to-right depth first order. i.e during preorder traversal.

The use of SDT's to implement two important classes of SDD's

1. If the grammar is LR parsable, then SDD is S-attributed.

2. If the grammar is LL parsable, then SDD is L-attributed.

Postfix Translation Schemes

The postfix SDT implements the desk calculator SDD with one change: the action for the first production prints the value. As the grammar is LR, and the SDD is S-attributed.

L →E n {print(E.val);}

E → E1 + T { E.val = E1.val + T.val }

E → E1 - T { E.val = E1.val - T.val }

E → T { E.val = T.val }

T → T1 * F { T.val = T1.val * F.val } T → F { T.val = F.val }

F → (E) { F.val = E.val }

F → digit { F.val = digit.lexval }

	PRODUCTION	SEMANTIC RULES
1)	$E \rightarrow E_1 + T$	$E.node = \textbf{new } Node('+', E_1.node, T.node)$
2)	$E \rightarrow E_1 - T$	$E.node = \textbf{new } Node('-', E_1.node, T.node)$
3)	$E \rightarrow T$	$E.node = T.node$
4)	$T \rightarrow (E)$	$T.node = E.node$
5)	$T \rightarrow \textbf{id}$	$T.node = \textbf{new } Leaf(\textbf{id}, \textbf{id}.entry)$
6)	$T \rightarrow \textbf{num}$	$T.node = \textbf{new } Leaf(\textbf{num}, \textbf{num}.val)$

UNIT IV

S.No	Question	Option A	Option B	Option C	Option D	Answer
1	The average time required to reach a storage	Seek time	Turn around time	transfer time	access time	access time
2	What characteristic of RAM memory makes it not suitable for permanent storage?	Too slow	Unreliable	It is volatile	Too bulky	It is volatile
3	Assembly language _____	Uses alphabetic codes in place of	Is the easiest language to write	Need not be translated into machine language	None of the mentioned	Uses alphabetic codes in place of binary
4	Select a Machine	Syntax Analysis	Intermediate Code	Lexical analysis	all the above	all the above
5	Which of the following system software resides in the main memory always	Text Editor	Assembler	Linker	Loader	Loader
6	Which of these features of	Instruction formats	Addressing modes	Program relocation	All of the mentioned	All of the mentioned
7	Which of these is not true about Symbol	All the labels of the instructions	Table has entry for symbol	Perform the processing of the	Created during pass 1	Perform the processing of the assembler
8	In Reverse Polish notation, expression A*B+C*D is written as	AB*CD*+	A*BCD*+	AB*CD+*	A*B*CD+	AB*CD*+
9	The circuit converting binary data in to decimal is_____	Encoder	Multiplexer	Decoder	Code converter	Code converter

10	In computers, subtraction is carried out generally by____	1's complement method	2's complement method	signed magnitude method	BCD subtraction method	2's complement method
11	The identification of common sub-expression and replacement of run-time computations by compile-time computations is	local optimization	loop optimization	constant folding	data flow analysis	constant folding
12	The graph that shows basic blocks and their successor relationship is called	DAG	Hamiltonion graph	Flow graph	control graph	Flow graph
13	The specific task storage manager performs	allocation/ deallocation of storage to programs	protection of storage area allocated to a program from illegal access by othere programs in the system	the status of each program	both (a) and (b)	both (a) and (b)
14	When a computer is first turned on or resrarted, a special type of absolute loader is executed called	" Compile and GO " loader	Boot loader	Boot strap loader	Relating loader	Boot strap loader

15	Function of the storage assignment is	assign storage to all variables referenced in the source program	assign storage to all temporary locations that are necessary for intermediate results	assign storage to literals, and to ensure that the storage is allocated and appropriate locations are initialized	all of these	all of these
16	Relocation bits used by relocating loader are specified by	relocating loader itself	linker	assembler	macro processor	linker
17	Running time of a program depends on	the way the registers and addressing modes are use	the order in which computations are performed	the usage of machine idioms	all of these	all of these
18	Advantage of panic mode of error recovery is that	it is simple to implement	it never gets into an infinite loop	both (a) and (b)	none of these	both (a) and (b)
19	Which of the following can be accessed by transfer vector approach of linking ?	external data segments	external sub-routines	data located in other procedure	all of these	external sub-routines
20	Generation of intermediate code based on a abstract machine model is useful in compilers because	it makes implementation of lexical analysis and syntax analysis easier	syntax directed translations can be written for intermediate code generation	it enhances the portability of the front end of the compiler	it is not possible to generate code for real machines directly from high level language programs	it makes implementation of lexical analysis and syntax analysis easier

21	Which of the following module does not incorporate initialization of values changed by the module ?	non reusable module	serially reusable module	re-enterable module	all of these	non reusable module
22	A self-relocating program is one which	cannot be made to execute in any area of storage other than the one designated for it at the time of its coding or translation	consists of a program and relevant information for its relocation	can itself perform the relocation of its address sensitive portions	all of these	can itself perform the relocation of its address sensitive portions
23	The string (a)|((b)*(c)) is equivalent to	Empty	abcabc	b*c|a	None of the mentioned	b*c|a
24	Which one of the following statements is FALSE ?	Context-free grammar can be used to specify both lexical and syntax rules.	Type checking is done before parsing.	High-level language programs can be translated to different Intermediate Representations.	Arguments to a function can be passed using the program stack.	Type checking is done before parsing.
25	Some code optimizations are carried out on the intermediate code because	they enhance the portability of the compiler to other target processors	program analysis is more accurate on intermediate code than on machine code	the information from dataflow analysis cannot otherwise be used for optimization	the information from the front end cannot otherwise be used for optimization	they enhance the portability of the compiler to other target processors

26	A non relocatable program is the one which	cannot be made to execute in any area of storage other than the one designated for it at the time of its coding or translation	consists of a program and relevant information for its relocation	can itself perform the relocation of its address sensitive portions	all of these	cannot be made to execute in any area of storage other than the one designated for it at the time of its coding or translation
27	A relocatable program form is one which	cannot be made to execute in any area of storage other than the one designated for it at the time of its coding or translation	consists of a program and relevant information for its relocation	can be processed to relocate it to a desired area of memory	all of these	can be processed to relocate it to a desired area of memory
28	A self-relocating program is one which	cannot be made to execute in any area of storage other than the one designated for it at the time of its coding or translation	consists of a program and relevant information for its relocation	can itself perform the relocation of its address sensitive portions	all of these	can itself perform the relocation of its address sensitive portions
29	In which storage allocation stragey size is required at compile time	static allocation	dynamic allocation	stack allocation	all	static allocation

30	Which field is not present in activation record	saved machine status	register allocation	optional control link	temporaries	register allocation
31	Which of the following are activation records?	return value	local data	temporaries	all	all
32	which of the following are storage	stack allocation	static allocation	heap allocation	all	all
33	_____ tree is used to depict the way control enters and leaves activation	Activation tree	tree	parse tree	none	Activation tree
34	In activation tree each node represent	activation of main program	activaiton of procedure	both (a) and (b)	none	
35	_____ can be used to keep	control stack	activation tree	activation node	none	
36	if the occurance of the name in the procedure is in the scope of declaration within the procedure then it is said to be	local	nonlocal	global	none	local
37	subdivision of runtime memory consists of	code	static data	stack	all	stack
38	In activation record, optional control link points to	activation record of caller	activation record of callee	both (a) and (b)	none	activation record of caller

39	The field of actual parameter in activation record is used by which procedure?	calling procedure	called procedure	both (a) and (b)	none	calling procedure
40	Allocation of activation record and entering information into fields is done by	return sequence	call sequence	both (a) and (b)	none	call sequence
41	call by reference is also called as	call-by-address	call-by-location	both (a) and (b)	none	both (a) and (b)
42	In which allocation, names are bound to	static	heap	stack	none	static
43	Flow of control in a program corresponds to which traversal of activation tree ?	Depth first traversal	Breadth first traversal	both (a) and (b)	none	Depth first traversal
44	Which is the correct sequence of compilation	Assembler → Compiler →	Compiler → Assenbler →	Preprocessor → Compiler → Assembler	Assembler → Compiler → Linking →	Preprocessor → Compiler → Assembler → Linking
45	Why is calloc() function used for?	allocates the specified number of bytes		increases or decreases the size of the specified block of memory and reallocates it if needed	calls the specified block of memory for execution.	allocates the specified number of bytes and initializes them to zero
46	The instruction 'ORG O' is a_____	Machine Instruction	Pseudo instruction	High level instruction	Memory instruction	Pseudo instruction

47	Memory unit accessed by content is called_____	Read only memory	Programmable Memory	Virtual Memory	Associative Memory	Associative Memory
48	_____ register keeps tracks of the instructions stored in program stored in memory.	AR (Address Register)	XR (Index Register)	PC (Program Counter)	AC (Accumulator)	PC (Program Counter)
49	The circuit converting binary data in to decimal is_____	Encoder	Multiplexer	Decoder	Code converter	Code converter
50	In computers, subtraction is generally done by _____	1's complement method	2's complement method	BCD subtraction method	signed magnitude method	2's complement method
51	PSW is saved in stack when there is a _____	Interrupt recognized	Execution of RST instruction	Execution of CALL instruction	All of these	Interrupt recognized
52	Memory unit accessed by content is called_____	Read only memory	Programmable Memory	Virtual Memory	Associative Memory	Associative Memory
53	'Aging registers' are _____	Counters which indicate how long ago their associated pages have been Referenced.	Registers which keep track of when the program was last accessed	Counters to keep track of last accessed instruction	Counters to keep track of the latest data structures referred	Counters which indicate how long ago their associated pages have been Referenced.
54	The size of the activation record can be determined at _____	Run time	Compile time	both (a) and (b)	none of these	both (a) and (b)

55	Which of the following are parameter passing method	call by value	call by reference	call by restore	all	all
56	Which one of the following statement is false for the SLR (1) and LALR (1) parsing tables for a context free grammar?	The reduce entries in both the tables may be different	The error entries in both the tables may be different	The go to part of both tables may be different	The shift entries in both the tables may be identical	The go to part of both tables may be different

KARPAGAM ACADEMY OF HIGHER EDUCATION	
(Deemed to be University)	
(Established under section 3 of UGC Act,1956	

CLASS : II B.SC IT	**COURSE NAME: System Programming**
COURSE CODE:16ITU603B	**BATCH: 2016-2019**

UNIT II: STORAGE ORGANIZATION

UNIT -4

SYLLABUS

Storage organization: Activation records stack allocation.

RUNTIME ENVIRONMENT

A program as a source code is merely a collection of text (code, statements etc.) and to make it alive, it requires actions to be performed on the target machine. A program needs memory resources to execute instructions. A program contains names for procedures, identifiers etc., that require mapping with the actual memory location at runtime.

By runtime, we mean a program in execution. Runtime environment is a state of the target machine, which may include software libraries, environment variables, etc., to provide services to the processes running in the system.

Runtime support system is a package, mostly generated with the executable program itself and facilitates the process communication between the process and the runtime environment. It takes care of memory allocation and de-allocation while the program is being executed.

➢ Runtime organization of different storage locations

➢ Representation of scopes and extents during program execution.

➢ Components of executing program reside in blocks of memory (supplied by OS).

➢ Three kinds of entities that need to be managed at runtime (code, variables and procedures)

Generated code for various procedures and programs. forms text or code segment of your program: size known at compile time.

Data objects:

• Global variables/constants: size known at compile time

• Variables declared within procedures/blocks: size known

• Variables created dynamically: size unknown.

Stack to keep track of procedure activations.

Subdivide memory conceptually into code (program) and data areas

STATIC VERSUS DYNAMIC STORAGE ALLOCATION

- Much (often most) data cannot be statically allocated. Either its size is not known at compile time or its lifetime is only a subset of the program's execution.
- Early versions of Fortranused only statically allocated data. This required that each array had a constant size specified in the program. Another consequence of supporting only static allocation was that recursion was forbidden (otherwise the compiler could not tell how many versions of a variable would be needed).
- Modern languages, including newer versions of Fortran, support both static and dynamic allocation of memory.
- The advantage supporting dynamic storage allocation is the increased flexibility and storage efficiency possible (instead of declaring an array to have a size adequate for the largest data set; just allocate what is needed). The advantage of static storage allocation is that it avoids the runtime costs for allocation/deallocation and may permit faster code sequences for referencing the data.
- An (unfortunately, all too common) error is a so-called memory leak where a long running program repeated allocates memory that it fails to delete, even after it can no longer be referenced. To avoid memory leaks and ease programming, several programming language systems employ automatic garbage collection. That means the runtime system itself can determine if data can no longer be referenced and if so automatically deallocates it.

STORAGE ALLOCATION:

• Compiler must do the storage allocation and provide access to variables and data

• Memory management

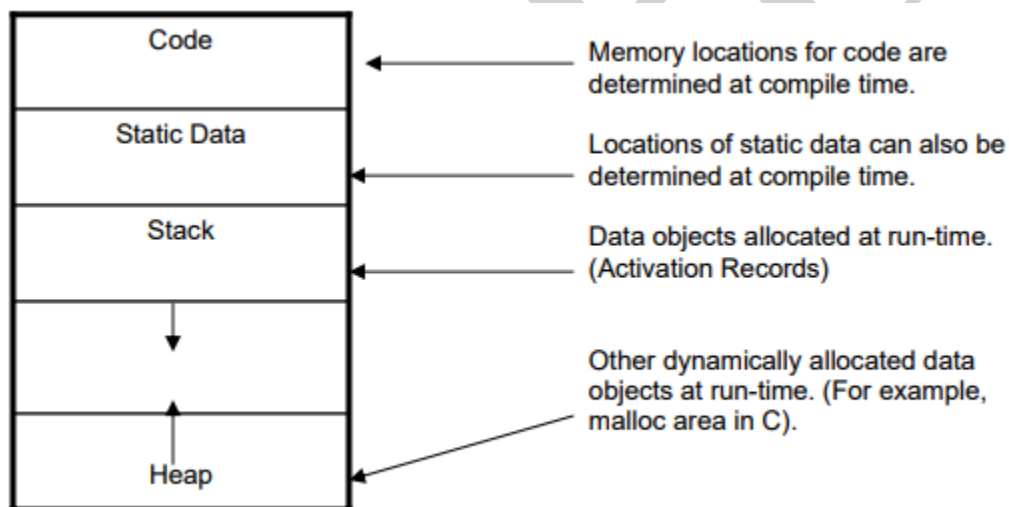 ✓ Stack allocation
  ✓ Heap management
  ✓ Garbage collection

Storage Allocation Strategies

• Static allocation (Code): lays out storage at compile time for all data objects

2

• Stack allocation(Procedures): manages the runtime storage as a stack

• Heap allocation (Variables): allocates and deallocates storage as needed at runtime from heap
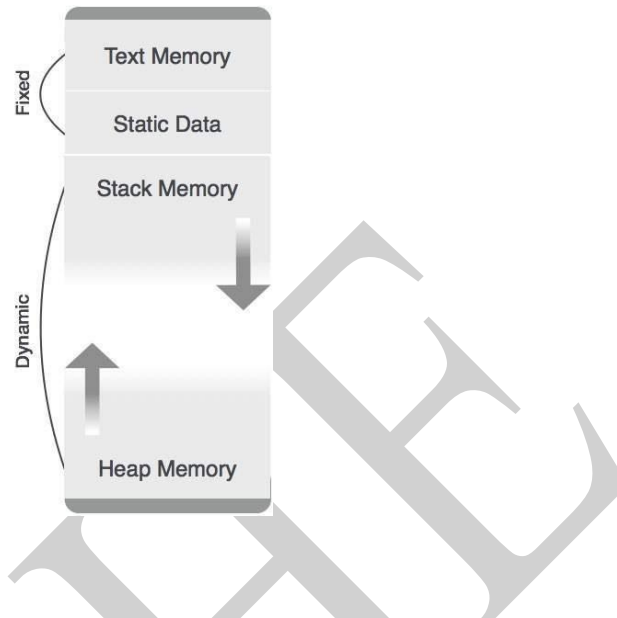
STORAGE ORGANIZATION

- Assumes a logical address space
- Operating system will later map it to physical addresses, decide how touse cache memory, etc.
- Memory typically divided into areas for
    - Program code
    - Other static data storage, including global constants and compiler generated data
    - Stack to support call/return policy for procedures
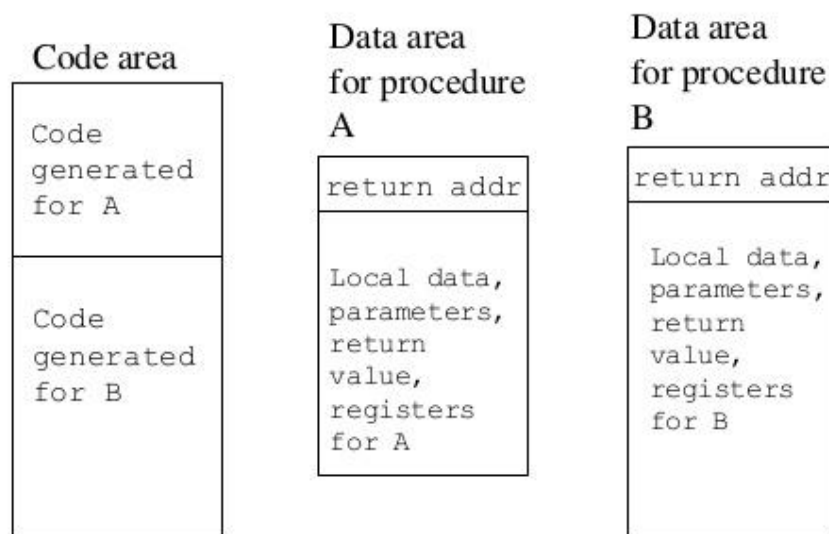   - Heap to store data that can outlive a call to a procedure

STATIC ALLOCATION

Statically allocated names are bound to storage at compile time. Storage bindings of statically allocated names never change, so even if a name is local to a procedure, its name is always bound to the same storage. The compiler uses the type of a name (retrieved from the symbol table) to determine storage size required. The required number of bytes (possibly aligned) is set aside for the name.The address of the storage is fixed at compile time.

Limitations:

- ✓ The size required must be known at compile time.
- ✓ Recursive procedures cannot be implemented as all locals are statically allocated.
- ✓ No data structure can be created dynamically as all data is static.

Static Allocation

Code area	Data area for procedure A	Data area for procedure B
Code generated for A	return addr	return addr
Code generated for B	Local data, parameters, return value, registers for A	Local data, parameters, return value, registers for B

Stack-dynamic allocation

- ✓ Storage is organized as a stack.
- ✓ Activation records are pushed and popped.
- ✓ Locals and parameters are contained in the activation records for the call.
- ✓ This means locals are bound to fresh storage on every call.

4

- ✓ If we have a stack growing downwards, we just need a stack_top pointer.
- ✓ To allocate a new activation record, we just increase stack_top.
- ✓ To deallocate an existing activation record, we just decrease stack_top.

RUN-TIME STACK AND HEAP

The STACK is used to store:

- o Procedure activations.
- o The status of the machine just before calling a procedure, so that the status can be restored when the called procedure returns.
- o The HEAP stores data allocated under program control (e.g. by malloc() in C).

ACTIVATION RECORDS

Any information needed for a single activation of a procedure is stored in the ACTIVATION RECORD (sometimes called the STACK FRAME). Today, we'll assume the stack grows DOWNWARD, as on, e.g., the Intel architecture. The activation record gets pushed for each procedure call and popped for each procedure return.

A program is a sequence of instructions combined into a number of procedures. Instructions in a procedure are executed sequentially. A procedure has a start and an end delimiter and everything inside it is called the body of the procedure. The procedure identifier and the sequence of finite instructions inside it make up the body of the procedure.The execution of a procedure is called its activation. An activation record contains all the necessary information required to call a procedure**.**

Each time the flow of control enters a function or procedure, we update its procedure activation record. This maintains the values of the function arguments and all local variables defined inside the function, and pointers to the start of the code segment, the current location in the code segment, and the segment of code to which we return on exit.

Whenever a procedure is executed, its activation record is stored on the stack, also known as control stack. When a procedure calls another procedure, the execution of the caller is suspended until the called procedure finishes execution. At this time, the activation record of the called procedure is stored on the stack.

We assume that the program control flows in a sequential manner and when a procedure is called, its control is transferred to the called procedure. When a called procedure is

executed, it returns the control back to the caller. This type of control flow makes it easier to represent a series of activations in the form of a tree, known as the **activation tree**.

Example:

Consider the quick sort program

```
int a[11];
void readArray() { /* Reads 9 integers into a[1], ..., a[9]. */
    int i;
    ...
}
int partition(int m, int n) {
    /* Picks a separator value v, and partitions a[m..n] so that
        a[m..p-1] are less than v, a[p] = v, and a[p+1..n] are
        equal to or greater than v. Returns p. */
    ...
}
void quicksort(int m, int n) {
    int i;
    if (n > m) {
        i = partition(m, n);
        quicksort(m, i-1);
        quicksort(i+1, n);
    }
}
main() {
    readArray();
    a[0] = -9999;
    a[10] = 9999;
    quicksort(1,9);
}
```
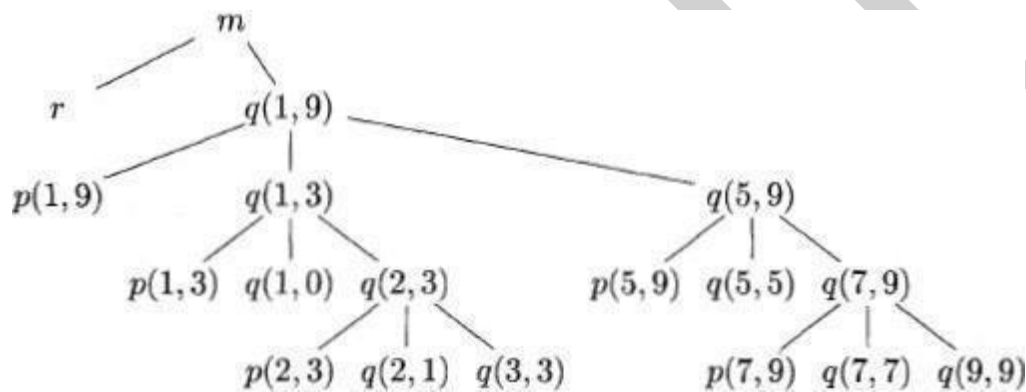
Activation for Quicksort:

```
enter main()
    enter readArray()
    leave readArray()
    enter quicksort(1,9)
        enter partition(1,9)
        leave partition(1,9)
        enter quicksort(1,3)
            ...
        leave quicksort(1,3)
        enter quicksort(5,9)
            ...
        leave quicksort(5,9)
    leave quicksort(1,9)
leave main()
```
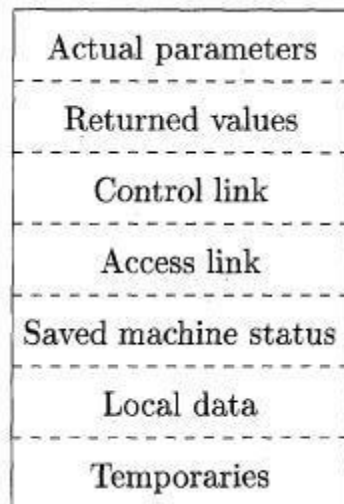
Activation tree representing calls during an execution of quicksort:

Activation records

- ✓ Procedure calls and returns are usually managed by a run-time stack called the control stack.
- ✓ Each live activation has an activation record (sometimes called a frame)
- ✓ The root of activation tree is at the bottom of the stack
- ✓ The current execution path specifies the content of the stack with the last
- ✓ Activation has record in the top of the stack.

A General Activation Record

```
Actual parameters
Returned values
Control link
Access link
Saved machine status
Local data
Temporaries
```

Activation Record

Fields	Elements
Temporaries	Stores temporary and intermediate values of an expression.
Local Data	Stores local data of the called procedure.
Machine Status	Stores machine status such as Registers, Program Counter etc., before the procedure is called.
Control Link	Stores the address of activation record of the caller procedure.
Access Link	Stores the information of data which is outside the local scope.
Actual Parameters	Stores actual parameters, i.e., parameters which are used to send input to the called procedure.
Return Value	Stores return values.

Downward-growing stack of activation records:

(a) Frame for *main*

(b) *r* is activated
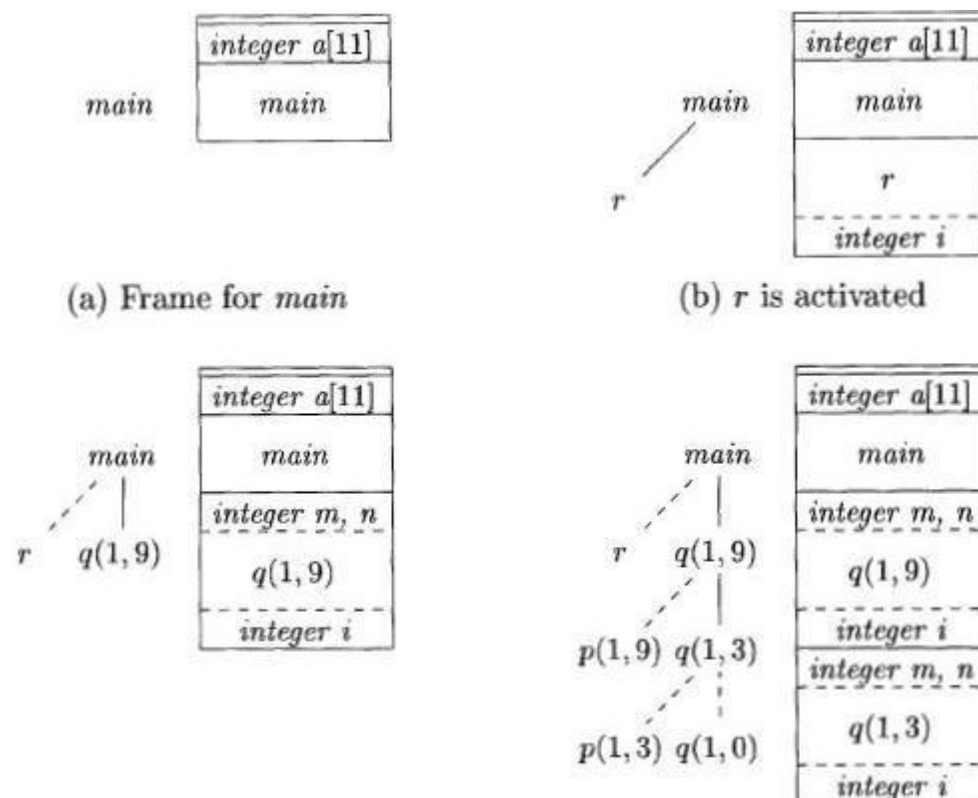
Address generation in stack allocation

The position of the activation record on the stack cannot be determined statically. Therefore the compiler must generate addresses RELATIVE to the activation record. If we have a downward-growing stack and a stack_top pointer, we generate addresses of the form stack_top + offset

HEAP ALLOCATION

Some languages do not have tree-structured allocations. In these cases, activations have to be allocated on the heap. This allows strange situations, like callee activations that live longer than their callers' activations. This is not common Heap is used for allocating space for objects created at run timeFor example: nodes of dynamic data structures such as linked lists and trees

- Dynamic memory allocation and deallocation based on the requirements of the programmalloc() and free() in C programs

  - new()and delete()in C++ programs
  - new()and garbage collection in Java programs

- Allocation and deallocation may be *completely manual* (C/C++), *semi-automatic*(Java), or *fully automatic* (Lisp)

PARAMETERS PASSING

The communication medium among procedures is known as parameter passing. The values of the variables from a calling procedure are transferred to the called procedure by some mechanism. Before moving ahead, first go through some basic terminologies pertaining to the values in a program.

r-value

The value of an expression is called its r-value. The value contained in a single variable also becomes an r-value if it appears on the right-hand side of the assignment operator. r-values can always be assigned to some other variable.

l-value

The location of memory (address) where an expression is stored is known as the l-value of that expression. It always appears at the left hand side of an assignment operator.

A language has first-class functions if functions can be declared within any scope passed as arguments to other functions returned as results of functions.

- In a language with first-class functions and static scope, a function value is generally represented by a closure.
- A pair consisting of a pointer to function code a pointer to an activation record.
- Passing functions as arguments is very useful in structuring of systems using upcalls

Formal Parameters

Variables that take the information passed by the caller procedure are called formal parameters. These variables are declared in the definition of the called function.

Actual Parameters

Variables whose values or addresses are being passed to the called procedure are called actual parameters. These variables are specified in the function call as arguments.

Formal parameters hold the information of the actual parameter, depending upon the parameter passing technique used. It may be a value or an address.

Pass by Value

In pass by value mechanism, the calling procedure passes the r-value of actual parameters and the compiler puts that into the called procedure's activation record. Formal parameters then hold the values passed by the calling procedure. If the values held by the formal parameters are changed, it should have no impact on the actual parameters.

Pass by Reference

In pass by reference mechanism, the l-value of the actual parameter is copied to the activation record of the called procedure. This way, the called procedure now has the address (memory location) of the actual parameter and the formal parameter refers to the same memory location. Therefore, if the value pointed by the formal parameter is changed, the impact should be seen on the actual parameter as they should also point to the same value.

Pass by Copy-restore

This parameter passing mechanism works similar to 'pass-by-reference' except that the changes to actual parameters are made when the called procedure ends. Upon function call, the values of actual parameters are copied in the activation record of the called procedure. Formal parameters if manipulated have no real-time effect on actual parameters (as l-values are passed), but when the called procedure ends, the l-values of formal parameters are copied to the l-values of actual parameters.

Pass by Name

Languages like Algol provide a new kind of parameter passing mechanism that works like preprocessor in C language. In pass by name mechanism, the name of the procedure being called is replaced by its actual body. Pass-by-name textually substitutes the argument expressions in a procedure call for the corresponding parameters in the body of the procedure so that it can now work on actual parameters, much like pass-by-reference.

```
An example:
main()
{ int x = 4;
int f (int y) {
return x*y;
}
int g (int →int h){
int x = 7;
return h(3) + x;
}

g(f);//returns 12

}
```

Passing Functions as Parameters – Implementation with
Static Scope

SL chain
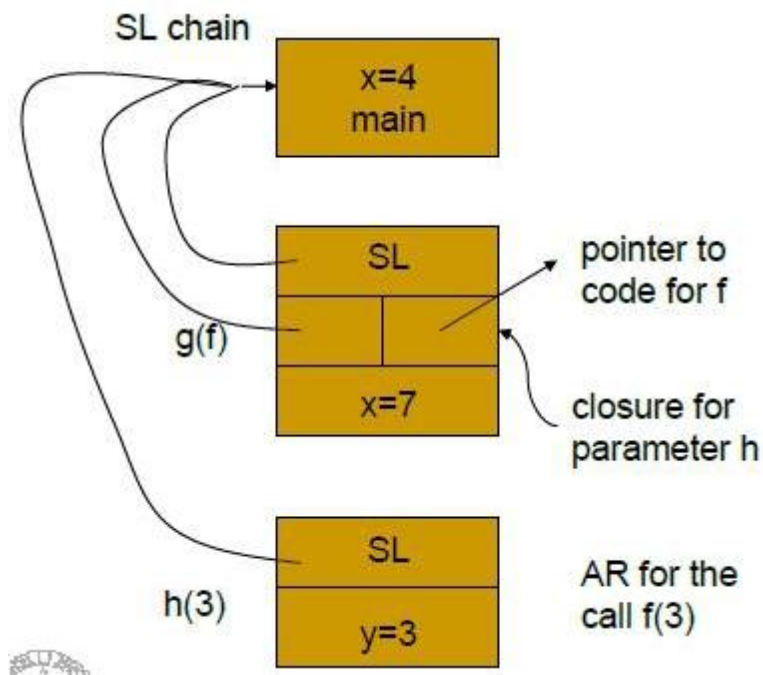
Designing Calling Sequences:

✓ Values communicated between caller and callee are generally placed at the beginning of callee's activation record

✓ Fixed-length items: are generally placed at the middle

✓ Items whose size may not be known early enough: are placed at the end of activation record We must locate the top-of-stack pointer judiciously: a common approach is to have it point to the end of fixed length fields

Access to dynamically allocated arrays:
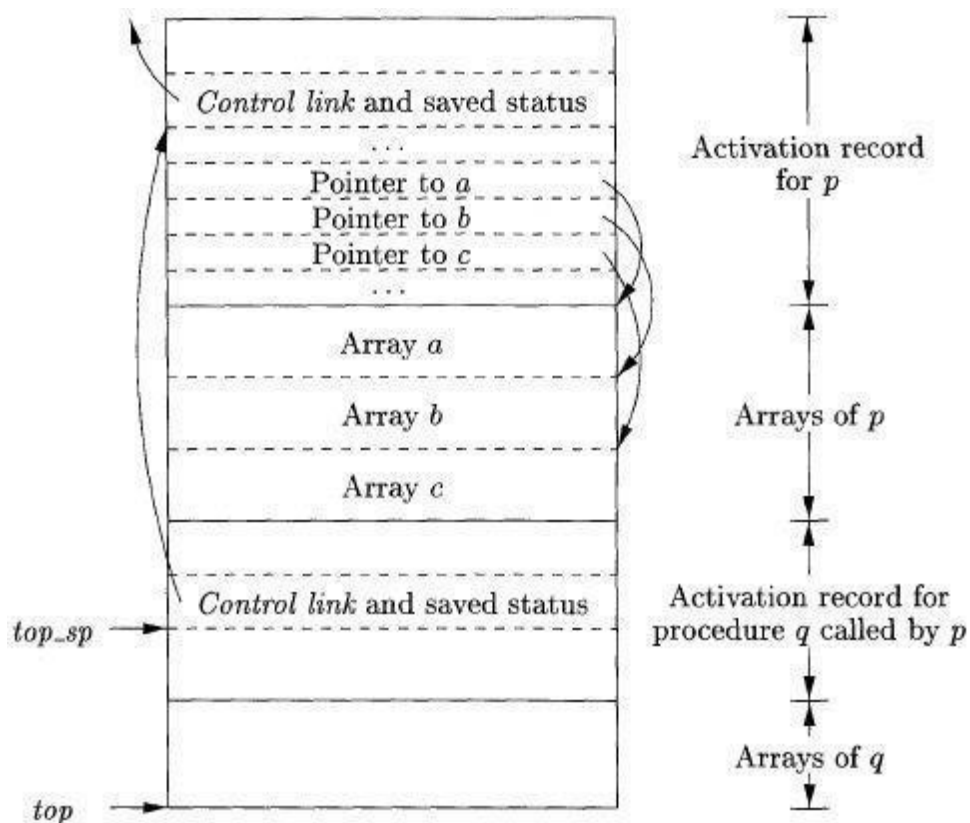
Memory Manager:

Two basic functions:

- ✓ Allocation
- ✓ Deallocation

Properties of memory managers:

- ✓ Space efficiency
- ✓ Program efficiency
- ✓ Low overhead

Typical Memory Hierarchy Configurations

Typical Sizes		Typical Access Times
> 2GB	Virtual Memory (Disk)	3 - 15 ms
256MB - 2GB	Physical Memory	100 - 150 ns
128KB - 4MB	2nd-Level Cache	40 - 60 ns
16 - 64KB	1st-Level Cache	5 - 10 ns
32 Words	Registers (Processor)	1 ns

Locality in Programs:

The conventional wisdom is that programs spend 90% of their time executing 10% of the code:

- ✓ Programs often contain many instructions that are never executed.
- ✓ Only a small fraction of the code that could be invoked is actually executed in typical run of the program.
- ✓ The typical program spends most of its time executing innermost loops and tight recursive cycles in a program.

CLASS : II B.SC IT	COURSE NAME: System Programming
COURSE CODE: 16ITU603B	BATCH: 2016-2019

UNIT II: Code Generation

UNIT -5

SYLLABUS

Code Generation: Object code generation

CODE GENERATION

Introduction

Optimization is a program transformation technique, which tries to improve the code
by making it consume less resources (i.e. CPU, Memory) and deliver high speed.

1. The term "code optimization" refers to techniques, a compiler can employ in an attempt to produce a better object language program than the most obvious for a given source program.

2. The quality of the object program is generally measured by its size (for small computation) or its running time (for large computation).

3. It is theoretically impassible for a compiler to produce the best possible object program for every source program under any reasonable cast function.

4. The accurate term for "code optimization" is "code improvement".

5. There are many aspects to code optimization.

    a. Cast

    b. Quick & straight forward translation (time).

The Principal Sources Of Optimization

It consists of detecting patterns in the program and replacing these patterns by equivalent and more efficient construct.

♣   The code optimization techniques consist of detecting patterns in the program and

Inner Loops

♣   "90-10" rule states that 90% of the time is spent in 10% of the code. Thus the most

Language Implementation Details Inaccessible To the User:

The optimization can be done by

1)   Programmer- Write source program (user can write)

2)   Compiler   -e.g.: array references are made by indexing, rather than by pointer or address calculation prevents the programmer from dealing with offset calculations in arrays.

♣   The term constant folding is used for the latter optimization.

Example:

    A [i+1]:=B [i+1] is easier.

    J: =i+1

    A[j]:=B[j]

♣   There are three types of code optimization

I.   Local optimization-performed within a straight line and no jump.

II.   Loop optimization

III.   Data flow analysis-the transmission of useful information from one part of the program to another.

<u>Optimization</u>

 Optimization is a program transformation technique, which tries to improve the code by making it consume less resource (i.e. CPU, Memory) and deliver high speed. In optimization, high-level general programming constructs are replaced by very efficient low-level programming codes. A code optimizing process must follow the three rules given below:

- The output code must not, in any way, change the meaning of the program.
- Optimization should increase the speed of the program and if possible, the program should demand less number of resources.
- Optimization should itself be fast and should not delay the overall compiling process.

Efforts for an optimized code can be made at various levels of compiling the process.

- At the beginning, users can change/rearrange the code or use better algorithms to write the code.
- After generating intermediate code, the compiler can modify the intermediate code by address calculations and improving loops.
- While producing the target machine code, the compiler can make use of memory hierarchy and CPU registers.

Optimization can be categorized broadly into two types : machine independent and machine dependent.

What Is a Loop?

Before we discuss loop optimizations, we should discuss what we identify as a loop. In our source language, this is rather straightforward, since loops are formed with while or for, where it is convenient to just elaborate a for loop into its corresponding while form.

The key to a loop is a back edge in the control-flow graph from a node l to a node h that dominates l. We call h the header node of the loop. The loop itself then consists of the nodes on a path from h to l. It is convenient to organize the code so that a loop can be identified with its header node. We then write loop(h, l) if line l is in the loop with header h.

When loops are nested, we generally optimize the inner loops before the outer loops. For one, inner loops are likely to be executed more often. For another, it could move computation to an outer loop from which it is hoisted further when the outer loop is optimized and so on

Machine-dependent Optimization

Machine-dependent optimization is done after the target code has been generated and when the code is transformed according to the target machine architecture. It involves CPU registers and may have absolute memory references rather than relative references. Machine-dependent optimizers put efforts to take maximum advantage of memory hierarchy.

For example:

```
do
{
  item = 10;
  value = value + item;
} while(value<100);
```

This code involves repeated assignment of the identifier item, which if we put this way:

```
Item = 10;
do
{
  value = value + item;
} while(value<100);
```

should not only save the CPU cycles, but can be used on any processor.

Basic Blocks

Source codes generally have a number of instructions, which are always executed in sequence and are considered as the basic blocks of the code. These basic blocks do not have any jump statements among them, i.e., when the first instruction is executed, all the instructions in the same basic block will be executed in their sequence of appearance without losing the flow control of the program.

A program can have various constructs as basic blocks, like IF-THEN-ELSE, SWITCH-CASE conditional statements and loops such as DO-WHILE, FOR, and REPEAT-UNTIL, etc.

Basic block identification

We may use the following algorithm to find the basic blocks in a program:

- Search header statements of all the basic blocks from where a basic block starts:

    o First statement of a program.

    o Statements that are target of any branch (conditional/unconditional).

    o Statements that follow any branch statement.

- Header statements and the statements following them form a basic block.

- A basic block does not include any header statement of any other basic block.

Basic blocks are important concepts from both code generation and optimization point of view.

```
w = 0;
x = x + y;
y = 0;
if( x > z)
    {
    y = x;
    x++;
    }
else
    {
    y = z;
    z++;
    }
w = x + z;
```

Source Code

```
w = 0;
x = x + y;
y = 0;
if( x > z)
```

```
y = x;
x++;
```

```
y = z;
z++;
```

```
w = x + z;
```

Basic Blocks

Basic blocks play an important role in identifying variables, which are being used more than once in a single basic block. If any variable is being used more than once, the register memory allocated to that variable need not be emptied unless the block finishes execution.

Advantages of Code Optimization-

- Optimized code has faster execution speed

- Optimized code utilizes the memory efficiently

- Optimized code gives better performance

Techniques for Code Optimization-
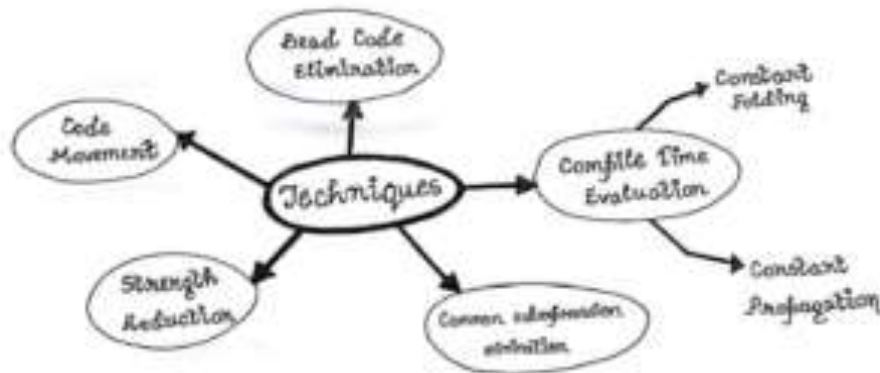
1. Compile Time Evaluation

2. Common sub-expression elimination

3. Dead Code Elimination

4. Code Movement

5. Strength Reduction

1.Compile Time Evaluation-

Two techniques that falls under compile time evaluation are-

A) Constant folding-

As the name suggests, this technique involves folding the constants by evaluating the expressions that involves the operands having constant values at the compile time.

- **Example-**

Circumference of circle = (22/7) x Diameter

Here, this technique will evaluate the expression 22/7 and will replace it with its result 3.14 at the compile time which will save the time during the program execution.

B) Constant Propagation-

In this technique, if some variable has been assigned some constant value, then it replaces that variable with its constant value in the further program wherever it has been used during compilation, provided that its value does not get alter in between.

- **Example-**

$$pi = 3.14$$

$$radius = 10$$

$$Area\ of\ circle = pi\ x\ radius\ x\ radius$$

Here, this technique will substitute the value of the variables 'pi' and 'radius' at the compile time and then it will evaluate the expression 3.14 x 10 x 10 at the compile time which will save the time during the program execution.

2. Common sub-expression elimination-

The expression which has been already computed before and appears again and again in the code for computation is known as a common sub-expression.

As the name suggests, this technique involves eliminating the redundant expressions to avoid their computation again and again. The already computed result is used in the further program wherever its required.

Example-

Code before Optimization	Code after Optimization
S1 = 4 x i S2 = a[S1] S3 = 4 x j	S1 = 4 x i S2 = a[S1] S3 = 4 x j

S4 = 4 x i **// Redundant Expression**	S5 = n
S5 = n	S6 = b[S1] + S5
S6 = b[S4] + S5	

3. Code Movement-

As the name suggests, this technique involves the movement of the code where the code is moved out of the loop if it does not matter whether it is present inside the loop or it is present outside the loop.

Such a code unnecessarily gets executed again and again with each iteration of the loop, thus wasting the time during the program execution.

Example-

Code before Optimization	Code after Optimization

for (int j = 0 ; j < n ; j ++)
 	
 {
 	
 x = y + z ;
 	
 a[j] = 6 x j;
 	
 }
	x = y + z ;
	
	 for (int j = 0 ; j < n ; j ++)
	
	 {
	
	 a[j] = 6 x j;
	
	 }

4. Dead code elimination-

As the name suggests, this technique involves eliminating the dead code where those statements from the code are eliminated which either never executes or are not reachable or even if they get execute, their output is never utilized.

Example-

Code before Optimization	Code after Optimization

i = 0 ;
 	
if (i == 1)
 	
{
 	
a = x + 5 ;
 	
}
	i = 0 ;

Dead code is one or more than one code statements, which are:

- Either never executed or unreachable,

- Or if executed, their output is never used.

Thus, dead code plays no role in any program operation and therefore it can simply be eliminated. **First** fig. depicts partial dead code, **second** fig. depicts complete dead code.
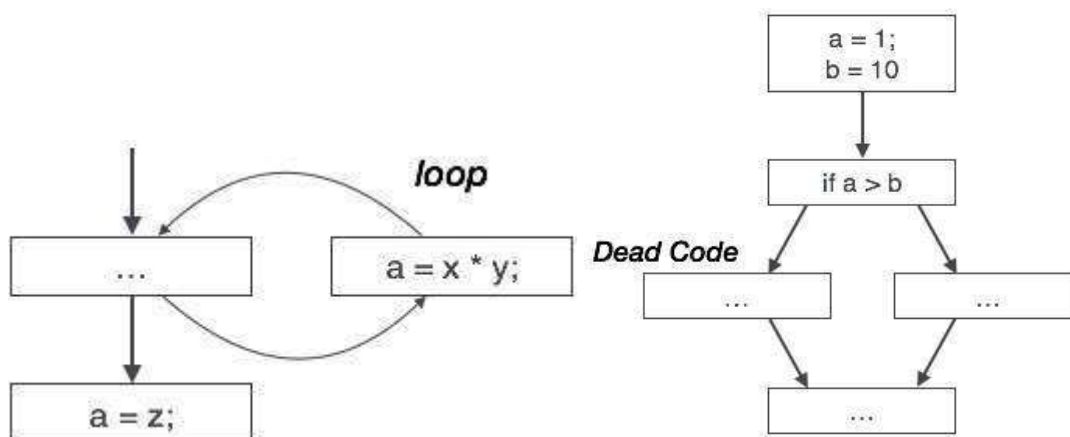
5. Strength reduction-

As the name suggests, this technique involves reducing the strength of the expressions by replacing the expensive and costly operators with the simple and cheaper ones.

Example-

Code before Optimization	Code after Optimization
B = A x 2	B = A + A

Here, the expression "A x 2" has been replaced with the expression "A + A" because the cost of multiplication operator is higher than the cost of addition operator.

Loop Optimization

Most programs run as a loop in the system. It becomes necessary to optimize the loops in order to save CPU cycles and memory. Loops can be optimized by the following techniques:

- **Invariant code**: A fragment of code that resides in the loop and computes the same value at each iteration is called a loop-invariant code. This code can be moved out of the loop by saving it to be computed only once, rather than with each iteration.

- **Induction analysis**: A variable is called an induction variable if its value is altered within the loop by a loop-invariant value.

- **Strength reduction**: There are expressions that consume more CPU cycles, time, and memory. These expressions should be replaced with cheaper expressions without compromising the output of expression. For example, multiplication $(x * 2)$ is expensive in terms of CPU cycles than $(x << 1)$ and yields the same result.

PEEPHOLE OPTIMIZATION

A statement-by-statement code-generations strategy often produce target code that contains redundant instructions and suboptimal constructs .The quality of such target code can be improved by applying "optimizing" transformations to the target program.

A simple but effective technique for improving the target code is peephole optimization, a method for trying to improving the performance of the target program by examining a short sequence of target instructions (called the peephole) and replacing these instructions by a shorter or faster sequence, whenever possible.

The peephole is a small, moving window on the target program. The code in the peephole need not contiguous, although some implementations do require this.it is characteristic of peephole optimization that each improvement may spawn opportunities for additional improvements.

We shall give the following examples of program transformations that are characteristic of peephole optimizations:

- Redundant-instructions elimination
- Flow-of-control optimizations
- Algebraic simplifications
- Use of machine idioms
- Unreachable Code

Code Generator

A code generator is expected to have an understanding of the target machine's runtime environment and its instruction set.

The code generator should take the following things into consideration to generate the code:

- **Target language** : The code generator has to be aware of the nature of the target language for which the code is to be transformed. That language may facilitate some machine-specific instructions to help the compiler generate the code in a more convenient way. The target machine can have either CISC or RISC processor architecture.

- **IR Type**: Intermediate representation has various forms. It can be in Abstract Syntax Tree (AST) structure, Reverse Polish Notation, or 3-address code.

- **Selection of instruction**: The code generator takes Intermediate Representation as input and converts (maps) it into target machine's instruction set. One representation can have many ways (instructions) to convert it, so it becomes the responsibility of the code generator to choose the appropriate instructions wisely.

- **Register allocation**: A program has a number of values to be maintained during the execution. The target machine's architecture may not allow all of the values to be kept in the CPU memory or registers. Code generator decides what values to keep in the registers. Also, it decides the registers to be used to keep these values.

- **Ordering of instructions**: At last, the code generator decides the order in which the instruction will be executed. It creates schedules for instructions to execute them.

Descriptors

The code generator has to track both the registers (for availability) and addresses (location of values) while generating the code. For both of them, the following two descriptors are used:

- **Register descriptor**: Register descriptor is used to inform the code generator about the availability of registers. Register descriptor keeps track of values stored in each register. Whenever a new register is required during code generation, this descriptor is consulted for register availability.

- **Address descriptor**: Values of the names (identifiers) used in the program might be stored at different locations while in execution. Address descriptors are used to keep track of memory locations where the values of identifiers are stored. These locations may include CPU registers, heaps, stacks, memory or a combination of the mentioned locations.

Code generator keeps both the descriptor updated in real-time. For a load statement, LD R1, x, the code generator:

- updates the Register Descriptor R1 that has value of x and

- updates the Address Descriptor (x) to show that one instance of x is in R1.

Code Generation

Basic blocks comprise of a sequence of three-address instructions. Code generator takes these sequence of instructions as input.

Note : If the value of a name is found at more than one place (register, cache, or memory), the register's value will be preferred over the cache and main memory. Likewise cache's value will be preferred over the main memory. Main memory is barely given any preference.

getReg : Code generator uses *getReg* function to determine the status of available registers and the location of name values. *getReg* works as follows:

- If variable Y is already in register R, it uses that register.

- Else if some register R is available, it uses that register.

- Else if both the above options are not possible, it chooses a register that requires minimal number of load and store instructions.

For an instruction x = y OP z, the code generator may perform the following actions. Let us assume that L is the location (preferably register) where the output of y OP z is to be saved:

- Call function getReg, to decide the location of L.

- Determine the present location (register or memory) of **y** by consulting the Address Descriptor of **y**. If **y** is not presently in register **L**, then generate the following instruction to copy the value of **y** to **L**:

  MOV y', L

  where **y'** represents the copied value of **y**.

- Determine the present location of **z** using the same method used in step 2 for **y** and generate the following instruction:

  OP z', L

  where **z'** represents the copied value of **z**.

- Now L contains the value of y OP z that is intended to be assigned to **x**. So, if L is a register, update its descriptor to indicate that it contains the value of **x**. Update the descriptor of **x** to indicate that it is stored at location **L**.

- If y and z has no further use, they can be given back to the system.

Other code constructs like loops and conditional statements are transformed into assembly language in general assembly way.

sno	Questions	opt1	opt2	opt3	opt4		Answer
1	Which of the following comment about peep-hole optimization	they enhance the portability of the compiler	program analysis is more accurate on intermediate code than	the information from dataflow analysis cannot	the information from the front end cannot		they enhance the portability of the compiler to
2	The method which merges the	Loop rolling	Loop jamming	Constant folding	None of the mention		Loop jamming
3	Running time of a	Addressing mode	Order of computation	The usage of machine	All of the		All of the mentioned
4	Which of the following is	TTL	ECL	CMOS	LSI		ECL
5	he optimization which	Loop unrolling	Loop jamming	Constant folding	None of the mention		Loop unrolling
6	Scissoring enables	A part of data to be	Entire data to be	None of the mentioned	No data to be		A part of data to be
7	Compiler should report the presence of _____ in	data	object	errors	text		errors
8	Compiler can check	syntax	logical	content	both a and b		syntax
9	Reduction in strength means	Replacing run time computation by	emoving loop invariant computation	Removing common sub expression	Replacing a costly operatio		Replacing run time computation by
10	A optimizing compiler	Is optimized to occupy less space	Is optimized to take less time for execution	Optimized the code	None of the above.		Optimized the code
11	Code can be optimized at	Source from user	Target code	Intermediate code	All of the above		Source from user

12	In which way(s) a macroprocessor for assembly language can be implemented?	Independent two-pass processor	Independent one-pass processor	Expand macrocalls and substitute arguments	All of the above		All of the above
13	A compiler for a high level language that runs on one machine and produce code for different machine is called	Optimizing compiler	One pass compiler	Cross compiler	Multipass compiler		Cross compiler
14	Local and loop optimization in turn provide motivation for	Data flow analysis	Constant folding	Pee hole optimization	DFA and constant folding		Data flow analysis
15	What is responsible for generation of final machine code tailored to target system?	Interpreter	Semantic analyzer	Code generator	Code optimizer		Code generator
16	Which programming language use compiler as well as interpreter to produce output?	C language	C++	Java	Cobol		Java

#	Question	A	B	C	D		Answer
17	Optimization of program that works within a single basic block is called	A. Local op	A. Global op	A. Loop un-c	A. Loop controlling		A. Local opt
18	Variable that can be accessed through out program is known as	A. Local va	A. Global Va	A. Integer	A. Constant		A. Global V
19	Gcc level of procedure integration, can be calculated as	1	2	3	4		3
20	Which languages necessarily need heap allocation in the runtime environment?	Those that support recursion	Those that use dynamic scoping	hose that allow dynamic data structures	Those that use global variables		hose that allow dynamic data structures
21	Some code optimizations are carried out on the intermediate code because	They enhan	Program anal	The informa	The information from the front end cannot otherwise be used for optimization		They enhance the portability of the compiler to other target processors
22	Input buffer is	symbol tab	divided into two halves	divided into Three halves	not divided		divided into two halves

23	Which of the following type of software should be used if you need to create,edit and print document ?	Word processing	Spreadsheet	Desktop publishing	UNIX		Word processing
24	What is bootstraping ?	A language interpreting other language program	A language compiling other language program	A language compile itself	All of above		A language compile itself
25	Shell is the exclusive feature of	UNIX	DOS	System software	Application software		UNIX
26	A program in execution is called_____	Process	Instruction	Procedure	Function		Process
27	A UNIX device driver is ___	Structured into two halves called top half and bottom half	Three equal partitions	Unstructured	None of the above		Structured into two halves called top half and bottom half
28	Memory_____	is an device that performs a sequence of operations specified by instructions in memory	is the device where information is stored	is a sequence of instructions	is a computational unit to perform specific functions		is the device where information is stored

		Serially usable	Re-entrable module	Non reusable module	None of these		Re-entrable module
29	In what module multiple instances of execution will yield the same result even if one instance has not terminated before the next one has begun ?	Serially usable	Re-entrable module	Non reusable module	None of these		Re-entrable module
30	The segment base is specified using the register named is _____	ORG instructions	TITLE instruction	ASSUME instruction	SEGMENT instruction		ORG instructions
31	If special forms are needed for printing the output, the programmer specifies these forms through _____	IPL	JCL	Load modules	Utility programs		JCL
32	Register or main memory location which contains the effective address of the operand is known as _____	pointer	indexed register	special location	scratch pad		pointer

#	Question	A	B	C	D		Answer
33	Name given to the organized collection of software that controls the overall operation of a computer is _____	working system	peripheral system	operating system	controlling system		operating system
34	Which of the following is not a function of the operating system?	Manage resources	Internet access	Provide a user interface	Load and run applications		Internet access
35	The items that a computer can use in its functioning are collectively called its	resources	stuff	capital	properties		
36	Programs that coordinate all of the computer's resources including memory, processing, storage, and	language translators	resources	applications	interfaces		resources
37	A compiler is a software tool that translates _____ _that the computer can understand.	Algorithm into data	Source code into data	Computer language into data	None of the above		Source code into data

		Integer	Source code	Linker	None of the above		Linker
38	The object code is then passed through a program called a _____ _ which turns it into an executable program.	Integer	Source code	Linker	None of the above		Linker
39	What is memory in Computer ?	is a sequence of instructions	is the device where information is stored	is an device that performs a sequence of operations specified by instructions in memory	none of these		is the device where information is stored
40	A program _____ _	is a sequence of instructions	is the device where information is stored	is a device that performs a sequence of operations specified by instructions in memory	none of these		is a sequence of instructions
41	The __ of a system includes the program s or instructions.	icon	software	hardware	information		software
42	System generation	is always quite simple	is always very difficult	varies in difficulty between systems	requires extensive tools to be understandable		requires extensive tools to be understandable
43	In computers, application software executes	all the time	when required	any time	for few hours		when required

44	To perform specific tasks or calculations in the computer we use	system software	application software	customized software	package software		application software
45	Computer can run without	application software	system software	operating system	windows		application software
46	Computer software which is also known as Off-the-shelf software is	customized software	package software	system software	utility program		package software
47	The number of clock cycles necessary to complete 1 fetch cycle in 8085 is	3 or 4	4 or 5	4 or 6	6 or 7		4 or 6
48	Which of the following electronic component are not found in ordinary ICs?	Diodes	Resistors	Inductors	Transistors		Inductors
49	The root directory of a disk should be placed	at a fixed address in main memory	at a fixed location on the disk	anywhere on the disk	none of these		at a fixed location on the disk

50	In analyzing the compilation of PL/I program the description " creation of more optimal matrix " is assosiated with _____	assembly and output	code generation	syntax analysis	machine independent optimization		machine independent optimization
51	Substitution of values for names whose values are constant, is done in	local optimization	oop optimization	constant folding	none of these		constant folding
52	A compiler for a high-level language that runs on one machine and produces code for a different machine is called	optimizing compiler	one pass compiler	cross compiler	multipass compiler		cross compiler
53	A linker reads four modules whose lengths are 200, 800, 600 and 500 words, respectively. If they are loaded in that order, what are the relocation constants ?	0, 200, 500, 600	0, 200, 1000, 1600	200, 500, 600, 800	200, 700, 1300, 2100		200, 500, 600, 800

54	Daisy chain is a device for ?	Interconnecting a number of devices to number of controllers	Connecting a number of devices to a controller	Connecting a number of controller to devices	Not connected to any devices		Connecting a number of devices to a controller
55	Input of Lex is ?	set to regular expression	statement	Numeric data	ASCII data		set to regular expression
56	Which of the following software tool is parser generator ?	Lex	Yacc	Lex and Yacc	assembler		Yacc
57	A Compiler has .... phases ?	7	6	5	9		8
58	A Lex compiler generates ?	Lex object code	Transition tables	C Tokens	Table		Transition tables

timization

ariable

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established under section 3 of UGC Act,1956)
Coimbatore-641021.
B.Sc INFORMATION TECHNOLOGY
FIRST INTERNAL EXAMINATION - DECEMBER 2018
Sixth Semester
SYSTEM PROGRAMMING

Date & Session: 18.12.2018 & FN   **Duration: 2 Hours**
Maximum   : 50 Marks   **Subject Code: 16ITU603B**

SECTION A – (20 X 1 = 20 Marks)
ANSWER ALL THE QUESTIONS

1. An assembler is _____.
   a. programming language dependent   b. Syntax dependent
   c. machine dependent d. data dependent

2. Translator for low level programming languages were termed as _____
   a. Compiler   b. Assembler   c. Loader   d. Linker

3. _____ loads the executable module to the main memory.
   a. Interpreter   b. Linker   c. Compiler   d. Loader

4. In two pass assembler the object code generation is done during _____ .
   a. second pass   b. one pass   c. zeorth pass   d. third pass

5. _____ header describes the size and position of the other pieces of the file.
   a. Object file   b. Source file   c. Obj file   d. Donald Knuth

6. _____ assemblers perform single scan over the source code.
   a. Two pass   b. One pass   c. Three pass   d. All of these

7. The instructions like MOV or ADD are called _____.
   a. opcode   b. operable code   c. ope code   d. Obj code

8.The assembler stores all the names and their corresponding values in _____.
    a. special purpose register   b. Symbol table   c. Value mapset
   d. register

9. Relocating Loader is otherwise called as _____ loader.
   a. Relative   b. Relational   c. Recursive   d. Redo

10. DLL files that support specific device operation are known as _____.
   a. Bootstrap   b. device drivers   c. Parsing   d. Scheduling

11. Source files are converted into a stream of tokens by _____.
   a. Scanner   b. Memory   c. Register   d. Unicode

12. _____ is a sequence of characters that can be treated as a single logical entity.
   a. Function   b. Method   c. Definition   d. Token

13. A _____ is a sequence of characters in the source program that is matched by the
    Pattern.
   a. lexical   b. lexeme   c. Analyser   d. combine

14.Forward reference table is arranged like _____
   a. stack   b. queue   c. linked list   d. double linked list

15. Function of lexical analyzer are _____.
    a. removing white space   b. removing constants, identifiers & keywords
    c. removing comments   d. all the above
16. The output of a lexical analyzer is_____.
    a. a prase tree   b. intermediate code   c. machine code   d. a stream of tokens
17. Which grammar defines Lexical Syntax.
    a. Regular Grammar   b. Syntactic Grammar
    c. Lexical Grammar d. Context free Grammar
18. _____ pass reads each line and records labels in a symbol table.
    a. First   b. Second   c. Third   d. First & Second
19. _____ takes executable module generated by a linker.
    a. Assembler   b. Linker editor   c. Loader   d. Compiler
20. A program in execution is called _____.
    a. process   b. instruction   c. procedure   d. function

SECTION – B (3 X 2 =6 Marks)
ANSWER ALL THE QUESTIONS

21. Define compiler.
22. State the difference between linker and loader
23. What is known as a symbol table?

SECTION – C (3 X 8 =24 Marks)
ANSWER ALL THE QUESTIONS

24.   (a) Write a short note on i) Assemblers, ii) Loaders and iii) Linkers.   [OR]

        (b). Discuss in detail about one pass assembler.

25.   (a) Explain the concept of dynamic linking.   [OR]

        (b). Discuss in detail about phases of compiler with diagram

26.   (a) Elaborate Relocating loader.   [OR]

        (b) Explain in detail about role of lexical analyzer in compiler.

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established under section 3 of UGC Act,1956)
Coimbatore-641021.
B.Sc INFORMATION TECHNOLOGY
FIRST INTERNAL EXAMINATION - DECEMBER 2018
Sixth Semester
SYSTEM PROGRAMMING

Date & Session: 18.12.2018 & FN **Duration: 2 Hours**
Maximum   : 50 Marks **Subject Code: 16ITU603B**

SECTION A – (20 X 1 = 20 Marks)
ANSWER ALL THE QUESTIONS

1. An assembler is _____.
   a. programming language dependent b. Syntax dependent
   c**. machine dependent** d. data dependent

2. Translator for low le.l vel programming languages were termed as _____
   a. Compiler b. **Assembler** c. Loader d. Linker

3. _____ loads the executable module to the main memory.
   a. Interpreter b. Linker c. Compiler d. **Loader**

4. In two pass assembler the object code generation is done during _____ .
   a. **second pass** b. one pass c. zeorth pass d. third pass

5. _____ header describes the size and position of the other pieces of the file.
   a. **Object file** b. Source file c. Obj file d. Donald Knuth

6. _____ assemblers perform single scan over the source code.
   a. Two pass b. **One pass** c. Three pass d. All of these

7. The instructions like MOV or ADD are called _____.
   a. **opcode** b. operable code c. ope code d. Obj code

8.The assembler stores all the names and their corresponding values in _____.
    a. special purpose register b. **Symbol table** c. Value mapset
   d. register

9. Relocating Loader is otherwise called as _____ loader.
   a. **Relative** b. Relational c. Recursive d. Redo

10. DLL files that support specific device operation are known as _____.
   a. Bootstrap b. **device drivers** c. Parsing d. Scheduling

11. Source files are converted into a stream of tokens by _____.
   a. **Scanner** b. Memory c. Register d. Unicode

12. _____ is a sequence of characters that can be treated as a single logical entity.
   a. Function b. Method c. Definition d. **Token**

13. A _____ is a sequence of characters in the source program that is matched by the
    Pattern.
   a. lexical b. **lexeme** c. Analyser d. combine

14.Forward reference table is arranged like _____
   a. stack b. queue c**. linked list** d. double linked list

15. Function of lexical analyzer are _____.

      a. removing white space   b. removing constants, identifiers & keywords

      c. removing comments   d. **all the above**

16. The output of a lexical analyzer is_____.

      a. a prase tree   b. intermediate code c. machine code   d. **a stream of tokens**

17. Which grammar defines Lexical Syntax.

      a. Regular Grammar   b. Syntactic Grammar

      c. **Lexical Grammar** d. Context free Grammar

18. _____ pass reads each line and records labels in a symbol table.

      a. **First**   b. Second   c. Third   d. First & Second

19. _____ takes executable module generated by a linker.

      a. Assembler   b. Linker editor   c. **Loader**   d. Compiler

20.A program in execution is called _____.

      a. **process**   b. instruction   c. procedure   d. function

SECTION – B (3 X 2 =6 Marks)
ANSWER ALL THE QUESTIONS

21. Define compiler.

      A compiler is a software program that transforms high-level source code that is written by a developer in a high-level programming language into a low level object code (binary code) in machine language, which can be understood by the processor. The process of converting high-level programming into machine language is known as compilation.

22. State the difference between linker and loader

BASIS FOR COMPARISON	LINKER	LOADER
Basic	It generates the executable module of a source program.	It loads the executable module to the main memory.
Input	It takes as input, the object code generated by an assembler.	It takes executable module generated by a linker.
Function	It combines all the object modules of a source code to generate an executable module.	It allocates the addresses to an executable module in main memory for execution.
Type/Approach	Linkage Editor, Dynamic linker.	Absolute loading, Relocatable loading and Dynamic Run-time loading.

23. What is known as a symbol table?

Symbol table is an important data structure created and maintained by compilers in order to store information about the occurrence of various entities such as variable names, function names, objects, classes, interfaces, etc. Symbol table is used by both the analysis and the synthesis parts of a compiler.

SECTION – C (3 X 8 =24 Marks)
ANSWER ALL THE QUESTIONS

24.   (a) Write a short note on i) Assemblers, ii) Loaders and iii) Linkers.   [OR]

Assemblers & Loaders, Linkers:
Assembly language is a low-level programming language for a computer or other programmable device specific to particular computer architecture in contrast to most high-level programming languages, which are generally portable across multiple systems. Assembly language is converted into executable machine code by a utility program referred to as an assembler like NASM, MASM, etc.

Linker and Loader are the utility programs that plays a major role in the execution of a program. The Source code of a program passes through compiler, assembler, linker, loader in the respective order, before execution. On the one hand, where the **linker** intakes the object codes generated by the assembler and combine them to generate the executable module. On the other hands, the **loader** loads this executable module to the main memory for execution.
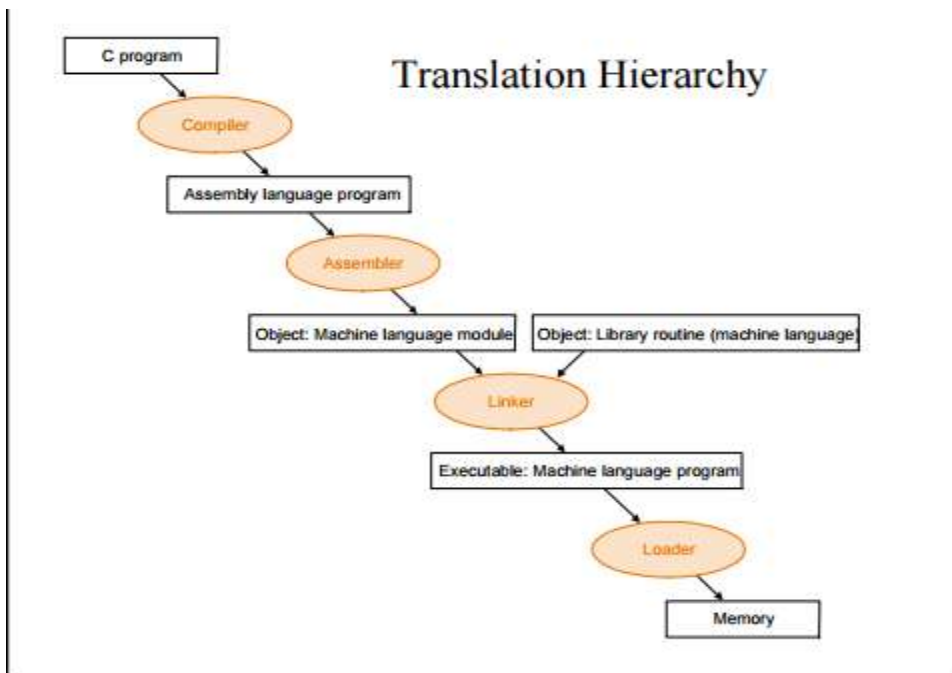
Assemblers

- Assemblers need to
  - translate assembly instructions and pseudo-instructions into machine instructions
  - Convert decimal numbers, etc. specified by programmer into binary
- Typically, assemblers make two passes over the assembly file
  - First pass: reads each line and records *labels* in a *symbol table*
  - Second pass: use info in symbol table to produce actual machine code for each line

Loader
It loads the executable module to the main memory. It takes executable module generated by a linker. It allocates the addresses to an executable module in main memory for execution. Absolute loading, Relocatable loading and Dynamic Run-time loading.

Linker

- Tool that merges the object files produced by *separate compilation* or assembly and creates an executable file
- Three tasks
  - Searches the program to find library routines used by program, e.g. printf(), math routines,…
  - Determines the memory locations that code from each module will occupy and relocates its instructions by adjusting absolute references
  - Resolves references among files
  -

Translation Hierarchy

(b). Discuss in detail about one pass assembler.

One-pass assemblers go through the source code once. Any symbol used before it is defined will require "errata" at the end of the object code (or, at least, no earlier than the point where the symbol is defined) telling the linker or the loader to "go back" and overwrite a placeholder which had been left where the as yet undefined symbol was used.

Multi-pass assemblers create a table with all symbols and their values in the first passes, then use the table in later passes to generate code.

In both cases, the assembler must be able to determine the size of each instruction on the initial passes in order to calculate the addresses of subsequent symbols. This means that if the size of an operation referring to an operand defined later depends on the type or distance of the operand, the assembler will make a pessimistic estimate when first encountering the operation, and if necessary pad it with one or more "no-operation" instructions in a later pass or the errata. In an assembler with peephole optimization, addresses may be recalculated between passes to allow replacing pessimistic code with code tailored to the exact distance from the target.

The original reason for the use of one-pass assemblers was speed of assembly – often a second pass would require rewinding and rereading the program source on tape or rereading a deck of cards or punched paper tape. Later computers with much larger memories (especially disc storage), had the space to perform all necessary processing without such re-reading. The advantage of the multi-pass assembler is that the absence of errata makes the linking process (or the program load if the assembler directly produces executable code) faster.[10]

Example: in the following code snippet a one-pass assembler would be able to determine the address of the backward reference *BKWD* when assembling statement *S2*, but would not

be able to determine the address of the forward reference*FWD* when assembling the branch statement *S1*; indeed *FWD* may be undefined. A two-pass assembler would determine both addresses in pass 1, so they would be known when generating code in pass 2,

S1 B *FWD*

 ...

FWD EQU *

 ...

BKWD EQU *

 ...

S2 B *BKWD*

Algorithm for Pass-1 Assembler

```
read first input line
if OPCODE='START' then
      begin
           save #[OPERAND] as starting address
           initialize LOCCTR to starting address
           write line to intermediate file
           read next input line
      end
else
      initialize LOCCTR to 0
while OPCODE≠'END' do
      begin
           if this is not a comment line then
           begin
               if there is a symbol in the LABEL field then
begin
               search SYMTAB for LABEL
               if found then
                  set error flag (duplicate symbol)
               else
                  insert (LABEL, LOCCTR) into SYMTAB
           end {if symbol}
           search OPTAB for OPCODE
           if found then
           add 3 {instruction length} to LOCCTR
           else if OPCODE='WORD' then
           add 3 to LOCCTR
           else if OPCODE='RESW' then
           add 3 * #[OPERAND] to LOCCTR
```

```
    else if OPCODE='RESB' then
            add #[OPERAND] to LOCCTR
        else if OPCODE='BYTE' then
        begin
            find length of constant in bytes
            add length to LOCCTR
        end {if BYTE}
        else
        set error flag (invalid operation code)
    end {if not a comment}
    write line to intermediate file
    read next input line
end {while not END}
Write last line to intermediate file
Save (LOCCTR-starting address) as program length
```

25.   (a) Explain the concept of dynamic linking.   [OR]

Dynamic Linking

An application that depends on **dynamic linking** calls the external files as needed during execution. The subroutines are typically part of the operating system, but may be auxiliary files that came with the application.

Dynamic linking has the following advantages: Saves **memory** and reduces swapping. Many processes can use a single DLL simultaneously, sharing a single copy of the DLL in **memory**. In contrast, Windows must load a copy of the library code into **memory** for each application that is built with a static link library.

A dynamic link library (DLL) is a collection of small programs that can be loaded when needed by larger programs and used at the same time. The small program lets the larger program communicate with a specific device, such as a printer or scanner. It is often packaged as a DLL program, which is usually referred to as a DLL file. DLL files that support specific device operation are known as device drivers.

Link editors are commonly known as linkers. The compiler automatically invokes the linker as the last step in compiling a program. The linker inserts code (or maps in shared libraries) to resolve program library references, and/or combines object modules into an executable image suitable for loading into memory. On Unix-like systems, the linker is typically invoked with the ld command.

Static linking is the result of the linker copying all library routines used in the program into the executable image. This may require more disk space and memory than dynamic linking, but is both faster and more portable, since it does not require the presence of the library on the system where it is run.

Dynamic linking is accomplished by placing the name of a sharable library in the executable image. Actual linking with the library routines does not occur until the image is run, when both the executable and the library are placed in memory. An advantage of dynamic linking is that multiple programs can share a single copy of the library.

Linking is often referred to as a process that is performed when the executable is compiled, while a dynamic linker is a special part of an operating system that loads external shared libraries into a running process and then binds those shared libraries dynamically to the running process. This approach is also called dynamic linking or late linking.

(b). Discuss in detail about phases of compiler with diagram

Phases of a compiler:

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. Let us understand the phases of a compiler.
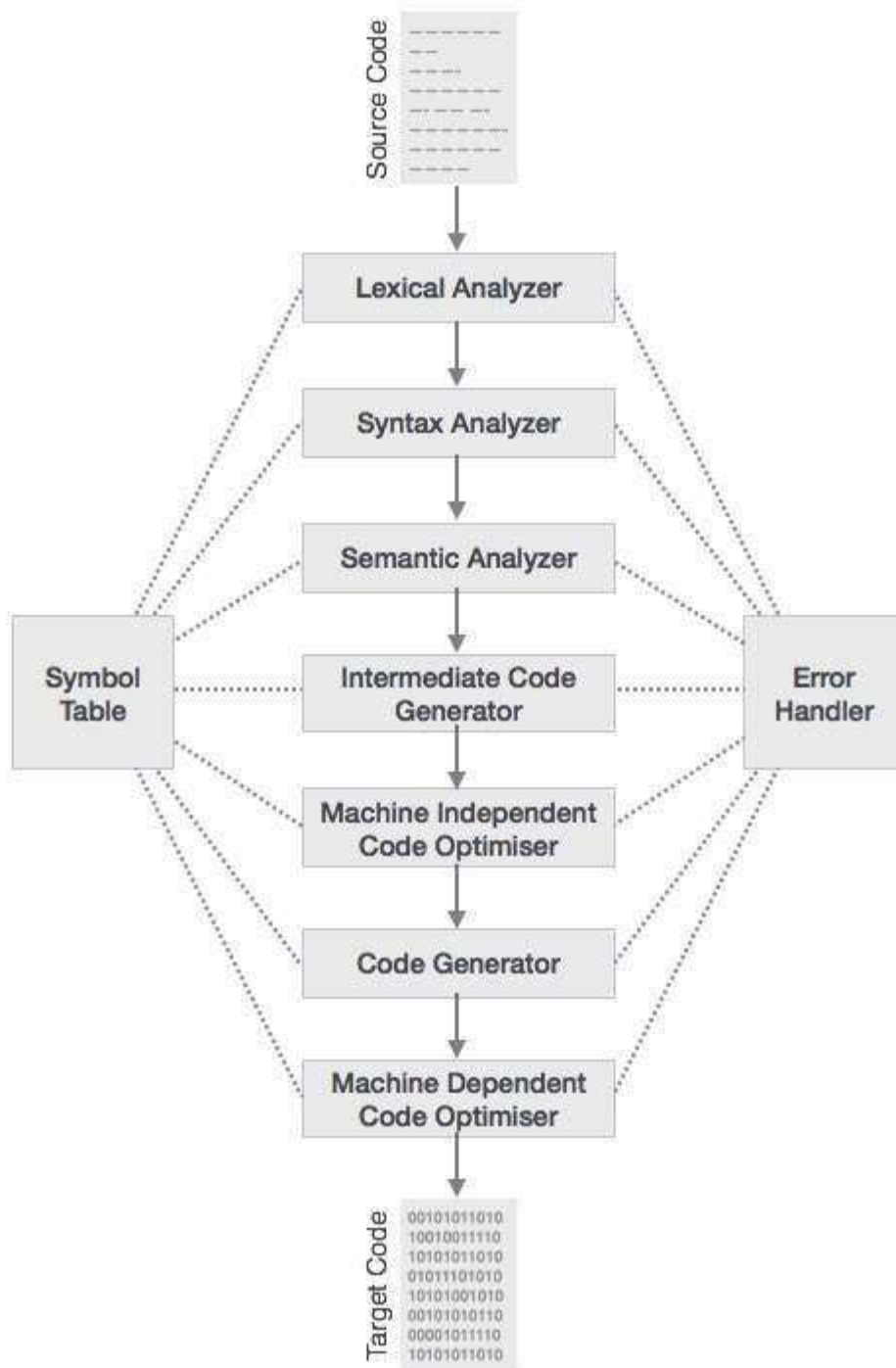
Lexical Analysis

The first phase of scanner works as a text scanner. This phase scans the source code as a stream of characters and converts it into meaningful lexemes. Lexical analyzer represents these lexemes in the form of tokens as:

<token-name, attribute-value>

Syntax Analysis

The next phase is called the syntax analysis or **parsing**. It takes the token produced by lexical analysis as input and generates a parse tree (or syntax tree). 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.

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 analyzer keeps track of identifiers, their types and expressions; whether identifiers are declared before use or not etc. The semantic analyzer 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. It is in between the high-level language and the machine language. This intermediate code should be generated in such a way that it makes it easier to be translated into the target machine code.

Code Optimization

The next phase does code optimization of the intermediate code. Optimization can be assumed as something that removes unnecessary code lines, and arranges the sequence of statements in order to speed up the program execution without wasting resources (CPU, memory).

Code Generation

In this phase, the code generator takes the optimized representation of the intermediate code and maps it to the target machine language. The code generator translates the intermediate code into a sequence of (generally) re-locatable machine code. Sequence of instructions of machine code performs the task as the intermediate code would do.

26.   (a) Elaborate Relocating loader.   [OR]

The relocating loader

The relocating loader will load the program anywhere in memory, altering the various addresses as required to ensure correct referencing. The decision as to where in memory the program is placed is done by the Operating System, not the programs header file. This is obviously more efficient, but introduces a slight overhead in terms of a small delay whilst all the relative offsets are calculated. The relocating loader can only relocate code that has been   produced   by   a   linker   capable   of   producing   relative   code.

Types of Loaders:
        Absolute Loader.
        Bootstrap Loader.
        Relocating Loader (Relative Loader)
        Linking Loader.

Two methods for specifying relocation as part of the object program:

The first method:
   * A Modification is used to describe each part of the object code that must be changed when the program is relocated.
   * Most of the instructions in this program use relative or immediate addressing.
   * The only portions of the assembled program that contain actual addresses are the extended format instructions on lines 15, 35, and 65. Thus these are the only items whose values are affected by relocation.
   * Each Modification record specifies the starting address and length of the field whose value is to be altered.
   * It then describes the modification to be performed.

The second method:

   * There are no Modification records.
   * The Text records are the same as before except that there is a *relocation bit* associated with each word of object code.

- Since all SIC instructions occupy one word, this means that there is one relocation bit for each possible instruction.

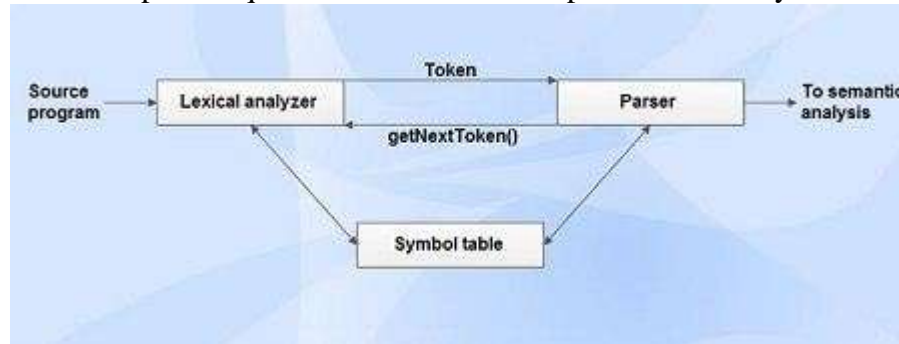(b) Explain in detail about role of lexical analyzer in compiler.

Over view of lexical analysis
To identify the tokens we need some method of describing the possible tokensthat can appear in the input stream. For this purpose we introduce regular expression, anotation that can be used to describe essentially all the tokens of programminglanguage.
Secondly , having decided what the tokens are, we need some mechanism torecognize these in the input stream. This is done by the token recognizers, which aredesigned using transition diagrams and finite automata.

Role of lexical analyzer
The LA is the first phase of a compiler. It main task is to read the input characterand produce as output a sequence of tokens that the parser uses for syntax analysis.

Upon receiving a 'get next token' command form the parser, the lexical analyzer reads the input character until it can identify the next token. The LA return to the parser representation for the token it has found. The representation will be an integer code, if the token is a simple construct such as parenthesis, comma or colon.

LA may also perform certain secondary tasks as the user interface. One such task is striping out from the source program the commands and white spaces in the form of blank, tab and new line characters. Another is correlating error message from the compiler with the source program.

Lexical analysis vs parsing

Lexical analysis	Parsing
A Scanner simply turns an input String (say a file) into a list of tokens. These tokens represent things like identifiers, parentheses, operators etc.	A parser converts this list of tokens into a Tree-like object to represent how the tokens fit together to form a cohesive whole (sometimes referred to as a sentence).
The lexical analyzer (the "lexer") parses individual symbols from the source code file into tokens. From there, the "parser" proper turns those whole tokens into sentences of your grammar	A parser does not give the nodes any meaning beyond structural cohesion. The next thing to do is extract meaning from this structure (sometimes called contextual analysis).

Need of Lexical Analyzer
✓ *Simplicity of design of compiler* The removal of white spaces and comments enables the syntax analyzer for efficient syntactic constructs.

✓ ***Compiler efficiency is improved*** Specialized buffering techniques for reading characters speed up the compiler process.
✓ ***Compiler portability is enhanced***

Issues in Lexical Analysis

Lexical analysis is the process of producing tokens from the source program. It has the following issues:

• Lookahead

• Ambiguities

Lookahead

> *Lookahead* is required to decide when one token will end and the next token will begin. The simple example which has lookahead issues are i *vs. if, = vs. ==.* Therefore a way to describe the lexemes of each token is required.
>
> A way needed to resolve ambiguities
>
> • Is if it is two variables *i* and *f* or if?
>
> • Is == is two equal signs =, = or ==?
>
> Hence, the number of lookahead to be considered and a way to describe the lexemes of each token is also needed.

Ambiguities

The lexical analysis programs written with lex accept ambiguous specifications and choose the longest match possible at each input point. Lex can handle ambiguous specifications. When more than one expression can match the current input, lex chooses as follows:

• The longest match is preferred.

• Among rules which matched the same number of characters, the rule given first is preferred.

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established under section 3 of UGC Act,1956)
Coimbatore-641021.
B.Sc INFORMATION TECHNOLOGY
SECOND INTERNAL EXAMINATION - DECEMBER 2018
Sixth Semester
SYSTEM PROGRAMMING

Date & Session: 05.02.2019 & FN   **Duration: 2 Hours**
Maximum   : 50 Marks   **Subject Code: 16ITU603B**

SECTION A – (20 X 1 = 20 Marks)
ANSWER ALL THE QUESTIONS

1. Resolution of externally defined symbols is performed by _____
   a. Linker   b. Loader   c. Compiler   d. Editor
2. System generation _____.
   a. is always quite simple   b. is always very difficult
   c. varies between systems   d. requires extensive tools
3. Which of the following grammars are phase-structured?
   a. irregular   b. context free grammer   c. Active   d. none
4. A pictorial representation of each statement in basic block is _____.
   a. tree   b. DAG   c. Graph   d. none
5. Linker and Loader are the _____.
   a. Utility programs   b. Sub-Task   c. Sub-problems   d. Process
6. Which one of the following is a top-down parser?
   a. Recursive descent parser   b. Operator precedence parse
    c. An LRk.parser   d. An LALRk. parser
7. Which phase of compiler is Syntax Analysis?
   a. First   b. Second   c.Third   d. Fourth
8. Which of the following derivations does a top-down parser use while parsing an input string?
   a. Leftmost derivation   b. Leftmost derivation in reverse
   c. Rightmost derivation   d. Rightmost derivation in reverse
9. Three address code involves _____
   a. excatly 3 address   b. at the most 3 address   c. no unary operators   d. none
10. What is the name of the process that determining whether a string of tokens can be generated by a grammar?
    a. Analyzing   b. Recognizing   c. Translating   d. Parsing
11. A grammar for a programming language is a formal description of _____.
    a. Syntax   b. Semantics   c. Structure   d. Library
12. The graph that shows basic blocks and relationship is called _____.
    a.DAG   b. Flow graph   c. Control graph   d. Hamiltonian graph

13. When is type checking is done ?
    a. during syntax directed translation   b. during lexical analysis
    c. during syntax analysis   d. during code optimization
14. Syntax directed translation scheme is desirable because _____.
    a. It is based on the syntax   b. Its description is independent of any implementation
    c. It is easy to modify   d. All of these
15. A lex program consists of _____.
    a. declarations   b. auxillary procedure   c. translation rules d. all of these
16. Which of these is also known as look-head LR parser?
    a. SLR   b. LR   c. LLR   d. LR(1)
17. Parsers are expected to parse the whole code.
    a. True   b. False   c. NULL   d. None
18. YACC stands for _____.
    a. yet accept compiler constructs   b. yet accept compiler compiler
    c. yet another compiler constructs   d. yet another compiler compiler
19. An intermediate code form is _____
    a. Postfix notation   b. Syntax trees   c. Three address code   d. All of these
20. Input to code generator is _____.
    a. Source Code   b. Intermediate code c. Target code   d. All of these

SECTION – B (3 X 2 =6 Marks)
ANSWER ALL THE QUESTIONS

21. What are the functions of symbol table?
22. What is parsing?
23. Differentiate compiler and Interpreter.

SECTION – C (3 X 8 =24 Marks)
ANSWER ALL THE QUESTIONS
24. a) Discuss in detail about specification and recognition of tokens.   [OR]
    b) What is symbol table? Explain the data structures of symbol table in detail.
25. a) Explain any one parser type in detail.   [OR]
    b) Explain three address code generation concepts in detail.
26. a) What is intermediate representation? Discuss in detail.   [OR]
    b) How Bottom-up parser works in compiler design? Explain.

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established under section 3 of UGC Act,1956)
Coimbatore-641021.
B.Sc INFORMATION TECHNOLOGY
SECOND INTERNAL EXAMINATION - DECEMBER 2018
Sixth Semester
SYSTEM PROGRAMMING

Date & Session: 05.02.2019 & FN   **Duration: 2 Hours**
Maximum   : 50 Marks   **Subject Code: 16ITU603B**

SECTION A – (20 X 1 = 20 Marks)
ANSWER ALL THE QUESTIONS

1. Resolution of externally defined symbols is performed by _____
   a. Linker   b. Loader   c. Compiler   d. Editor
2. System generation _____.
   a. is always quite simple   b. is always very difficult
   c. varies between systems   d. **requires extensive tools**
3. Which of the following grammars are phase-structured?
   a. irregular   b. **context free grammer**   c. Active   d. none
4. A pictorial representation of each statement in basic block is _____.
   a. tree   b. **DAG**   c. Graph   d. none
5. Linker and Loader are the _____.
   a. Utility programs   b. Sub-Task   c. Sub-problems   d. Process
6. Which one of the following is a top-down parser?
   a. Recursive descent parser   b. Operator precedence parse
    c. An LRk.parser   d. An LALRk. parser
7. Which phase of compiler is Syntax Analysis?
   a. First   b. **Second**   c.Third   d. Fourth
8. Which of the following derivations does a top-down parser use while parsing an input string?
   a. **Leftmost derivation**   b. Leftmost derivation in reverse
   c. Rightmost derivation   d. Rightmost derivation in reverse
9. Three address code involves _____
   a. excatly 3 address   b. **at the most 3 address**   c. no unary operators   d. none
10. What is the name of the process that determining whether a string of tokens can be generated by a grammar?
    a. Analyzing   b. Recognizing   c. Translating   d. **Parsing**
11. A grammar for a programming language is a formal description of _____.
    a. Syntax   b. Semantics   c. **Structure**   d. Library
12. The graph that shows basic blocks and relationship is called _____.
    a.DAG   b. **Flow graph**   c. Control graph   d. Hamiltonian graph

13. When is type checking is done ?
    a. during syntax directed translation   b. during lexical analysis
    c. during syntax analysis   d. during code optimization
14. Syntax directed translation scheme is desirable because _____.
    a. It is based on the syntax   b. Its description is independent of any implementation
    c. It is easy to modify   d. All of these
15. A lex program consists of _____.
    a. declarations   b. auxillary procedure   c. translation rules d. **all of these**
16. Which of these is also known as look-head LR parser?
    a. SLR   b. LR   c. **LLR**   d. LR(1)
17. Parsers are expected to parse the whole code.
    a. **True**   b. False   c. NULL   d. None
18. YACC stands for _____.
    a. yet accept compiler constructs   b. yet accept compiler compiler
    c. yet another compiler constructs   d. **yet another compiler compiler**
19. An intermediate code form is _____
    a. Postfix notation   b. Syntax trees   c. Three address code   d. **All of these**
20. Input to code generator is _____.
    a. Source Code   b. **Intermediate code**   c. Target code   d. All of these

SECTION – B (3 X 2 =6 Marks)
ANSWER ALL THE QUESTIONS

21. What are the functions of symbol table?
   Symbol table is an important data structure created and maintained by compilers in order to store information about the occurrence of various entities such as variable names, function names, objects, classes, interfaces, etc. Symbol table is used by both the analysis and the synthesis parts of a compiler. Operations performed are insert() and lookup().

22. What is parsing?
   A parser is a compiler or interpreter component that breaks data into smaller elements for easy translation into another language. A parser takes input in the form of a sequence of tokens or program instructions and usually builds a data structure in the form of a parse tree or an abstract syntax tree.

23. Differentiate compiler and Interpreter.

Interpreter	Compiler
Translates program one statement at a time.	Scans the entire program and translates it as a whole into machine code.
It takes less amount of time to analyze the source code but the overall execution time is slower.	It takes large amount of time to analyze the source code but the overall execution time is comparatively faster.
No intermediate object code is generated, hence are memory efficient.	Generates intermediate object code which further requires linking, hence requires more memory.
Continues translating the program until the first error is met, in which case it stops. Hence	It generates the error message only after scanning the whole program. Hence debugging

debugging is easy.	is comparatively hard.
Programming language like Python, Ruby use interpreters.	Programming language like C, C++ use compilers.

SECTION – C (3 X 8 =24 Marks)
ANSWER ALL THE QUESTIONS
24. a) Discuss in detail about specification and recognition of tokens.
Specification of tokens
There are 3 specifications of tokens:
1) Strings
2) Language
3) Regular expression
Strings and Languages
An alphabet or character class is a finite set of symbols.

A string over an alphabet is a finite sequence of symbols drawn from that alphabet.

A language is any countable set of strings over some fixed alphabet. In language theory, the terms "sentence" and "word" are often used as synonyms for "string."

The length of a string s, usually written |s|, is the number of occurrences of symbols in s. For example, banana is a string of length six. The empty string, denoted ε, is the string of length zero

Operations on strings
The following string-related terms are commonly used:
1. A prefix of string s is any string obtained by removing zero or more symbols from the end of string s.
For example, ban is a prefix of banana.
2. A suffix of string s is any string obtained by removing zero or more symbols from the beginning of s.
For example, nana is a suffix of banana.
3. A substring of s is obtained by deleting any prefix and any suffix from s.
For example, nan is a substring of banana.
4. The proper prefixes, suffixes, and substrings of a string s are those prefixes, suffixes, and substrings, respectively of s that are not ε or not equal to s itself.
5. A subsequence of s is any string formed by deleting zero or more not necessarily consecutive positions of s.
For example, ban is a subsequence of banana.
Operations on languages:
The following are the operations that can be applied to languages:
1.Union
2.Concatenation
3.Kleene closure
4.Positive closure
The following example shows the operations on strings:

Let L={0,1} and S={a,b,c}
1. Union : L U S={0,1,a,b,c}
2. Concatenation : L.S={0a,1a,0b,1b,0c,1c}
3. Kleene closure : L*={ ε,0,1,00….}
4. Positive closure : L+ ={0,1,00….}

REGULAR EXPRESSIONS

s Each regular expression r denotes a language L(r).
- ✓ Regular expressions are notation for specifying patterns.
- ✓ Each pattern matches a set of strings.
- ✓ Regular expressions will serve as names for sets of strings.

Here are the rules that define the regular expressions over some alphabet Σ and the languages that

those expressions denote:

1. ε is a regular expression, and L(ε) is { ε }, that is, the language whose sole member is the empty string.

2. If 'a' is a symbol in Σ, then 'a' is a regular expression, and L(a) = {a}, that is, the language with

one string, of length one, with 'a' in its one position.

3. Suppose r and s are regular expressions denoting the languages L(r) and L(s). Then,
   - a) (r)|(s) is a regular expression denoting the language L(r) U L(s).
   - b) (r)(s) is a regular expression denoting the language L(r)L(s). c)
   - (r)* is a regular expression denoting (L(r))*.
   - d) (r) is a regular expression denoting L(r).

4. The unary operator * has highest precedence and is left associative.

5. Concatenation has second highest precedence and is left associative.

6. | has lowest precedence and is left associative.

Regular set

A language that can be defined by a regular expression is called a regular set. If two regular expressions r and s denote the same regular set, we say they are equivalent and write r = s.

There are a number of algebraic laws for regular expressions that can be used to manipulate into equivalent forms.

For instance, r|s = s|r is commutative; r|(s|t)=(r|s)|t is associative.

Regular Definitions

Giving names to regular expressions is referred to as a Regular definition. If Σ is an

alphabet of basic symbols, then a regular definition is a sequence of definitions of the form

dl → r 1

d2 → r2

………

dn → rn

1. Each di is a distinct name.

2. Each ri is a regular expression over the alphabet Σ U {dl
, d2,. . . , di-l}.

Example: Identifiers is the set of strings of letters and digits beginning with a letter. Regular definition for this set:

letter → A | B | …. | Z | a | b | …. | z |

digit → 0 | 1 | …. | 9

id → letter (letter | digit) *

Shorthands

Certain constructs occur so frequently in regular expressions that it is convenient to introduce notational shorthands for them.

1. **One or more instances (+):**

- The unary postfix operator + means " one or more instances of" .

- If r is a regular expression that denotes the language L(r), then (r)+ is a regular expression that denotes the language (L (r))+

- Thus the regular expression a+ denotes the set of all strings of one or more a's.

- The operator + has the same precedence and associativity as the operator *

. **2. Zero or one instance (?):**

- The unary postfix operator ? means "zero or one instance of". -

The notation r? is a shorthand for r | ε.

- If 'r' is a regular expression, then (r)? is a regular expression that denotes the language L(r) U { ε }.

3. Character Classes:

- The notation [abc] where a, b and c are alphabet symbols denotes the regular expression a | b |c.

- Character class such as [a - z] denotes the regular expression a | b | c | d | ….|z.

- We can describe identifiers as being strings generated by the regular expression, [AZa-z][A-Za-z0-9]*

Non-regular Set A language which cannot be described by any regular expression is a non-regular set.

Example: The set of all strings of balanced parentheses and repeating strings cannot be described by a

regular expression. This set can be specified by a context-free grammar.

RECOGNITION OF TOKENS

Consider the following grammar fragment:

stmt → if expr then stmt

    | if expr then stmt else stmt

    | ε

expr → term relop term

    | term

term → id

    | num

where the terminals if , then, else, relop, id and num generate sets of strings given by the following regular definitions:

if → if
then → then
else → else
relop → <|<=|=|<>|>|>=
id → letter(letter|digit)*
num → digit+(.digit+)?(E(+|-)?digit+)?

For this language fragment the lexical analyzer will recognize the keywords if, then, else, as well as the lexemes denoted by relop, id, and num. To simplify matters, we assume keywords are reserved; that is, they cannot be used as identifiers.

b) What is symbol table? Explain the data structures of symbol table in detail.

SYMBOL TABLE

Symbol table is an important data structure created and maintained by compilers in order to store information about the occurrence of various entities such as variable names, function names, objects, classes, interfaces, etc. Symbol table is used by both the analysis and the synthesis parts of a compiler.

- ✓ A symbol table may serve the following purposes depending upon the language in hand:
- ✓ To store the names of all entities in a structured form at one place.
- ✓ To verify if a variable has been declared.
- ✓ To implement type checking, by verifying assignments and expressions in the source code are semantically correct.
- ✓ To determine the scope of a name (scope resolution).

A symbol table is simply a table which can be either linear or a hash table. It maintains an entry for each name in the following format:

     <symbol name, type, attribute>

For example, if a symbol table has to store information about the following variable declaration:

     static int interest;

then it should store the entry such as:

<interest, int, static>

The attribute clause contains the entries related to the name.

Implementation

If a compiler is to handle a small amount of data, then the symbol table can be implemented as an unordered list, which is easy to code, but it is only suitable for small tables only. A symbol table can be implemented in one of the following ways:

- ✓ Linear (sorted or unsorted) list
- ✓ Binary Search Tree
- ✓ Hash table

Among all, symbol tables are mostly implemented as hash tables, where the source code symbol itself is treated as a key for the hash function and the return value is the information about the symbol.

Operations

A symbol table, either linear or hash, should provide the following operations.

insert()

This operation is more frequently used by analysis phase, i.e., the first half of the compiler where tokens are identified and names are stored in the table. This operation is used to add information in the symbol table about unique names occurring in the source code. The format or structure in which the names are stored depends upon the compiler in hand.

An attribute for a symbol in the source code is the information associated with that symbol. This information contains the value, state, scope, and type about the symbol. The insert() function takes the symbol and its attributes as arguments and stores the information in the symbol table.

For example:

int a;

should be processed by the compiler as:

insert(a, int);

lookup()

lookup() operation is used to search a name in the symbol table to determine:

- ✓ if the symbol exists in the table.
- ✓ if it is declared before it is being used.
- ✓ if the name is used in the scope.
- ✓ if the symbol is initialized.
- ✓ if the symbol declared multiple times.

The format of lookup() function varies according to the programming language. The basic format should match the following:

lookup(symbol)

This method returns 0 (zero) if the symbol does not exist in the symbol table. If the symbol exists in the symbol table, it returns its attributes stored in the table.

Scope Management

A compiler maintains two types of symbol tables: a **global symbol table** which can be accessed by all the procedures and **scope symbol tables** that are created for each scope in the program.

To determine the scope of a name, symbol tables are arranged in hierarchical structure as shown in the example below:

```
. . .
int value=10;

void pro_one()
    {
    int one_1;
    int one_2;

        {             \
        int one_3;    |_  inner scope 1
        int one_4;    |
        }             /

    int one_5;

        {             \
        int one_6;    |_  inner scope 2
        int one_7;    |
        }             /
    }

void pro_two()
    {
    int two_1;
    int two_2;

        {             \
        int two_3;    |_  inner scope 3
        int two_4;    |
        }             /

    int two_5;
    }
. . .
```
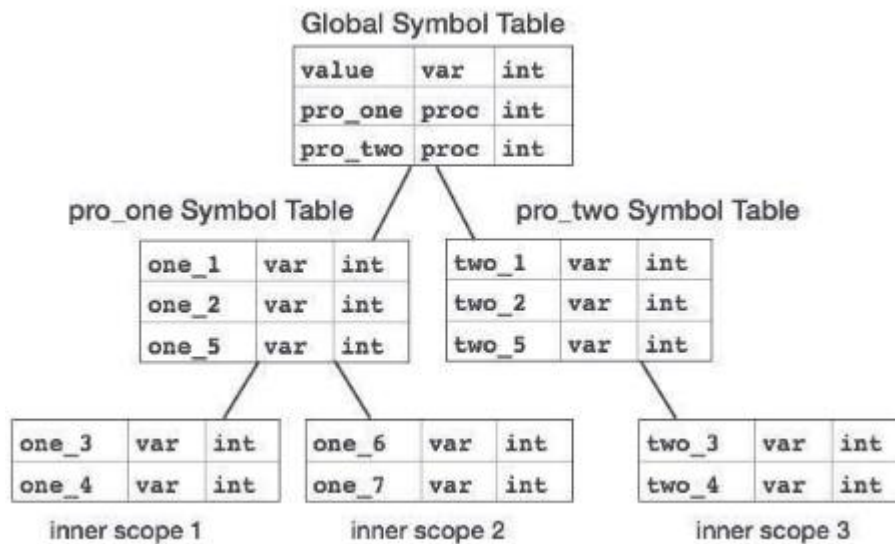
The above program can be represented in a hierarchical structure of symbol

Global Symbol Table

value	var	int
pro_one	proc	int
pro_two	proc	int

pro_one Symbol Table

one_1	var	int
one_2	var	int
one_5	var	int

pro_two Symbol Table

two_1	var	int
two_2	var	int
two_5	var	int

one_3	var	int
one_4	var	int

inner scope 1

one_6	var	int
one_7	var	int

inner scope 2

two_3	var	int
two_4	var	int

inner scope 3

tables:

The global symbol table contains names for one global variable (int value) and two procedure names, which should be available to all the child nodes shown above. The names mentioned in the pro_one symbol table (and all its child tables) are not available for pro_two symbols and its child tables.

This symbol table data structure hierarchy is stored in the semantic analyzer and whenever a name needs to be searched in a symbol table, it is searched using the following algorithm:

- ✓ first a symbol will be searched in the current scope, i.e. current symbol table.

- ✓ if a name is found, then search is completed, else it will be searched in the parent symbol table until,

- ✓ either the name is found or global symbol table has been searched for the name.

25. a) Explain any one parser type in detail.   [OR]

LR Parser

The LR parser is a non-recursive, shift-reduce, bottom-up parser. It uses a wide classof context-free grammar which makes it the most efficient syntax analysis technique. LR parsers are also known as LR(k) parsers, where L stands for left-to-right scanning of the input stream; R stands for the construction of right-most derivation in reverse, and k denotes the number of look ahead symbols to make decisions.

An LL Parser accepts LL grammar. LL grammar is a subset of context-free grammar but with some restrictions to get the simplified version, in order to achieve easy implementation. LL grammar can be implemented by means of both algorithms, namely, recursive-descent or table-driven.

LL parser is denoted as LL(k). The first L in LL(k) is parsing the input from left to right, the second L in LL(k) stands for left-most derivation and k itself represents the number of look aheads. Generally k = 1, so LL(k) may also be written as LL(1).

```
token = next_token()

repeat forever
   s = top of stack

   if action[s, token] = "shift si" then
       PUSH token
       PUSH si
       token = next_token()

   else if action[s, token] = "reduce A::= β" then
       POP 2 * |β| symbols
       s = top of stack
       PUSH A
       PUSH goto[s,A]

   else if action[s, token] = "accept" then
       return

   else
       error()
```

LL	LR
Does a leftmost derivation.	Does a rightmost derivation in reverse.
Starts with the root nonterminal on the stack	Ends with the root nonterminal on the stack.
Ends when the stack is empty	Starts with an empty stack.
Uses thestack for designating what is still to be expected.	Uses the stack for designating what is already seen
Builds the parse tree top-down.	Builds the parse tree bottom-up.
Continuously pops a nonterminal off the stack, and pushes the corresponding right hand side.	Tries to recognize a right hand side on thestack, pops it, and pushes the corresponding nonterminal.
Expands the non-terminals	Reduces the non-terminals.
Reads the terminals when it pops one off the stack.	Reads the terminalswhile itpushes them on the stack.
Pre-order traversal of the parse tree.	Post-order traversal of the parse tree

There are three widely used algorithms available for constructing an LR parser:

• SLR(l) - Simple LR

   o Works on smallest class of grammar.

      Few number of states, hence very small table.

   o Simple and fast construction.

• LR(1) - LR parser

   o Also called as Canonical LR parser.

   o Works on complete set of LR(l) Grammar.

o Generates large table and large number of states.

o Slow construction.

• LALR(l) - Look ahead LR parser

o Works on intermediate size of grammar.

o Number of states are same as in SLR(l).

Reasons for attractiveness of LR parser

• LR parsers can handle a large class of context-free grammars.

• The LR parsing method is a most general non-back tracking shift-reduce parsing method.

• An LR parser can detect the syntax errors as soon as they can occur.

• LR grammars can describe more languages than LL grammars.

Drawbacks of LR parsers

• It is too much work to construct LR parser by hand. It needs an automated parser generator.

• If the grammar contains ambiguities or other constructs then it is difficult to parse in a left-to-right scan of the input.

Model of LR Parser

LR parser consists of an input, an output, a stack, a driver program and a parsing table that has two functions

1. Action

2. Goto

The driver program is same for all LR parsers. Only the parsing table changes from one parser to another.

The parsing program reads character from an input buffer one at a time, where a shift reduces parser would shift a symbol; an LR parser shifts a state. Each state summarizes the information contained in the stack.

The stack holds a sequence of states, s_o, s_1, $\cdots$, S_m, where S_m is on the top.
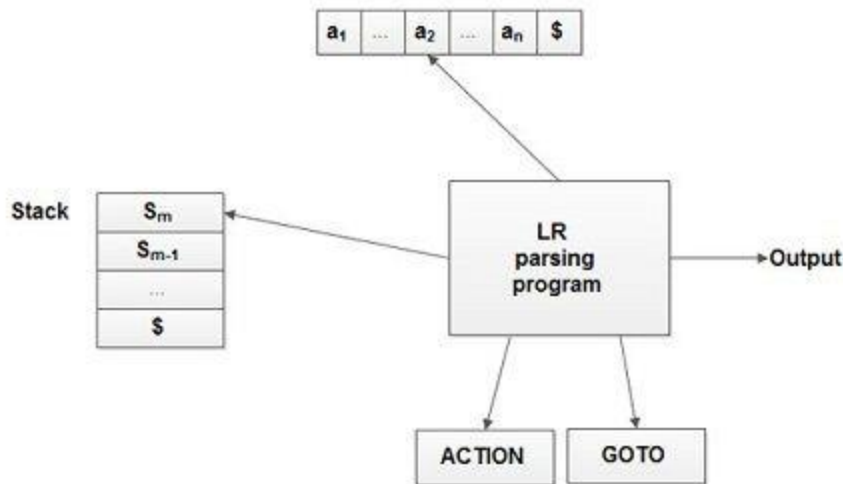
Action This function takes as arguments a state i and a terminal a (or $, the input end marker). The value of ACTION [i, a] can have one of the four forms:

i) Shift j, where j is a state.

ii) Reduce by a grammar production A---> β.

iii) Accept.

iv) Error.

Goto This function takes a state and grammar symbol as arguments and produces a state.

If GOTO [I_i ,A] = I_j, the GOTO also maps a state i and non terminal A to state j.

Behavior of the LR parser

1. If ACTION[s_m, ai] = shift s. The parser executes the shift move, it shifts the next state s onto the stack, entering the configuration

a) S_m - the state on top of the stack.

b) a_i- the current input symbol.

2. If ACTION[s_m, a_i] =reduce A---> β, then the parser executes a reduce move, entering the configuration

$$(s_0s_1 \dots S_{(m-r)}S, \text{ a}_{i+1} \dots a_n\$)$$

a) where r is the length of β and s= $GOTO[s_m$ - r, A].

b) First popped r state symbols off the stack, exposing state S_{m-r}.

 Then pushed s, the entry for $GOTO[s_{m-r}$, A], onto the stack.

3. If ACTION[s_m, a_i] = accept, parsing is completed.

4. If ACTION[s_m, a_i] = error, the parser has discovered an error and calls an error recovery routine.

   b) Explain three address code generation concepts in detail.

Addresses and Instructions

• TAC consists of a sequence of instructions, each instruction may have up to three addresses, proto typically t1 = t2 op t3

• Addresses may be one of:

o A name. Each name is a symbol table index. For convenience, we write the names as the identifier.

o A constant.

o A compiler-generated temporary. Each time a temporary address is needed, the compiler generates another name from the stream t1, t2, t3, etc.

> • Temporary names allow for code optimization to easily move Instructions
> • At target-code generation time, these names will be allocated to registers or to memory.
> • TAC Instructions

o Symbolic labels will be used by instructions that alter the flow of control.

> The instruction addresses of labels will be filled in later.
> L: t1 = t2 op t3

Types of three address code

There are different types of statements in source program to which three address code has to be generated. Along with operands and operators, three address code also use labels to provide flow of control for statements like if-then-else, for and while. The different types of three address code statements are:

Assignment statement

a = b op c

In the above case b and c are operands, while op is binary or logical operator. The result of applying op on b and c is stored in a.

Unary operation

a = op b This is used for unary minus or logical negation.

Example: a = b * (- c) + d

Three address code for the above example will be

t1 = -c

t2 = t1 * b

t3 = t2 + d

a = t3

Copy Statement

a=b

The value of b is stored in variable a.

Unconditional jump

goto L

Creates label L and generates three-address code 'goto L'

v. Creates label L, generate code for expression exp, If the exp returns value true then go to the statement labelled L. exp returns a value false go to the statement immediately following the if statement.

Function call

For a function fun with n arguments a1,a2,a3….an ie.,

fun(a1, a2, a3,…an),

the three address code will be

Param a1

Param a2

…

Param an

Call fun, n

Where param defines the arguments to function.

Array indexing

In order to access the elements of array either single dimension or multidimension, three address code requires base address and offset value. Base address consists of the address of first element in an array. Other elements of the array can be accessed using the base address and offset value.

Example: x = y[i]

Memory location m = Base address of y + Displacement i

x = contents of memory location m

similarly x[i] = y

Memory location m = Base address of x + Displacement i

The value of y is stored in memory location m

Pointer assignment

x = &y x stores the address of memory location y

x = *y y is a pointer whose r-value is location

*x = y sets r-value of the object pointed by x to the r-value of y

Intermediate representation should have an operator set which is rich to implement. The operations of source language. It should also help in mapping to restricted instruction set of target machine.

QUADRUPLES-

Quadruples consists of four fields in the record structure. One field to store operator op, two fields to store operands or arguments arg1and arg2 and one field to store result res. res = arg1op arg2

Example: a = b + c

b is represented as arg1, c is represented as arg2, + as op and a as res.

Unary operators like '-'do not use agr2. Operators like param do not use agr2 nor result. For conditional and unconditional statements res is label. Arg1, arg2 and res are pointers to symbol table or literal table for the names.

Example: a = -b * d + c + (-b) * d

Three address code for the above statement is as follows

t1 = - b

t2 = t1 * d

t3 = t2 + c

t4 = - b

t5 = t4 * d

t6 = t3 + t5

a = t6

Quadruples for the above example is as follows

Op	Arg1	Arg2	Res
-	B		t1
*	t1	d	t2
+	t2	c	t3
-	B		t4
*	t4	d	t5
+	t3	t5	t6
=	t6		a

TRIPLES

Triples uses only three fields in the record structure. One field for operator, two fields foroperands named as arg1 and arg2. Value of temporary variable can be accessed by theposition of the statement the computes it and not by location as in quadruples.

Example: a = -b * d + c + (-b) * d

Triples for the above example is as follows

Stmt no	Op	Arg1	Arg2
(0)	-	b	
(1)	*	d	(0)
(2)	+	c	(1)
(3)	-	b	
(4)	*	d	(3)
(5)	+	(2)	(4)
(6)	=	a	(5)

Arg1 and arg2 may be pointers to symbol table for program variables or literal table forconstant or pointers into triple structure for intermediate results.Example: Triples for statement x[i] = y which generates two records is as follows

Stmt no	Op	Arg1	Arg2
(0)	[]=	x	i
(1)	=	(0)	y

INDIRECT TRIPLES

Indirect triples are used to achieve indirection in listing of pointers. That is, it uses pointers totriples than listing of triples themselves.

Example: a = -b * d + c + (-b) * d

	Stmt no	Stmt no	Op	Arg1	Arg2
(0)	(10)	(10)	-	b	
(1)	(11)	(11)	*	d	(0)
(2)	(12)	(12)	+	c	(1)
(3)	(13)	(13)	-	b	
(4)	(14)	(14)	*	d	(3)
(5)	(15)	(15)	+	(2)	(4)
(6)	(16)	(16)	=	a	(5)

Conditional operator and operands. Representations include quadruples, triples and indirect triples

26. a) What is intermediate representation? Discuss in detail.

Intermediate code forms:

An intermediate code form of source program is an internal form of a program created by the compiler while translating the program created by the compiler while translating the program from a high –level language to assembly code(or)object code(machine code).an intermediate source form represents a more attractive form of target code than does assembly. An optimizing Compiler performs optimizations on the intermediate source form and produces an object module.

<div align="center">
Analysis + syntheses=translation

Creates an generate   target code

Intermediate code
</div>

Logical Structure of a Compiler Front End

In the analysis –synthesis model of a compiler, the front-end translates a source program into anintermediate representation from which the back-end generates target code, in many compilers thesource code is translated into a language which is intermediate in complexity between a HLL andmachine code .the usual intermediate code introduces symbols to stand for various temporaryquantities.

Intermediate representations span the gap between the source and target languages.
• High Level Representations
  - closer to the source language
  - easy to generate from an input program
  - code optimizations may not be straightforward

• Low Level Representations
  - closer to the target machine
  - Suitable for register allocation and instruction selection
  - easier for optimizations, final code generation

There are several options for intermediate code. They can be either Specific to the language being implemented
  - P-code for Pascal
  - Byte code for Java

We assume that the source program has already been parsed and statically checked.. the variousintermediate code forms are:

> a) Polish notation
> b) Abstract syntax trees(or)syntax trees
> c) Quadruples
> d) Triples   three address code
> e) Indirect triples
> f) Abstract machine code(or)pseudocopde

Postfix
The ordinary (infix) way of writing the sum of a and b is with the operator in the middle: a+b. thepostfix (or postfix polish)notation for the same expression places the operator at the right end,

as ab+.In general, if e1 and e2 are any postfix expressions, and Ø to the values denoted by e1 and e2 isindicated in postfix notation nby e1e2Ø.no parentheses are needed in postfix notation because theposition and priority (number of arguments) of the operators permits only one way to decode apostfix expression.

Example:

1. (a+b)*c in postfix notation is ab+c*,sinceab+ represents the infix expression(a+b).
2. a*(b+c)is abc+* in postfix.
3. (a+b)*(c+d) is ab+cd+* in postfix.

Postfix notation can be generalized to k-ary operators for any k>=1.if k-ary operator Ø is applied topostfix expression e1,e2,………..ek, then the result is denoted by e1e2…….ek Ø. if we know thepriority of each operator then we can uniquely decipher any postfix expression by scanning it fromeither end.

Example:

Consider the postfix string ab+c*.

The right hand * says that there are two arguments to its left. since the next –to-rightmost symbol isc, simple operand, we know c must be the second operand of *.continuing to the left, we encounterthe operator +.we know the sub expression ending in + makes up the first operand of *.continuing in this way ,we deduce that ab+c* is "parsed" as (((a,b)+),c)*.

b**. syntax tree**:

The parse tree itself is a useful intermediate-language representation for a source program,especially in optimizing compilers where the intermediate code needs to extensively restructure.
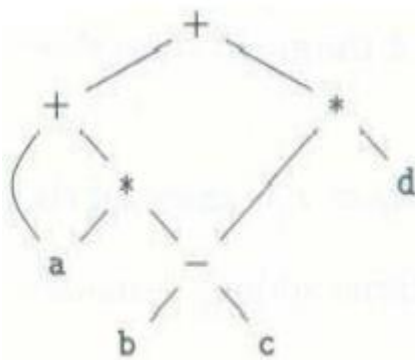
A parse tree, however, often contains redundant information which can be eliminated, Thusproducing a more economical representation of the source program. One such variant of a parse treeis what is called an (abstract) syntax tree, a tree in which each leaf represents an operand and eachinterior node an operator.

Exmples: 1) Syntax tree for the expression a*(b+c)/d

c.Three-Address Code: • In three-address code, there is at most one operator on the right side of aninstruction; that is, no built-up arithmetic expressions are permitted.

x+y*z t1 = y * z t2 = x + t1 • Example

$$t_1 = b - c$$
$$t_2 = a * t_1$$
$$t_3 = a + t_2$$
$$t_4 = t_1 * d$$
$$t_5 = t_3 + t_4$$

(a) DAG   (b) Three-address code

LANGUAGE INDEPENDENT 3-ADDRESS CODE

IR can be either an actual language or a group of internal data structures that are shared by the phases of the compiler. C used as intermediate language as it is flexible, compiles into efficient machine code and its compilers are widely available.In all cases, the intermediate code is a linearization of the syntax tree produced during syntax and semantic analysis. It is formed by breaking down the tree structure into sequential instructions, each of which is equivalent to a single, or small number of machine instructions.

Machine code can then be generated (access might be required to symbol tables etc). TAC can range from high- to low-level, depending on the choice of operators. In general, it is a statement containing at most 3 addresses or operands. The general form is x := y op z, where "op" is an operator, x is the result, and y and z are operands. x, y, z are variables, constants, or "temporaries". A three-address instruction consists of at most 3 addresses for each statement.

It is a linear zed representation of a binary syntax tree. Explicit names correspond to interiornodes of the graph. E.g. for a looping statement , syntax tree represents components of thestatement, whereas three-address code contains labels and jump instructions to represent theflow-of-control as in machine language. A TAC instruction has at most one operator on theRHS of an instruction; no built-up arithmetic expressions are permitted.

e.g. x + y * z can be translated as

t1 = y * z

t2 = x + t1

Where t1 & t2 are compiler–generated temporary names.

Since it unravels multi-operator arithmetic expressions and nested control-flow statements,it is useful for target code generation and optimization.

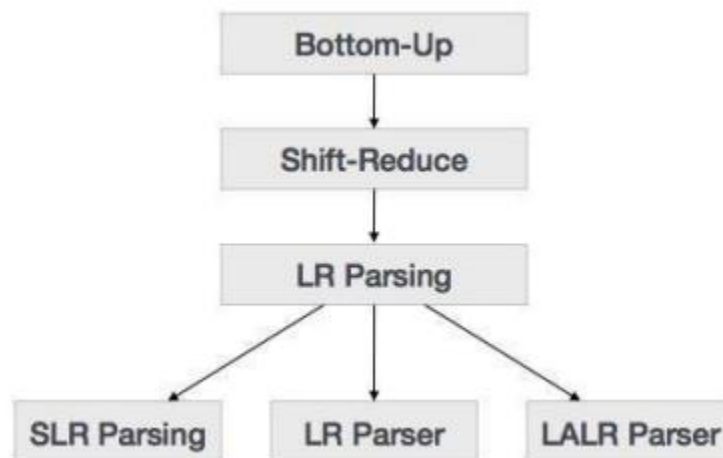### b) How Bottom-up parser works in compiler design? Explain.

Bottom-up Parsing

As the name suggests, bottom-up parsing starts with the input symbols and tries toconstruct the parse tree up to the start symbol.

Note:

In both the cases the input to the parser is being scanned from left to right, onesymbol at a time.The bottom-up parsing method is called "Shift Reduce" parsing. The top-down parsingis called "Recursive Decent" parsing.

Bottom-up parsing starts from the leaf nodes of a tree and works in upward directiontill it reaches the root node. Here, we start from a sentence and then apply productionrules in reverse manner in order to reach the start symbol. The image given below depictsthe bottom-up parsers available

An operator-precedence parser is one kind of shift reduce parser and predictive parseris one kind of recursive descent parser.

Shift reduce parsing methods

It is called as bottom up style of parsing. Shift-reduce parsing uses two unique steps for bottom-up parsing. These steps are known as shift-step and reduce-step.

Shift step

The shift step refers to the advancement of the input pointer to the next input symbol, which is called the shifted symbol. This symbol is pushed onto the stack. The shifted symbol is treated as a single node of the parse tree.

Reduce step

When the parser finds a complete grammar rule (RHS) and replaces it to (LHS), it is known as reduce-step. This occurs when the top of the stack contains a handle. To reduce, a POP function is performed on the stack which pops off the handle and replaces it with LHS non-terminal symbol.

Reducing a string W to the start symbol S of a grammar.

At each step a string matching the right side of a production is replaced by the symbol on the left.

Example:

S→ aAcBe; A→Ab; A→ b; B→d and the string is abbcde, we have to reduce it to S.

    Abbcde → abbcBe
            → aAbcBe
            → aAcBe
            →S

Each replacement of the right side of the production the left side in the process above is called reduction .by reverse of a right most derivation is called Handle

$S^* \rightarrow \alpha Aw \rightarrow \alpha \beta w, then\ A \rightarrow \beta$ in partition following is a handle of αβw. The string w to the right of the handle contains only terminal symbol.

A rightmost derivation in reverse often called a canonical reduction sequence, is obtained by "Handle Pruning".

Example:
    E→ E+E
    E→ E*E
    E→(E)
    E→id
Input: $id_1 + id_2 * id_3 \rightarrow E$

Right Sentential Form	Handle	Reducing production
$id_1 + id_2 * id_3$	id_1	E→id
$E + id_2 * id_3$	id_2	E→id
$E + E * id_3$	id_3	E→id
E+E*E	E*E	E→E*E
E+E	E+E	E→E+E
E		

KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established Under Section 3 of UGC Act 1956)
COIMBATORE – 641 021

INFORMATION TECHNOLOGY

First Semester
THIRD INTERNAL EXAMINATION - March 2019

SYSTEM PROGRAMMING

Class & Section: III B.Sc (IT), **Duration: 2 hours**
Date & Session : 12.03.2019(FN) **Maximum marks: 50 marks**
Sub.Code: 16ITU603B

PART- A (20 * 1= 20 Marks)
Answer ALL the Questions

1. What characteristic of RAM memory makes it not suitable for permanent storage?
   a) Too slow b) Unreliable c) It is volatile d) Too bulky
2. Select a Machine Independent phase of the compiler
   a) Syntax Analysis b) Intermediate Code generation c) Lexical analysis d) all the above
3. Which of the following system software resides in the main memory always _____
   a) Text Editor b) Assembler c) Linker d) Loader
4. The graph that shows basic blocks and their successor relationship is called _____
   a) DAG b) Hamiltonian graph c) Flow graph d)control graph
5. When a computer is first turned on or restarted, a special type of absolute loader is executed called _____
   a) " Compile and GO " loader b) Boot loader
   c) Boot strap loader d) Relating loader
6. Which of the following are storage allocation strategies?
   a) stack allocation b) static allocation c) heap allocation d) all
7. Flow of control in a program corresponds to which traversal of activation tree ?
   a) Depth first traversal b) Breadth first traversal c) both (a) and (b) d)none
8. Memory unit accessed by content is called_____ .
   a) Read only memory b) Programmable Memory
   c) Virtual Memory d) Associative Memory
9. _____ register keeps tracks of the instructions stored in program stored in memory.
   a) AR (Address Register) b) XR (Index Register)
   c) PC (Program Counter) d) AC (Accumulator)
10. In computers, subtraction is generally done by _____
    a) 1's complement method b) 2's complement method
    c) BCD subtraction method d) signed magnitude method
11. Which of the following comment about peep-hole optimization is true?
    a) they enhance the portability of the compiler to other target processors
    b) program analysis is more accurate on intermediate code than on machine code
    c) the information from dataflow analysis cannot otherwise be used for optimization

d) the information from the front end cannot otherwise be used for optimization

12. Which of the following is the fastest logic?
    a) TTL   b) ECL   c) CMOS   d) LSI

13. he optimization which avoids test at every iteration is _____
    a) Loop unrolling   b) Loop jamming   c) Constant folding   d)None

14. Compiler should report the presence of _____in source program, in translation process.
    a) data   b) object   c) errors   d) text

15. What is responsible for generation of final machine code tailored to target system?
    a) Interpreter   b) Semantic analyzer   c) Code generator   Code optimizer

16. Optimization of program that works within a single basic block is called _____
    a) Local optimization   b) Global optimization
    c) Loop un-controlling   d) Loop controlling

17. Variable that can be accessed through out program is known as _____.
    a) Local variable   b) Global Variable   c) Integer   d) Constant

18. What is boot strapping?
    a) A language interpreting other language program
    b) A language compiling other language program
    c) A language compile itself   d) All of above

19. Name given to the organized collection of software that controls the overall operation of a computer is _____.
    a) working system   b) peripheral system   c) operating system   d) controlling system

20. The __ of a system includes the program s or instructions.
    a) icon   b) software   c) hardware   d) information

PART- B (3 * 2= 6 Marks)
Answer ALL the Questions

21. Differentiate between static and dynamic storage allocation.
22. Write the function of activation record in run-time environment.
23. What is Optimization?

PART- C (3 * 8= 24 Marks)
Answer ALL the Questions

24. a) Discuss in detail about storage allocation in run-time environment.   [OR]
    b) Explain the structure and working principles of activation record in detail.

25. a) Write a detail note on Parameter passing techniques.   [OR]
    b) What is machine independent optimization? Discuss in detail.

26. a) Explain Peep-hole optimization.   [OR]
    b) Discuss code generator phase in compiler design in detail.

KARPAGAMACADEMY OF HIGHER EDUCATION
(Deemed to be University)
(Established Under Section 3 of UGC Act 1956)
COIMBATORE – 641 021

INFORMATION TECHNOLOGY

Second Semester
THIRD INTERNAL EXAMINATION - March 2019

PROGRAMMING IN JAVA

Class & Section: III B.Sc (IT),   **Duration: 2 hours**
Date & Session :   **Maximum marks: 50 marks**
Subj.Code: 16ITU613B

PART- A (20 * 1= 20 Marks)
Answer ALL the Questions

1. What characteristic of RAM memory makes it not suitable for permanent storage?

 a) Too slow   b) Unreliable   c) **It is volatile**   d) Too bulky

2. Select a Machine Independent phase of the compiler

a) Syntax Analysis   b) Intermediate Code generation   c) Lexical analysis   d) **all the above**

3.Which of the following system software resides in the main memory always _____

a) Text Editor   b) Assembler   c) Linker   d) **Loader**

4. The graph that shows basic blocks and their successor relationship is called _____

 a) **DAG**   b) Hamiltonian graph   c) Flow graph   d)control graph

5. When a computer is first turned on or restarted, a special type of absolute loader is executed

called _____

 a) " Compile and GO " loader   b) Boot loader

c) **Boot strap loader**   d) Relating loader

6. Which of the following are storage allocation strategies?

a) stack allocation   b) static allocation   c) heap allocation   d) **all**

7.Flow of control in a program corresponds to which traversal of activation tree ?

 a) **Depth first traversal**   b) Breadth first traversal   c) both (a) and (b)   d)none

8.Memory unit accessed by content is called_____ .

 a) Read only memory   b) Programmable Memory

c) Virtual Memory   d) **Associative Memory**

9._____ register keeps tracks of the instructions stored in program stored in memory.

a) AR (Address Register)   b) XR (Index Register)

c) PC (Program Counter)   d) AC (Accumulator)

10. In computers, subtraction is generally done by _____

a) 1's complement method   b) **2's complement method**

c) BCD subtraction method   d) signed magnitude method

11. Which of the following comment about peep-hole optimization is true?

a) **they enhance the portability of the compiler to other target processors**

 b) program analysis is more accurate on intermediate code than on machine code

 c) the information from dataflow analysis cannot otherwise be used for optimization

d) the information from the front end cannot otherwise be used for optimization

12. Which of the following is the fastest logic?

a) TTL   b) **ECL**   c) CMOS   d) LSI

13. he optimization which avoids test at every iteration is _____

a) **Loop unrolling**   b) Loop jamming   c) Constant folding   d)None

14. Compiler should report the presence of _____in source program, in translation process.

a) data   b) object   c) **errors**   d) text

15. What is responsible for generation of final machine code tailored to target system?

a) Interpreter b) Semantic analyzer   c) **Code generator**   Code optimizer

16. Optimization of program that works within a single basic block is called _____

  a) **Local optimization**   b) Global optimization

 c) Loop un-controlling   d) Loop controlling

17. Variable that can be accessed through out program is known as _____.
a) Local variable   b)**Global Variable**   c) Integer   d) Constant

18. What is bootstrapping?

 a) A language interpreting other language program

b) A language compiling other language program

c) **A language compile itself**   d) All of above

19. Name given to the organized collection of software that controls the overall operation of a

computer is _____.

   a) working system   b) peripheral system   c**) operating system**   d) controlling system

20. The __ of a system includes the program s or instructions.

   a) icon   b) **software**   c) hardware   d) information

PART- B (3 * 2= 6 Marks)

Answer ALL the Questions

21. Differentiate between static and dynamic storage allocation.

he major difference between static and dynamic memory allocations are:

Static Memory Allocation	Dynamic Memory Allocation
In this case, variables get allocated permanently	In this case, variables get allocated only if your program unit gets active
Allocation is done before program execution	Allocation is done during program execution
It uses the data structure called stack for implementing static allocation	It uses the data structure called heap for implementing dynamic allocation
Less efficient	More efficient
There is no memory reusability	There is memory reusability and memory can be freed when not required

22. Write the function of activation record in run-time environment.

Activation Record

   ✓ Control stack is a run time stack which is used to keep track of the live procedure
   activations i.e. it is used to find out the procedures whose execution have not been
   completed.

- ✓ When it is called (activation begins) then the procedure name will push on to the stack and when it returns (activation ends) then it will popped.
- ✓ Activation record is used to manage the information needed by a single execution of a procedure.
- ✓ An activation record is pushed into the stack when a procedure is called and it is popped when the control returns to the caller function.

23. What is Optimization?

Optimization is a program transformation technique, which tries to improve the code by making it consume less resources (i.e. CPU, Memory) and deliver high speed.

In optimization, high-level general programming constructs are replaced by very efficient low-level programming codes. A code optimizing process must follow the three rules given below:

- The output code must not, in any way, change the meaning of the program.

- Optimization should increase the speed of the program and if possible, the program should demand less number of resources.

- Optimization should itself be fast and should not delay the overall compiling process.

PART- C (3 * 8= 24 Marks)

Answer ALL the Questions

24. a)Discuss in detail about storage allocation in run-time environment.   **[OR]**

Storage Allocation

Runtime environment manages runtime memory requirements for the following entities:

Code : It is known as the text part of a program that does not change at runtime. Its memory requirements are known at the compile time.

Procedures : Their text part is static but they are called in a random manner. That is why, stack storage is used to manage procedure calls and activations.

Variables : Variables are known at the runtime only, unless they are global or constant. Heap memory allocation scheme is used for managing allocation and de-allocation of memory for variables in runtime.

Static Allocation

In this allocation scheme, the compilation data is bound to a fixed location in the memory and it does not change when the program executes. As the memory requirement and storage locations are known in advance, runtime support package for memory allocation and de-allocation is not required.

Stack Allocation

Procedure calls and their activations are managed by means of stack memory allocation. It works in last-in-first-out (LIFO) method and this allocation strategy is very useful for recursive procedure calls.

Heap Allocation

Variables local to a procedure are allocated and de-allocated only at runtime. Heap allocation is used to dynamically allocate memory to the variables and claim it back when the variables are no more required.

Except statically allocated memory area, both stack and heap memory can grow and shrink dynamically and unexpectedly. Therefore, they cannot be provided with a fixed amount of memory in the system.
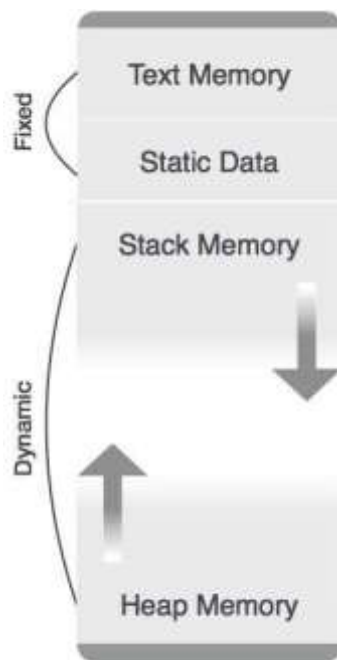
As shown in the figure above, the text part of the code is allocated a fixed amount of memory. Stack and heap memory are arranged at the extremes of total memory allocated to the program. Both shrink and grow against each other.

b) Explain the structure and working principles of activation record in detail.

The information needed for each invocation of a procedure is kept in a runtime data structure called an *activation record* (AR) or *frame*. The frames are kept in a stack called the *control stack*.

Note that this is memory used by the compiled program, not by the compiler. The compiler's job is to generate code that obtains the needed memory and to correctly reference the variables stored in the ARs.

At any point in time the number of frames on the stack is the current depth of procedure calls. For example, in the fibonacci execution shown above when f(4) is active there are three activation records on the control stack.

ARs vary with the language and compiler implementation. Typical components are described below and pictured to the right. In the diagrams the stack grows down the page.
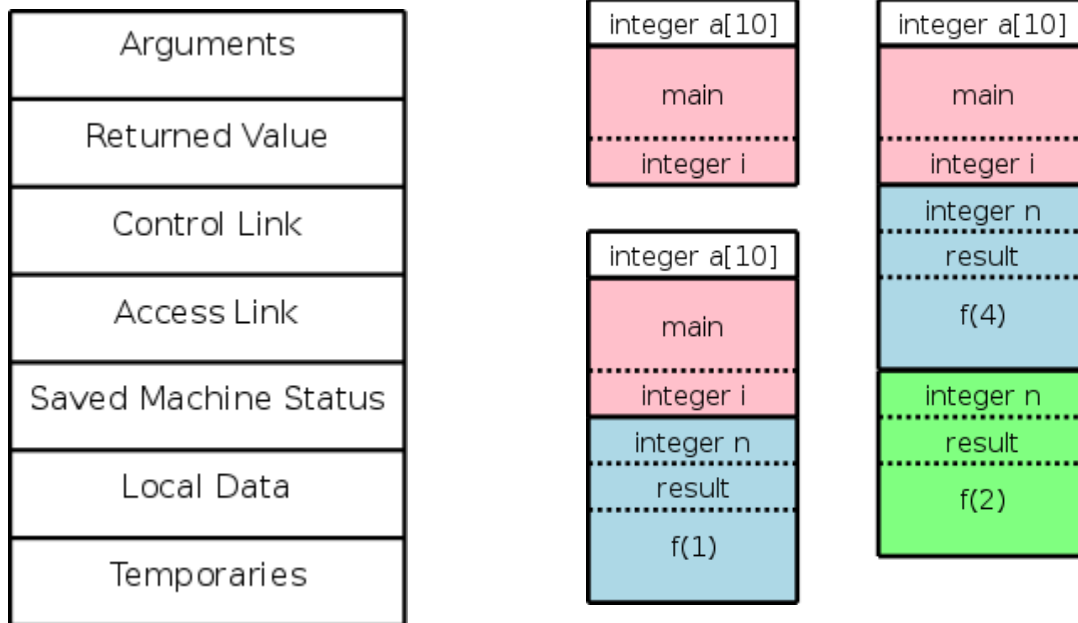
1. The arguments (sometimes called the actual parameters). The first few arguments are often placed in registers.
2. The returned value. This is often placed in a register (if it is a scalar).
3. The **control link** connects the ARs by pointing to the AR of the caller.
4. The **access link** (described below).
5. Saved status from the caller, which typically includes the return address and the machine registers. The register values are restored when control returns to the caller.
6. Data local to the procedure being activated.
7. Temporaries. For example, recall the temporaries generated during expression evaluation. Often these can be held in machine registers. When that is not possible (e.g., there are more temporaries than registers), the temporary area is used.

The diagram on the right shows (part of) the control stack for the fibonacci example at three points during the execution. The solid lines separate ARs; the dashed lines separate components within an AR.

In the upper left we have the initial state, We show the global variable a, although it is not in an activation record and actually is allocated before the program begins execution (it is statically allocated; recall that the stack and heap are each dynamically allocated). Also shown is the activation record for main, which contains storage for the local variable i. Recall that local variables are near the end of the AR.

Below the initial state we see the next state when main has called f(1) and there are two activation records, one for main and one for f. The activation record for f contains space for the argument n and and also for the returned value. Recall that arguments and the return value are allocated near the beginning of the AR. There are no local variables in f.

At the far right is a later state in the execution when f(4) has been called by main and has in turn called f(2). There are three activation records, one for main and two for f. It is these multiple activations for f that permits the recursive execution. There are two locations for n and two for the returned value.

Arguments

Returned Value

Control Link

Access Link

Saved Machine Status

Local Data

Temporaries

integer a[10]
main
integer i

integer a[10]
main
integer i

integer n
result

f(4)

integer a[10]
main
integer i
integer n
result
f(1)

integer n
result
f(2)

25 a) Write a detail note on Parameter passing techniques.   **[OR]**

Calling Sequences

The *calling sequence*, executed when one procedure (the caller) calls another (the callee), allocates an activation record (AR) on the stack and fills in the fields. Part of this work is done by the caller; the remainder by the callee. Although the work is shared, the AR is called the callee's AR.

Since the procedure being called is defined in one place, but normally called from many places, we would expect to find more instances of the caller activation code than of the callee activation code. Thus it is wise, all else being equal, to assign as much of the work to the callee as possible.

Although details vary among implementations, the following principles are often followed.

1. Values computed by the caller are placed before any items of size unknown by the caller. This way they can be referenced by the caller using fixed offsets. One possibility is to place values computed by the caller at the beginning of the activation record, i.e., near the AR of the caller. The number of arguments may

not be the same for different calls of the same function (so called varargs, e.g. printf() in C). However the (compiler of the) caller knows how many arguments there are so, where pink calls blue, the compilers knows how far the return values is from the beginning of the blue AR. Since this beginning of the blue AR is the end of the pink AR (or is one location further depending on how you count), the caller knows (but only at run time) the offset of the return value location from **its own** stack pointer (sp, see below).

2. Fixed length items are placed next. Their sizes are known to the caller and callee at compile time. Examples of fixed length items include the links and the saved status.

3. Finally come items allocated by the callee whose size is known only at run-time, e.g., arrays whose size depends on the parameters.

4. The stack pointer sp is between the last two. One consequence of this location is that the temporaries and local data are actually *above* the stack. This would seem more surprising if I used the book's terminology, which is top_sp. Fixed length data can be referenced by fixed offsets (known to the intermediate code generator) from the sp.

The picture above illustrates the situation where a pink procedure (the caller) calls a blue procedure (the callee). Also shown is Blue's AR. Note that responsibility for this single AR is shared by both procedures. The picture is just an approximation: For example, the returned value is actually Blue's responsibility, although the space might well be allocated by Pink. Also some of the saved status, e.g., the old sp, is saved by Pink.

The picture to the right shows what happens when Blue, the callee, itself calls a green procedure and thus Blue is also a caller. You can see that Blue's responsibility includes part of its AR as well as part of Green's.

Calling Sequence

The following actions occur during a call.

1. The caller begins the process of creating the callee's AR by evaluating the arguments and placing them in the AR of the callee. (I use arguments for the caller, parameters for the callee.)

2. The caller stores the return address and the (soon-to-be-updated) sp in the callee's AR.

3. The caller increments sp so that instead of pointing into its AR, it points to the corresponding point in the callee's AR.

4. The callee saves the registers and other (system dependent) information.

5. The callee allocates and initializes its local data.

6. The callee begins execution.

Return Sequence

When the procedure returns, the following actions are performed by the callee, essentially undoing the effects of the calling sequence.

1. The callee stores the return value. Note that this address can be determined by the caller using the old (soon-to-be-restored) sp.

2. The callee restores sp and the registers.

3. The callee jumps to the return address.

Note that varagrs are supported.

Also note that the values written during the calling sequence are not erased and the space is not *explicitly* reclaimed. Instead, the sp is restored and, if and when the caller makes another call, the space will be reused.

Variable-Length Data on the Stack

There are two flavors of variable-length data.

- Data obtained by malloc/new have hard to determine lifetimes and are stored in the heap instead of the stack.
- Data, such as arrays with bounds determined by the parameters are still stack like in their lifetimes (if A calls B, these variables of A are allocated before and released after the corresponding variables of B).

It is the second flavor that we wish to allocate on the stack. The goal is for the callee to be able to access these arrays using addresses determined at compile time even though the size of the arrays is not known until the program is called, and indeed often differs from one call to the next (even when the two calls correspond to the same source statement).

The solution is to leave room for pointers to the arrays in the AR. These pointers are fixed size and can thus be accessed using static offsets. When the procedure is invoked and the sizes are known, the pointers are filled in and the space allocated.

A difficulty caused by storing these variable size items on the stack is that it no longer is obvious where the real top of the stack is located relative to sp. Consequently another pointer (call it real-top-of-stack) is also kept. This is used on a call to tell where the new allocation record should begin.
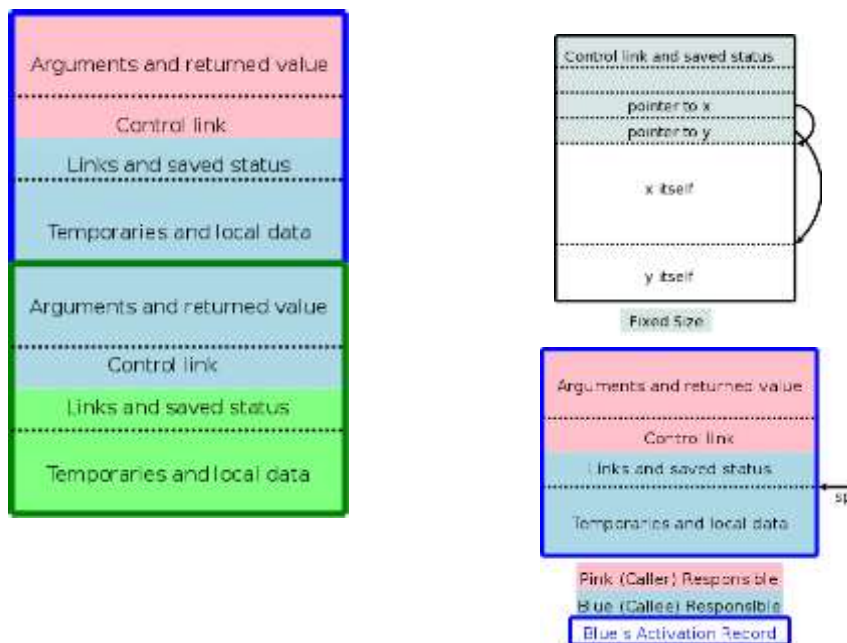
b) What is machine dependent optimization? Discuss in detail.

Machine-independent Optimization

In this optimization, the compiler takes in the intermediate code and transforms a part of the code that does not involve any CPU registers and/or absolute memory locations. For example:

```
do
{
  item = 10;
  value = value + item;
} while(value<100);
```

This code involves repeated assignment of the identifier item, which if we put this way:

```
Item = 10;

do

{

  value = value + item;

} while(value<100);
```

should not only save the CPU cycles, but can be used on any processor.

Machine-dependent Optimization

Machine-dependent optimization is done after the target code has been generated and when the code is transformed according to the target machine architecture. It involves CPU registers and may have absolute memory references rather than relative references. Machine-dependent optimizers put efforts to take maximum advantage of memory hierarchy.

Basic Blocks

Source codes generally have a number of instructions, which are always executed in sequence and are considered as the basic blocks of the code. These basic blocks do not have any jump statements among them, i.e., when the first instruction is executed, all the instructions in the same basic block will be executed in their sequence of appearance without losing the flow control of the program.
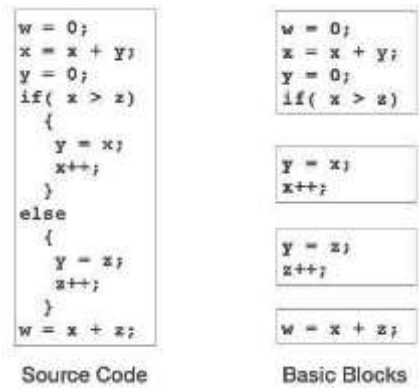
A program can have various constructs as basic blocks, like IF-THEN-ELSE, SWITCH-CASE conditional statements and loops such as DO-WHILE, FOR, and REPEAT-UNTIL, etc.

Basic block identification

We may use the following algorithm to find the basic blocks in a program:

- Search header statements of all the basic blocks from where a basic block starts:
    - First statement of a program.
    - Statements that are target of any branch (conditional/unconditional).
    - Statements that follow any branch statement.
- Header statements and the statements following them form a basic block.
- A basic block does not include any header statement of any other basic block.
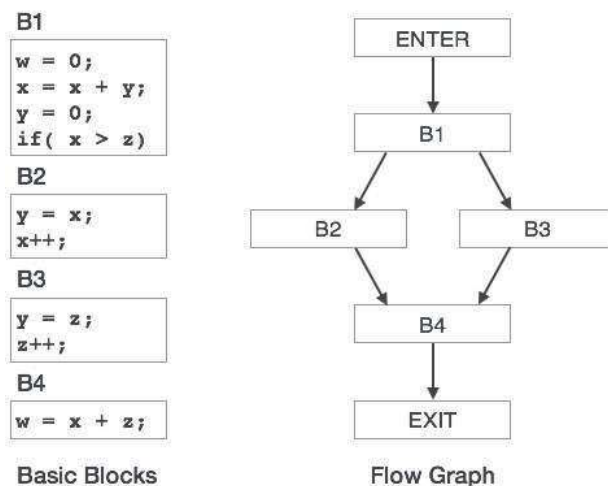
Basic blocks are important concepts from both code generation and optimization point of view.

```
w = 0;
x = x + y;
y = 0;
if( x > z)
{
    y = x;
    x++;
}
else
{
    y = z;
    z++;
}
w = x + z;
```
Source Code

```
w = 0;
x = x + y;
y = 0;
if( x > z)
```
```
y = x;
x++;
```
```
y = z;
z++;
```
```
w = x + z;
```
Basic Blocks

Basic blocks play an important role in identifying variables, which are being used more than once in a single basic block. If any variable is being used more than once, the register memory allocated to that variable need not be emptied unless the block finishes execution.

Control Flow Graph

Basic blocks in a program can be represented by means of control flow graphs. A control flow graph depicts how the program control is being passed among the blocks. It is a useful tool that helps in optimization by help locating any unwanted loops in the program.

B1
```
w = 0;
x = x + y;
y = 0;
if( x > z)
```
B2
```
y = x;
x++;
```
B3
```
y = z;
z++;
```
B4
```
w = x + z;
```
Basic Blocks

ENTER

B1

B2   B3

B4

EXIT

Flow Graph

Loop Optimization

Most programs run as a loop in the system. It becomes necessary to optimize the loops in order to save CPU cycles and memory. Loops can be optimized by the following techniques:

- **Invariant code** : A fragment of code that resides in the loop and computes the same value at each iteration is called a loop-invariant code. This code can be moved out of the loop by saving it to be computed only once, rather than with each iteration.

- **Induction analysis** : A variable is called an induction variable if its value is altered within the loop by a loop-invariant value.

- **Strength reduction** : There are expressions that consume more CPU cycles, time, and memory. These expressions should be replaced with cheaper expressions without compromising the output of expression. For example, multiplication (x * 2) is expensive in terms of CPU cycles than (x << 1) and yields the same result.

Dead-code Elimination

Dead code is one or more than one code statements, which are:

- Either never executed or unreachable,
- Or if executed, their output is never used.

Thus, dead code plays no role in any program operation and therefore it can simply be eliminated.

Partially dead code

There are some code statements whose computed values are used only under certain circumstances, i.e., sometimes the values are used and sometimes they are not. Such codes are known as partially dead-code.
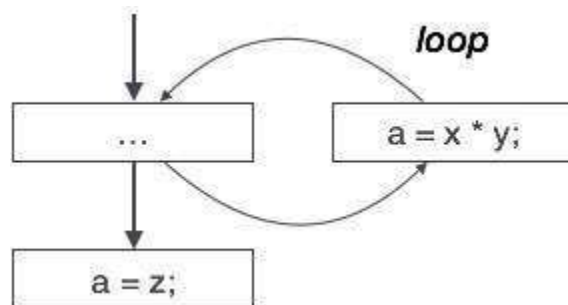

The above control flow graph depicts a chunk of program where variable 'a' is used to assign the output of expression 'x * y'. Let us assume that the value assigned to 'a' is never used inside the loop.Immediately after the control leaves the loop, 'a' is assigned the value of variable 'z', which would be used later in the program. We conclude here that the assignment code of 'a' is never used anywhere, therefore it is eligible to be eliminated.
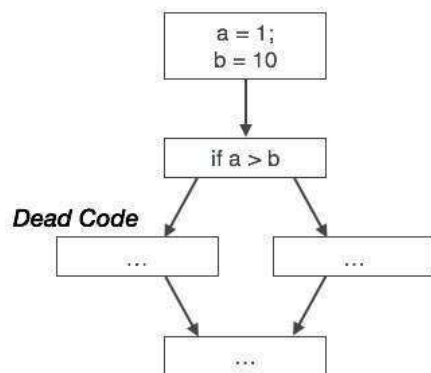
Likewise, the picture above depicts that the conditional statement is always false, implying that the code, written in true case, will never be executed, hence it can be removed.

Partial Redundancy

Redundant expressions are computed more than once in parallel path, without any change in operands.whereas partial-redundant expressions are computed more than once in a path, without any change in operands. For example,

[redundant expression]

[partially redundant expression]
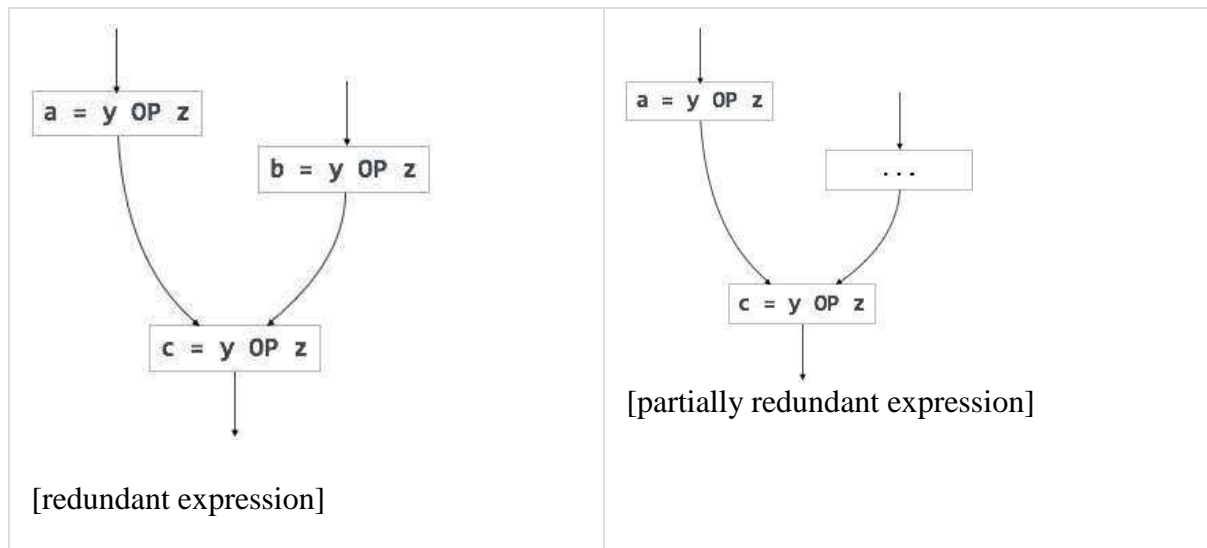
Loop-invariant code is partially redundant and can be eliminated by using a code-motion technique.

Another example of a partially redundant code can be:

```
If (condition)
{
   a = y OP z;
}
else
{
   ...
}
c = y OP z;
```

We assume that the values of operands (**y** and **z**) are not changed from assignment of variable **a** to variable **c**. Here, if the condition statement is true, then y OP z is computed twice, otherwise once. Code motion can be used to eliminate this redundancy, as shown below:

```
If (condition)
{
   ...
   tmp = y OP z;
   a = tmp;

   ...
}
```

```
else

{

  ...

  tmp = y OP z;

}

c = tmp;
```

Here, whether the condition is true or false; y OP z should be computed only once.

26. a) Explain Peep-hole optimization.   [OR]

Peephole Optimization

This optimization technique works locally on the source code to transform it into an optimized code. By locally, we mean a small portion of the code block at hand. These methods can be applied on intermediate codes as well as on target codes. A bunch of statements is analyzed and are checked for the following possible optimization:

Redundant instruction elimination

At source code level, the following can be done by the user:

int add_ten(int x)	int add_ten(int x)	int add_ten(int x)	int add_ten(int x)
{	{	{	{
int y, z;	int y;	int y = 10;	return x + 10;
y = 10;	y = 10;	return x + y;	}
z = x + y;	y = x + y;	}	
return z;	return y;		
}	}		

At compilation level, the compiler searches for instructions redundant in nature. Multiple loading and storing of instructions may carry the same meaning even if some of them are removed. For example:

- MOV x, R0
- MOV R0, R1

We can delete the first instruction and re-write the sentence as:

```
MOV x, R1
```

Unreachable code

Unreachable code is a part of the program code that is never accessed because of programming constructs. Programmers may have accidently written a piece of code that can never be reached.

Example:

```
void add_ten(int x)
{
  return x + 10;
  printf("value of x is %d", x);
}
```

In this code segment, the **printf** statement will never be executed as the program control returns back before it can execute, hence **printf** can be removed.

Flow of control optimization

There are instances in a code where the program control jumps back and forth without performing any significant task. These jumps can be removed. Consider the following chunk of code:

```
...
MOV R1, R2
GOTO L1
...
L1 :  GOTO L2
L2 :  INC R1
```

In this code, label L1 can be removed as it passes the control to L2. So instead of jumping to L1 and then to L2, the control can directly reach L2, as shown below:

```
...
MOV R1, R2
GOTO L2
...
L2 :  INC R1
```

Algebraic expression simplification

There are occasions where algebraic expressions can be made simple. For example, the expression **a = a + 0** can be replaced by **a** itself and the expression a = a + 1 can simply be replaced by INC a.

Strength reduction

There are operations that consume more time and space. Their 'strength' can be reduced by replacing them with other operations that consume less time and space, but produce the same result.

For example, **x * 2** can be replaced by **x << 1**, which involves only one left shift. Though the output of a * a and a^2 is same, a^2 is much more efficient to implement.

Accessing machine instructions

The target machine can deploy more sophisticated instructions, which can have the capability to perform specific operations much efficiently. If the target code can accommodate those instructions directly, that will not only improve the quality of code, but also yield more efficient results.

b) Discuss code generator phase in compiler design in detail.

Code Generator

A code generator is expected to have an understanding of the target machine's runtime environment and its instruction set. The code generator should take the following things into consideration to generate the code:

- **Target language** : The code generator has to be aware of the nature of the target language for which the code is to be transformed. That language may facilitate some machine-specific instructions to help the compiler generate the code in a more convenient way. The target machine can have either CISC or RISC processor architecture.

- **IR Type** : Intermediate representation has various forms. It can be in Abstract Syntax Tree (AST) structure, Reverse Polish Notation, or 3-address code.

- **Selection of instruction** : The code generator takes Intermediate Representation as input and converts (maps) it into target machine's instruction set. One representation can have many ways (instructions) to convert it, so it becomes the responsibility of the code generator to choose the appropriate instructions wisely.

- **Register allocation** : A program has a number of values to be maintained during the execution. The target machine's architecture may not allow all of the values to be kept in the CPU memory or registers. Code generator decides what values to keep in the registers. Also, it decides the registers to be used to keep these values.

- **Ordering of instructions** : At last, the code generator decides the order in which the instruction will be executed. It creates schedules for instructions to execute them.

Descriptors

The code generator has to track both the registers (for availability) and addresses (location of values) while generating the code. For both of them, the following two descriptors are used:

- **Register descriptor** : Register descriptor is used to inform the code generator about the availability of registers. Register descriptor keeps track of values stored in each register.

Whenever a new register is required during code generation, this descriptor is consulted for register availability.

- **Address descriptor** : Values of the names (identifiers) used in the program might be stored at different locations while in execution. Address descriptors are used to keep track of memory locations where the values of identifiers are stored. These locations may include CPU registers, heaps, stacks, memory or a combination of the mentioned locations.

Code generator keeps both the descriptor updated in real-time. For a load statement, LD R1, x, the code generator:

- updates the Register Descriptor R1 that has value of x and

- updates the Address Descriptor (x) to show that one instance of x is in R1.

Code Generation

Basic blocks comprise of a sequence of three-address instructions. Code generator takes these sequence of instructions as input.

Note : If the value of a name is found at more than one place (register, cache, or memory), the register's value will be preferred over the cache and main memory. Likewise cache's value will be preferred over the main memory. Main memory is barely given any preference.

getReg : Code generator uses *getReg* function to determine the status of available registers and the location of name values. *getReg* works as follows:

- If variable Y is already in register R, it uses that register.

- Else if some register R is available, it uses that register.

- Else if both the above options are not possible, it chooses a register that requires minimal number of load and store instructions.

For an instruction x = y OP z, the code generator may perform the following actions. Let us assume that L is the location (preferably register) where the output of y OP z is to be saved:

- Call function getReg, to decide the location of L.

- Determine the present location (register or memory) of **y** by consulting the Address Descriptor of **y**. If **y** is not presently in register **L**, then generate the following instruction to copy the value of **y** to **L**:

  MOV y', L

  where **y'** represents the copied value of **y**.

- Determine the present location of **z** using the same method used in step 2 for **y** and generate the following instruction:

  OP z', L

  where **z'** represents the copied value of **z**.

- Now L contains the value of y OP z, that is intended to be assigned to **x**. So, if L is a register, update its descriptor to indicate that it contains the value of **x**. Update the descriptor of **x** to indicate that it is stored at location **L**.

- If y and z has no further use, they can be given back to the system.

Other code constructs like loops and conditional statements are transformed into assembly language in general assembly way.