DATA STRUCTURES USING C

MODULE1

Introduction – Basic Terms

Data

- A value or set of values.
- It specifies value of a variable or constant.
- Example: name,address

Data Item:- Single unit of values

- **Elementary Data :-** Data items that can't be divided into sub items. Eg: Mark, age
- **Grouped Data :-** Data items that can be divided into sub items. Eg; Address,name

Entity

- An entity is an object which has a set of properties called attributes.
- We can assign values to this attribute.
- Example: Employee

Entity Set

- Entities with similar attributes
- Example: Employees in an organization

Information

Meaningful data or processed data

Field:- A field is a single elementary unit of information representing an attribute of an entity.Eg: name,number,class,age,mark

Record:- a record is a collection of field values of a given entity.Eg: details of a single student(name,number,age,mark)

File:- a file is the collection of records of the entities in a given entity set.

Eg: If there are 50 students in a class, it will contains 50 records.

Primary key.:-Each record in a file may contain many field items, but the value in a certain field may uniquely determine the record in the file. Such a field is called primary key.

Data Structure Definitions

- A data structure is a group of data elements which comes under one name.
- Particular way of storing and organizing data in a computer so that it can be used efficiently.
- The logical or mathematical model of a particular organization of data.

- Data structures are building blocks of programs.
- Data Structure is a way to store and organize data so that it can be used efficiently.

Types of Data Structures

There are two types of data structures:

- Primitive data structure
- Non-primitive data structure

Primitive Data structure

- Consists of fundamental data types which are supported by a programming language.
- The int, char, float, double are the primitive data structures that can hold a single value.
- In C the basic data types used are

DATA TYPE	SIZE (IN BYTE)
char	1
short int	2
int	4
long int	4
float	4
double	8
long double	12
void	MEANING LESS

Non-primitive data structure

- Created using primitive data structures
- Example: Stack,Queue,Tree,Graph
- Non primitive data structures are divided into
  - Linear data structures
  - Non linear data structures

Linear Data Structures

- If the elements of the data structures are stored in a linear or sequential order then it is called as linear data structure.
- Example: Array, Stack , Queue, Linked list
- Stored in two ways

- Stored in sequential memory location
- Elements are connected using links

Non Linear Data Structures

- If the elements of a data structure are not stored in sequential order are called non linear data structure.
- Example: Tree,Graph

ARRAYS

- An Array is a finite ordered homogeneous set of elements.
- The elements of the array are stored in consecutive memory locations.
- Elements are accessed using an index or subscripts.

Syntax:

Data_type arrayname[max_size];

- Also called subscripted variables.
- Example : int a[10];
- Here a is the name of the array which can store a maximum of integer elements
- In C the index starts from zero. i.e, the elements are a[0] to a[9].

Memory Representation

a[0] a[1] a[9]

STACK

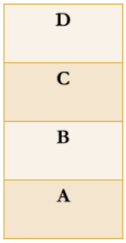
- Linear data structure where insertion and deletion of elements are done at only one end which is known as the **top** of the stack.
- STACK is a Last in First Out(LIFO) structure because the last element which is added to the stack is the first element which is deleted from the stack.
- A stack support two operations

1. **Push :** Inserting an element to the top of the stack.
2. **Pop :** Removing an element from the top of the stack.

- **A** Stack can be implemented using arrays or linked list.

Implementation of a stack using Array

- Let MAX be the number of elements in a stack.
- Let top represent the position of the top element in the stack.



Stack Overflow and Underflow conditions

- **If top=MAX-1 then the stack is full. This is called overflow condition.**
- **We cant insert an element if the stack is already full.**
- **If top=null or -1 then the stack is empty.**
- **We cant delete an element if the stack is empty(underflow condition)**

QUEUE

- **A queue is a First In First Out(FIFO) data structure in which the element that is inserted first is the first one to be taken out.**
- **The elements in a queue are added at one end called rear end and are removed from the other end called front.**
- **Queues also can be implemented using arrays and linked list.**

- **Here front=0, rear=4**
- **If we want to add one more value to the queue then the rear is incremented by one.**
- **i.e; front=0 and rear=5**
- **If we want to delete one element from the queue then the value of front will be incremented by one.**
- **i.e; front=1 and rear=5**

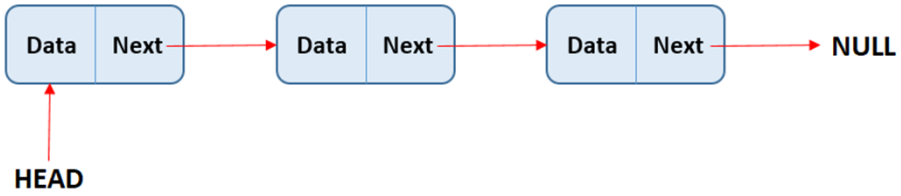
Queue

- **Overflow ……..> check whether rear=MAX-1(full)**
- **Underflow ……..> Queue is already empty.**

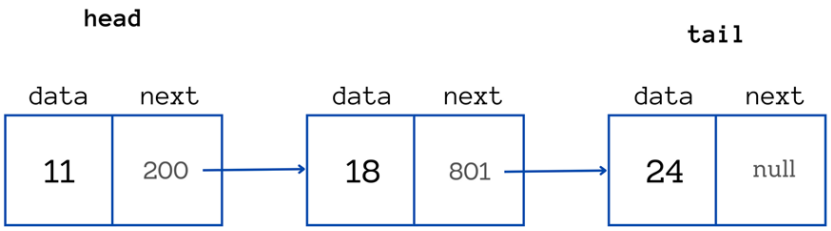
  front=null and rear=null.

Linked List

- **A linked list is a linear dynamic data structure.**
- **The elements in a linked list are called nodes.**
- **A node contains 2 parts :**
- **Data part: value stored in the node**
- **Link or pointers: Points to the next node in the list.**



- **A linked list is dynamic in nature because each node is allocated space when it is added to the list.**
- **The last node in the list contains a null pointer(tail of the list).**
- **Since the memory of the node is dynamically allocated to the total number of nodes that can be added to a list depends on the amount of memory available.**



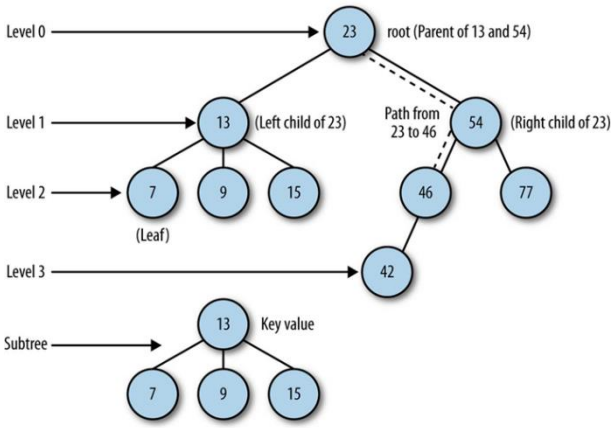
Non linear Data Structures

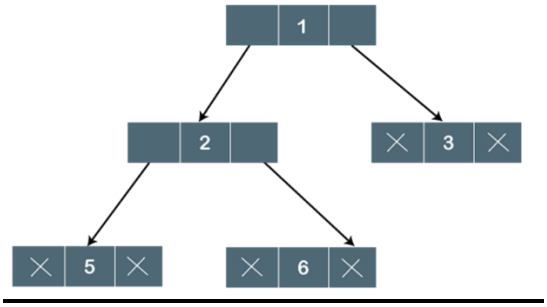
- **In non linear data structure the elements of a data structure are not stored in sequential order.**
- **Example : Tree, Graph**

Tree

- **A tree is non linear data structure which consists of collection of nodes arranged in a hierarchical order.**
- **One of the node is taken as the root node.**
- **The remaining nodes are partitioned into sub trees of the root.**
- **The simplest form of tree is a binary tree.**

Binary Trees

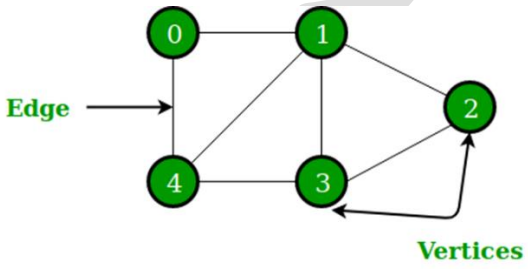




- In a tree parent node can have any number of children but a child can have only one parent.
- A binary tree consists of a root node and left and right sub trees are also binary trees.
- Each node consists of a data element, a left pointer which points to left sub tree and right pointer which points to right sub tree.
- The top most node is always the root.
- If root=NULL then the tree is empty.

Graph

- A graph is a non linear data structure which is a collection of vertices and edges that connect these vertices.
- A graph is similar to a tree but it can have more complex relationships.
- Here a parent node can be connected to any number of nodes and vice versa.
- Graphs do not have any root node.
- Every node in a graph can be connected to any other nodes in the graph.



Applications of Data Structures

- Data structures are used in almost every program or software system.
- Each field uses different type of data structure.
- It depends on how the data should be organized, accessed, inserted and deleted.

- Arrays, stacks, queues, linked lists, tree and graphs are used depending on the application.

Some of the common areas where data structures are applied:

- Compiler design
- DBMS
- Operating system
- Graphics
- Artificial Intelligence
- Numerical analysis
- Simulations

Arrays:- RDBMS, Matrices, Vectors used to implement stacks , queues , linked lists etc.

Linked List:- In web browsers, which creates a linked list of web pages visited.

Stack :- Recursion, Evaluation of expressions.

Queue:- CPU Scheduling, Disk Scheduling, waiting list for processes.

Tree:- DBMS hierarchical model, system directories, compiler design.

Graph:- DBMS network model.

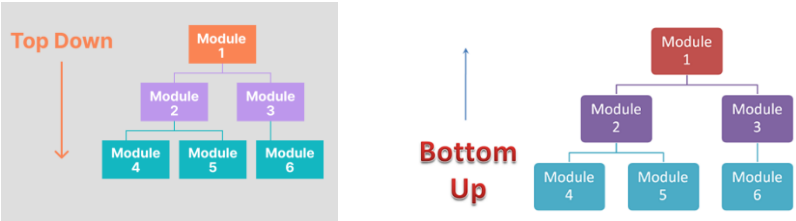
Algorithm

- An algorithm is a set of steps for solving a particular problem.
- The main characteristics of an algorithm are

1. Each step should be simple and precise.
2. Each step should be finite, it should be carried out in a particular time.
3. An algorithm can accept zero or more inputs.
4. It should produce desired output.

Different approaches to Design an algorithm

- A complex algorithm can be divided into smaller units called modules.
- This process of dividing an algorithm into modules is called modularization.
- The main advantages of modularization are
  - Complex algorithm can be made simple to design and implement.
  - There are two ways of design an algorithm



Bottom Up approach

- It is the reverse of top down approach.
- Here first the basic modules are designed.
- Then these sub modules are grouped together to form a higher level module.
- The higher level modules are again grouped and this process is repeated until the complete algorithm is obtained.

Algorithm Complexity: Time-space trade off

- The efficiency of an algorithm depends upon two measures time and space.
- The complexity of an algorithm is a function **f(n)** which measures time and or space used by an algorithm in terms of the input size n.
- Time complexity means the time taken to run a program which is expressed as a function of input size.
- Space complexity means the amount of computer memory required during program execution expressed as a function of input size.
- We can express the time complexity in 3 ways.

1.Worst case running time

- This is the maximum time taken by an algorithm.
- For searching an algorithm if the item to be searched is the last element in an array, then it is called the **worst case**.
- Search reaches the upper bound.

2.Best case running time

- It is the shortest time taken.
- In a searching algorithm the element to be searched is the first element in the array.
- Search takes the lower bound.

3.Average case running time

- It is the running time of an average input.
- i.e the element may be around the middle of the array.
- Number of comparisons can be 1,2,3,……n

- So probability p=1/n
- C(n) =1.1/n+2.1/n+……n.1/n=(1+2+3+…….n).1/n
- =n(n+1)/2*1/n=(n+1)/2

Rate of growth of functions

- M- algorithm
- n – size of input data
- Complexity f(n) increases as n increases
- Usually f(n) will be some standard functions such as $\log_2 n$, $n \log_2 n$, n^2, n^3, 2^n.

g(n) / n	log n	n	n log₂ n	n^2	n^3	2^n
5	3	5	15	25	125	32
10	4	10	40	100	10^3	10^3
100	7	100	700	10^4	10^6	10^{30}
1000	10	10^3	10^4	10^6	10^9	10^{300}

Asymptotic notations for complexity

- There are many asymptotic notations to represent the complexity of algorithms.

Big O notations (o)

- The Big O notation defines the upper bound of an algorithm, it bounds a function only from above.
- It describes the worst-case scenario.
- It can be used to describe the execution time required or the space taken by an algorithm.

Big O Notation

Formal Definition:

- Let f(n) and g(n) are functions defined on positive integers.
- F(n) is bounded by some multiple of g(n) for almost all n.
- Let n_0 be a positive integer and M be a positive number such that for all $n>n_0$, we have f(n)<=M.g(n), then we can write
- F(n) = O(g(n)) means that **f(n) is of order g(n).**

Omega notation(Ω)

- **Big Omega** is used to give a **lower bound** for the growth of a function.
- It's defined in the same way as Big O
- But with the inequality sign turned around. It takes the best case.

Formal Definition:

- Let f(n) and g(n) are functions defined on positive integers.
- F(n) is bounded by some multiple of g(n) for almost all n.
- Let n_0 be a positive integer and M be a positive number such that for all $n>n_0$, we have $f(n)>=M.g(n)$, then we can write
- F(n)= Ω (g(n)) means that **f(n) is omega of g(n).**

Theta notation (θ)

- It is used when the function f(n) is bounded both from above and below by the function g(n).

Formal Definition:

- Let f(n) and g(n) are functions defined on positive integers.
- F(n) is bounded by some multiple of g(n) for almost all n.
- Let n_0 be a positive integers and C_1 and C_2 are two positive constants such that for all $n>n_0$, we have
- $C_1g(n)<=f(n)<=C_2g(n)$, then we can write
- F(n)= θ g(n)) means that **f(n) is theta of g(n)**
- Function g(n) is both an upper bound and lower bound for the function f(n).
- F(n) is such that f(n)=O(g(n)) and f(n)= Ω (g(n))

Little Oh notations(o)

- F(n) = o(g(n)) (read as f(n) is little oh of g(n)) iff
- f(n) = O(g(n))
- f(n) $\neq$ Ω (g(n))

Data Structure Operations

- **There are 6 operations**
- **Traversing:** It means to access each data item exactly once, so that it can be processed.
- Ex: Print the name of student in a class, find the sum of the elements of an array.
- **Searching:** It is used to find whether an element is present in a given list or not. Searching can be based on a given condition.
- The search can be successful or unsuccessful.
- It also returns the location of the element if it is present.

- Ex: Check whether the number 10 is present in the array or not
- **Inserting:** It is used to add new data items to the given list.
- Ex: Adding new student to the class.
- **Deleting:** It is used to remove a particular data item from a given list.
- Ex: Remove the name of student who has left the course
- **Sorting :** Arranging data item in ascending or descending order.
- Ex: Arranging the names of students in alphabetical order.
- **Merging:-**List of two sorted data items can be combined to form a single list of sorted data items.

Data Type	Data Structure
A data type is the kind of a variable. It defines that a particular variable will only assign values of a given type only.	Data structure is the collection of different form of data
It is in the form of abstract implementation	Implementation is called concrete implementation
It can hold values and not data. It is called a dataless.	It can hold different types of data within one single object
Values can be directly assigned to variable	Some algorithms and operations like push,pop are used to assign value
No problem of time complexity	Time complexity is there
Eg: integer,character,double etc	Eg: Linked List, Queue, Tree etc

String

String :- Strings are defined as an array of characters.

String is terminated with a special character '\0' (null character)

Eg: "Amal"

char str[ ] = "Amal"

0	1	2	3	4
A	m	a	l	'\0'

Declaration of Strings

char string_name[size];

Ex: char firstname[10];

char lastname[10];

Initialization of Strings

char firsname[10] = “Amal”;

char firsname[ ] = “Amal”;

char firsname[10] = {‘A’,’m’,’a’,’l’,’\0’};

char firsname[ ] = {‘A’,’m’,’a’,’l’,’\0’};

Operations on String

- Length
- Concatenation
- Comparison
- Copy
- Substring
- Indexing

String Operation : Length

- Number if characters in a string is called its length.
- Pass string variable whose length we have to find. LEGNTH(string);
- This function returns the length of string passed. LEGTH(“string operations”);
- It deosn’t count null character ‘\0’.

The strlen() function returns the length of the given string. It doesn't count null character '\0'.

```
#include<stdio.h>
#include <string.h>
int main(){
char ch[20]={'j', 'a', 'v', 'a', 't', 'p', 'o', 'i', 'n', 't', '\0'};
   printf("Length of string is: %d",strlen(ch));
 return 0;
}
```

Length of string is: 10

String Operation : Concatenation

The concatenation of strings is a process of combining two strings to form a single string. If there are two strings, then the second string is added at the end of the first string.

For example, Hello + javaTpoint = Hello javaTpoint

The string function which is pre-defined in a string.h header file is a strcmp() function. The strcmp() function consider two strings as a parameter, and this function returns an integer value where the integer value can be zero, positive or negative.

The syntax of the strcmp() function is given below:

```
int strcmp (const char* str1, const char* str2);
```

```
#include <stdio.h>
int main() {
  char s1[100] = "programming ", s2[] = "is awesome";
  int length, j;
  // store length of s1 in the length variable
  length = 0;
  while (s1[length] != '\0') {
    ++length;
  }
  // concatenate s2 to s1
  for (j = 0; s2[j] != '\0'; ++j, ++length) {
    s1[length] = s2[j];
  }
  // terminating the s1 string
  s1[length] = '\0';
  printf("After concatenation: ");
  puts(s1);
  return 0;
}
```

String Operation : Comparison

The strcmp(first_string, second_string) function compares two string and returns 0 if both strings are equal.

```
#include<stdio.h>
#include <string.h>
int main(){
  char str1[20],str2[20];
```

```
 printf("Enter 1st string: ");
 gets(str1);//reads string from console
 printf("Enter 2nd string: ");
 gets(str2);
 if(strcmp(str1,str2)==0)
    printf("Strings are equal");
 else
    printf("Strings are not equal");
return 0;
}
```

Enter 1st string: hello

Enter 2nd string: hello

Strings are equal

String Operation : Copy

The strcpy(destination, source) function copies the source string in destination

```
#include<stdio.h>
#include <string.h>
int main(){
 char ch[20]={'j', 'a', 'v', 'a', 't', 'p', 'o', 'i', 'n', 't', '\0'};
   char ch2[20];
   strcpy(ch2,ch);
   printf("Value of second string is: %s",ch2);
 return 0;
}
```

Value of second string is: javatpoint

String Operation : Substring

The strstr() function returns pointer to the first occurrence of the matched string in the given string. It is used to return substring from first match till the last character.

Syntax:

```
char *strstr(const char *string, const char *match)  ;
```

```
#include<stdio.h>
#include <string.h>
int main(){
  char str[100]="this is javatpoint with c and java";
  char *sub;
  sub=strstr(str,"java");
  printf("\nSubstring is: %s",sub);
 return 0;
}
```

Output:

javatpoint with c and java

String Operation : Indexing

Strings are ordered sequences of character data. Indexing allows you to access individual characters in a string directly by using a numeric value. String indexing is zero-based: the first character in the string has index 0, the next is 1, and so on

This program is used to find the character at index in a string and string is defined using pointers.

```
#include<stdio.h>
void main()
{
 char *str = "testing codingpointer.com";
 int index;
 char ch;
 printf("Enter index: ");
 scanf("%d", &index);
 ch = str[index];
 printf("\ncharacter at index %d: %c\n", index, ch);
}
```

Output:

Enter index: 5

character at index 5: n

Pattern Matching

- **Pattern matching** finds whether or not a given string pattern appears in a string text.
- Commonly used pattern matching algorithms are Naïve Algorithm for pattern matching and pattern matching algorithm using finite automata.

Naïve Algorithm for pattern matching

PAT and TEXT are two strings with length R and S respectively. This algorithm finds INDEX(P)

1. SET K=1 and MAX=S-R+1.
2. Repeat Steps 3 to 5 while K<=MAX:
3. Repeat for L=1 to R:

   if TEXT[K+L-1]!= PAT[L], then: Go to Step 5.
4. SET INDEX=K, and EXIT
5. K=K+1
6. SET INDEX=0
7. EXIT

Pattern matching algorithm using finite automata

The second algorithm uses a table which is derived from pattern PAT independent of TEXT.

The pattern matching table F(Q,TEXT) of pattern PAT is in memory. The input is an N character string TEXT = T1,T2,T3,……..Tn, This algorithm finds INDEX(PAT) in TEXT.

1. SET K=1 and MAX=S-R+1.
2. Repeat Steps 3 to 5 while K<=MAX:
3. Repeat for L=1 to R:

   if TEXT[K+L-1]!= PAT[L], then: Go to Step 5.
4. SET INDEX=K, and EXIT
5. K=K+1
6. SET INDEX=0
7. EXIT