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DATA STRUCTURE USING IN C

UNIT – 1

Data structure

- Data Structure is a branch of Computer Science.
- A data structure is a storage that is used to store and organize all the data items.
- used for processing, retrieving, and storing data.

Why do we use data structure

- Necessary for designing efficient algorithms.
- It helps to organization of all data items within the memory.
- It requires less time.
- Easy access to the large database.

Classification/ Types of Data structure

- **Linear data structure --**allows data elements to be arranged in a sequential or linear fashion.
  Example: arrays, linked lists, stack, and queue etc.
- **Non-Linear data structure --** It is a form of data structure where the data elements do not stay arranged linearly or sequentially.
  Example: Tree, graph etc.

Terminologies in Data structure

- **Data --** Data are values or set of values.
- **Data Item --** Data item refers to single unit of values.
- **Entity --** An entity is that which contains certain attributes or properties, which may be assigned values.
- **Entity Set --** Entities of similar attributes form an entity set.
- **Field --** Field is a single elementary unit of information representing an attribute of an entity.
- **Record --** Record is a collection of field values of a given entity.
- **File --** File is a collection of records of the entities in a given entity set.

Datatypes in C programming

- **Primitive Data Types –** It is the most basic data types that are used for representing simple values such as:
  - Integers – 23, 33432 ,342342 etc.
  - Float – 23.2342, 232.00,2342.0000,323.323 etc.
  - Characters - ‘2’, ‘a, ‘$’, ‘@,’g’ etc.
  - Void – used to specify the type of functions which returns nothing.
- **Non-Primitive Data Types –** It is derived from primitive data types.
  - Arrays
  - Linked-list
  - Queue
  - Stack etc.

Algorithm

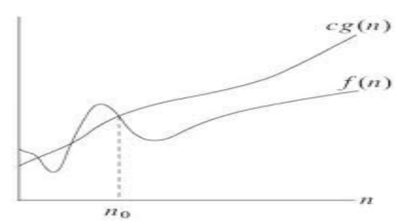
- An algorithm is a step-by-step procedure of any problem.
- **Criteria of an algorithm --**
  1. Input 2. Output 3. Definiteness 4. Finiteness 5. Effectiveness
- **Way of analyzing an algorithm --**
  1.Best case 2. Average case 3. Worst case
- **Complexity of an algorithm --**
  - Complexity in algorithms refers to the amount of resources required to solve a problem or perform a task.
  - Resources may be time and space.
- **Types of Complexities of an algorithm --**
  - **Time complexity** of an algorithm is the amount of time it needs to run to completion.
  - **Space complexity** of an algorithm is the amount of space it needs to run to completion.
- **order of Complexity of an algorithm --**

O(1) < O(logn) < O(n) < O(nlogn) < O(n^2) < O(n^3) < O(2^n) < O(3^n) < O(n!)

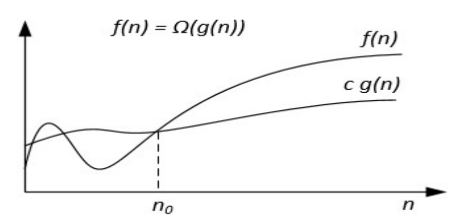
Asymptotic Notation

It is used to write possible running time for an algorithm.It also referred to as 'best case' and 'worst case' scenarios respectively.

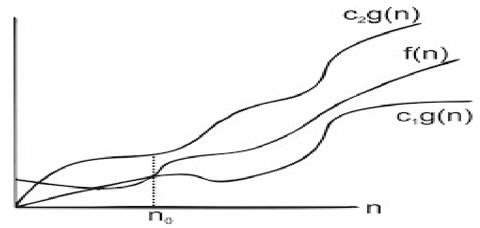
- **Big-oh notation**:
  - It is the method of expressing the upper bound of an algorithm's running time.
  - It is the measure of the longest amount of time. The function f (n) = O (g (n))
  - f(n) <= c.g(n) where n>n0
  - Example: 3n+2=O(n) as 3n+2≤4n for all n≥2



- **Big-Omega notation**:
  - It is the method of expressing the lower bound of an algorithm's running time.
  - It is the measure of the smallest amount of time. The function f (n) = Ω(g (n))
  - f(n) >= c.g(n) where n>n0
  - Example: 3n-3= Ω (n) as 3n-3 >=2n for all n≥3



- **Theta(Θ) notation**:
  - It is the method of expressing the both lower and upper bound of an algorithm's running time.
  - It is the measure of the average amount of time. The function f (n) = Θ(g (n))
  - c1.g(n) <= f(n) <= c2.g(n) where n>n0
  - Example: 3n-3=O(n) as 2n<= 3n-3 <= 4n for all n≥3



Time-Space Trade-Off in Algorithms

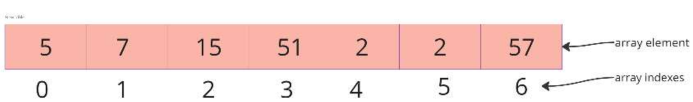
- It is a problem solving technique in which we solve the problem:
  - Either in less time and using more space, or
  - In very little space by spending more time.
- The best algorithm is that which helps to solve a problem that requires less space in memory as well as takes less time to generate the output.
- it is not always possible to achieve both of these conditions at the same time.

Abstract Data type (ADT)

- It is a type (or class) for objects whose behaviour is defined by a set of values and a set of operations.
- The definition of ADT only mentions what operations are to be performed but not how these operations will be implemented.
- Example : if we talk about LIST then here we can store multiple value and it has many built in function so that we will work on that data .
  Function such as insert(), delete(), pop(), remove() etc.

Array

- An array is a collection of items stored at contiguous memory locations.
- Array is linear data structure. It is one of the simplest DS.
- The idea is to store multiple items of the same type together.
- **Syntax --** type variable_name [size];
- **Example –** int arr[10]; this is a array declaration of the array now here we can only store 10 integer values in this array
- Array has two type:



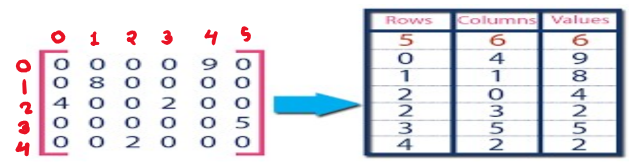
array representation

1. One dimensional 2. Multidimensional

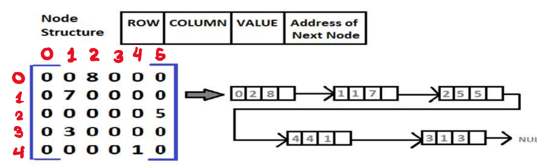
- **One dimensional Array :**
  - Array represented as one-one dimension such as row or column and that holds finite number of same type of data items is called 1D array .
  - **Example --** int arr[10];
- **Multi-dimensional Array :**
  - Array represented as more than one dimension . there are no restriction to number of dimensions that we can have.
  - **Example --** int arr[2][4][5];
- **Application of Array :**
  - Arrays can be storing data in tabular format
  - It is used to implement vectors, and lists in C++ STL.
  - Arrays are used as the base of all sorting algorithms.
  - It is used to implement other DS like stack, queue, etc.
  - Used for implementing matrices.
  - Graphs are also implemented as arrays in the form of an adjacency matrix etc.

Sparse Matrix

- It is matrix in which most of the elements of the matrix have zero value .
- Only we stored non-zero elements with triples- (Row, Column, value).
- **Array representation of Sparse Matrix –**



- **Linked list representation of sparse matrix –**

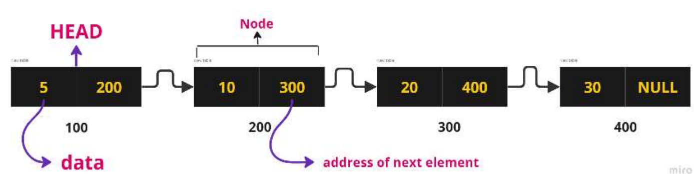


Linked List

- A linked list is a collection of “nodes” connected together via links.
- These nodes consist of the data to be stored and a pointer to the address of the next element .
- Linked list has multiple types:
  1. singly linked list 2. Doubly linked list 3. Circular linked list

Singly Linked List (SLL)

- It is a linear data structure in which the elements are not stored in contiguous memory locations .
- Each element is connected only to its next element using address.



- **Representation Node of SLL :**

```
struct node{
 int data;  //data item for storing value of the node
 struct node *next; //address of the next node
};
```

- **create Node of SLL:**

```
struct Node* Node(int data){
                struct Node* newNode=(struct Node*)malloc(sizeof(struct
                                                                  Node ));
      newNode->data=data;
      newNode->next=NULL;
   return newNode;
}
```

Operations on SLL

- **Insert At beginning :**

```
struct Node * addAtBeg(int data, struct Node* head){
  struct Node* newNode=Node(data);
  if(head==NULL){
    return newNode;
  }
  newNode->next=head;
  return newNode;
}
```

- **Insert At End :**

```
struct Node * addAtEnd(int data, struct Node* head){
  struct Node* newNode=Node(data);
  if(head==NULL){
    return newNode;
  }
  struct Node* temp=head;
  while ( temp->next !=NULL)
  {
    temp=temp->next;
  }
  temp->next=newNode;
  return head;
}
```

- **Insert At specific Position :**

```
struct Node* addAtPos(int data , int pos , struct Node* head)
{
  if(pos==1){
    return addAtBeg(data,head);  }
  struct Node*  temp=head;
  for (int i = 1; i <=pos; i++)
  {            if(i!=pos && temp==NULL ){
        return head;  //invalid position
      }
      if(i==pos-1){
        struct Node * newNode=Node(data);
        newNode->next=temp->next;
        temp->next=newNode;
        return head;
      }
    temp=temp->next;
  }
  return head;
   }
```

- **Delete at beginning :**

```
struct Node * deleteAtBeg( struct Node* head){
  if(head==NULL){
    return NULL;
  }
  return head->next;
}
```

- **Delete at End :**

```
struct Node * deleteAtEnd( struct Node* head){
   if( head==NULL || head->next == NULL){
    return NULL;
  }
  struct Node* temp=head;
  while (temp->next->next !=NULL){
    temp=temp->next;
  }
  temp->next=NULL;
  return head;
}
```

- **Traverse Linked List:**

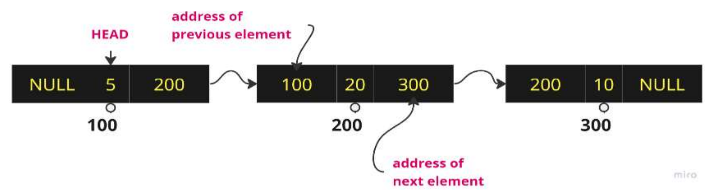
```
void traverse(struct Node* head){
  while (head->next!=NULL){
    printf("%d ", head->data);
    head=head->next;
  }
}
```

Advantage & disadvantage of singly linked list

- **Advantages:**
  - very easier for the accessibility of a node in the forward direction.
  - the insertion and deletion of a node are very easy.
  - require less memory when compared to doubly, circular linked list.
  - very easy data structure
  - Insertion and deletion of elements don't need the movement of all the elements when compared to an array.
- **Disadvantages :**
  - Accessing the preceding node of a current node is not possible as there is no backward traversal.
  - Accessing of a node is very time-consuming.

Doubly Linked List(DLL)

- A DLL is a complex version of a SLL .
- A DLL has each node pointed to next node as well as previous node.



- **Representation Node of DLL :**

```
struct node
{
 int data;  //data item for storing value of the node
 struct node *next; //address of the next node
 struct node *prev; //address of the previous node
};
```

- **create Node of DLL:**

```
struct Node* Node(int data){
    struct Node* newNode=(struct Node*)malloc(sizeof(struct
Node ));
    newNode->prev= NULL;
    newNode->data=data;
    newNode->next=NULL;
  return newNode;
}
```

Operations on DLL

- **Insert At beginning :**

```
struct Node * addAtBeg(int data, struct Node* head){
  struct Node* newNode=Node(data);
  if(head==NULL){
    return newNode;
  }
  newNode->next=head;
  head->prev=newNode;
  return newNode;
}
```

- **Insert At End :**

```
struct Node * addAtEnd(int data, struct Node* head){
   struct Node* newNode=Node(data);
   if(head==NULL){
      return newNode;
   }
   struct Node* temp=head;
   while ( temp->next !=NULL)
   {
      temp=temp->next;
   }
   temp->next=newNode;
   newNode->prev=temp;
   return head;
}
```

- **Delete At beginning:**

```
struct Node * deleteAtBeg( struct Node* head){
   if(head==NULL || head->next==NULL){
      return NULL;
   }
   head ->next->prev = NULL;
   return head->next;
}
```

- **delete At End :**

```
struct Node * deleteAtEnd( struct Node* head){
    if( head==NULL || head->next == NULL){
      return NULL;
   }
   struct Node* temp=head;
   while (temp->next->next !=NULL){
      temp=temp->next;
   }
   temp->next=NULL;
   return head;
}
```

- **Traverse DLL :**

```
void traverse(struct Node* head){
   while (head!=NULL){
      printf("%d ", head->data);
      head=head->next;   }    }
```

- **ReverseTraverse DLL:**

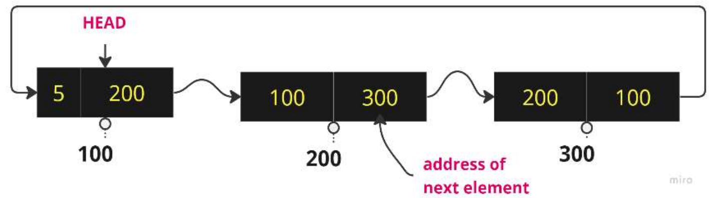
```
void traverseRev(struct Node* head){
   if(head==NULL)
       return;
   while (head->next!=NULL)
      head=head->next;
   while (head!=NULL){
      printf("%d ", head->data);
      head=head->prev;
   }
   }
```

Advantage & disadvantage of DLL

- **Advantages:**
  - It is bi-directional traversal
  - It is efficient deletion
  - Insertion and deletion at both ends in constant time
- **Disadvantages :**
  - Increased memory usage
  - More complex implementation
  - It is slower traversal

Circular Linked List (CLL)

- All nodes are connected to form a circle.
- the first node and the last node are connected to each other which forms a circle.
- There is no NULL at the end.



Operations on CLL

- Insert at beginning
- Insert at specific Position
- Insert at   end
- delete at beginning
- delete at specific position
- delete at end

Advantage & disadvantage of CLL

- **Advantages:**
  - No need for a NULL pointer
  - Efficient insertion and deletion
  - Flexibility
- **Disadvantages :**
  - Traversal can be more complex
  - Reversing of circular list is a complex as SLL.

Row major order & Column major order

```
int arr[2][3]=
{ {1,2,3},
  {4,5,6}  } //2D array

//row major order
{1,2,3,4,5,6}
//column major order
{1,4,2,5,3,6}
```

Address of any element in 1D array

Address of A[I] = B + W * (I – LB)

I =element, B = Base address, LB = Lower Bound

W = size of element in any array(in byte),

Example: Given the base address of an array A[1300 ………… 1900] as 1020 and the size of each element is 2 bytes in the memory, find the address of A[1700].

Solution :

Address of A[I] = B + W * (I – LB)

Address of A[1700] = 1020 + 2 * (1700 – 1300)

= 1020 + 2 * (400) = 1020 + 800=**1820**

Address of any element in 2D array

Row major order : ***A[I][J] = B + W * ((I – LR) * N + (J – LC))***

I = Row element , j=column element , LR=lower limit of row

N = No. of column given in the matrix , LC=lower limit of column

Example: Given an array, arr[1………10][1………15] with base value 100 and the size of each element is 1 Byte in memory. Find the address of arr[8][6] with the help of row-major order.

Formula:

Address of A[I][J] = B + W * ((I – LR) * N + (J – LC))

Solution:

N = Upper Bound column – Lower Bound column + 1

A[8][6] = 100 + 1 * ((8 – 1) * 15 + (6 – 1)) = 100 + 1 * ((7) * 15 + (5))

= 100 + 1 * (110)=**210**

column major order :

A[I][J] = B + W * ((J– LC) * M + (I – LR))

N = No. of rows given in the matrix

Example: Given an array, arr[1………10][1………15] with base value 100 and the size of each element is 1 Byte in memory. Find the address of arr[8][6] with the help of row-major order.

Formula:

A[I][J] = B + W * ((J– LC) * M + (I – LR))

Solution:

M = Upper Bound row – Lower Bound row + 1

A[I][J] = B + W * ((J – LC) * M + (I – LR))

A[8][6] = 100 + 1 * ((6 – 1) * 10 + (8 – 1))

= 100 + 1 * ((5) * 10 + (7))= 100 + 1 * (57)= **157**

Difference between Array and Linked List

Array	Linked List
It is stored in a contiguous memory location.	It can be stored randomly in the memory .
elements are independent of each other.	elements are dependent on each other
memory is allocated at compile-time.	memory is allocated at run time
Accessing any element in an array is faster	Accessing an element in a linked list is slower
Array takes more time while performing any operation like insertion, deletion, etc.	Linked list takes less time while performing any operation like insertion, deletion, etc.