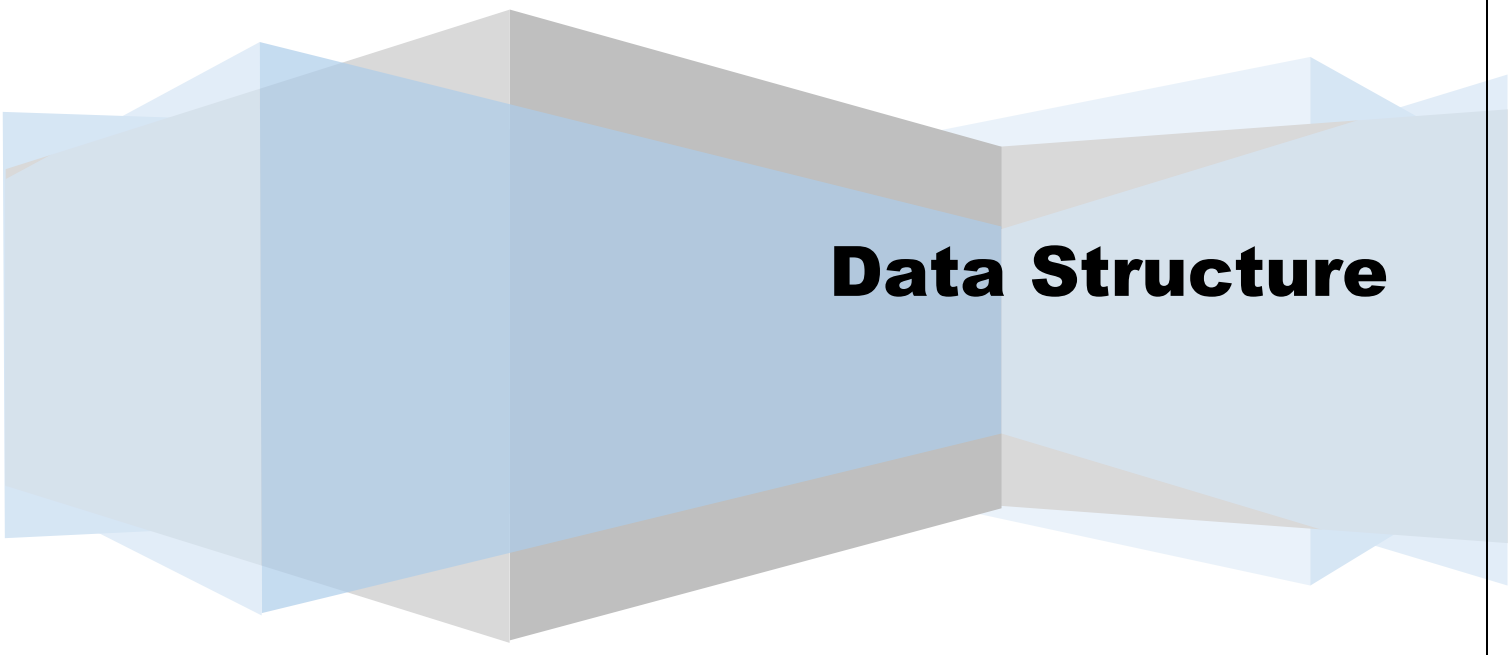
Institute for Advanced Computing & Software Development

IACSD



Data Structure

Sorting Algorithm

Data Structure:

Data Structure is an arrangement of data in computer's memory (or sometimes on a disk) so that we can retrieve it & manipulate it correctly and efficiently. Data structures are essential in almost every aspect where data is involved. In general, algorithms that involve efficient data structure is applied in the following areas:

Numerical analysis, Operating system, Statistical analysis, Compiler Design, Operating System, Database Management System, Statistical analysis package, Numerical Analysis, Graphics, Artificial Intelligence, Simulation

Sorting:

Arranging in an ordered sequence is called "sorting". Sorting is a common operation in many applications, and efficient algorithms to perform it have been developed.
The most common uses of sorted sequences are:

- Making lookup or search efficient.
- Making merging of sequences efficient.
- Enable processing of data in a defined order.

Following are some Common sorting algorithms,

1. **Bubble Sort**
2. **Selection Sort**
3. **Insertion Sort**
4. **Quick Sort**
5. **Merge Sort**

Bubble sort:

```
for( int i = 0; i < passes; i++ ) {
        for( int j = 0; j < comps - i; j++ )
         {
          if( arr[j+1] < arr[j] )
         {
          int temp = arr[j+1];
          arr[j+1] = arr[j];
          arr[j] = temp;
          }
        }
```

- Number of iterations : (n-1)(n-1)
- $T \alpha n^2 - 2n + 1$
- If $n > 1, n^2 > n$ then all lower order terms are ignored
- $T \alpha n^2$
- Time complexity $= O(n^2)$

Selection Sort:

```
for( int i = 0; i < size-1; i++ ) {
    int min = i;
    for( int j = i+1; j < size; j++ ) {
      if( arr[j] < arr[min] ) {
        min = j;
      }
    }
    int temp = arr[i];
    arr[i] = arr[min];
    arr[min] = temp;
  }
```

- Number of iterartions: $1+2+3+\ldots..+n-1=n(n-1)/2$
- $T \alpha n(n-1)/2$
- $T \alpha n^2 - n$
- If $n > 1, n^2 > n$ then all lower order terms are ignored
- $T \alpha n^2$
- Time complexity $= O(n^2)$

Insertion Sort:

```
for( int  j = 0; j < size; j++ ) {
    for( int i = 0; i < j; i++ ) {
      if( arr[j] < arr[i] ) {
        int temp = arr[j];
        arr[j] = arr[i];
        arr[i] = temp;
      }
    }
  }
```

- Base case: O(n)
- Average/worst case: $O(n^2)$

Quick Sort:

```
void quickSort( int * arr, int left, int right ) {
    if( left >= right ) {
    return;
  }
  int leftHold = left, rightHold = right;
  int pivot = arr[left];
  while( left < right ) {
     while( arr[right] > pivot && left != right ) {
      right--;
    }
    if( left != right ) {
      arr[left] = arr[right];
      left++;
    }
    while( arr[left] < pivot && left != right ) {
      left++;
    }
    if( left != right ) {
      arr[right] = arr[left];
      right--;
    }
  }
  arr[left] = pivot;
  quickSort(arr, leftHold, left-1 );
  quickSort(arr, left+1, rightHold );   }
```

- Average/worst case: O(n log n)
- Worst case: $O(n^2)$

Merge Sort:

```
if( left < right ) {
    int mid = ( left + right ) / 2;
    mergeSort( arr, left, mid );
    mergeSort( arr, mid+1, right );
    merge( arr, left, mid, mid+1, right );
   }
```

Average/worst case: O(n log n)

```
void merge( int * arr, int leftStart, int leftEnd, int rightStart, int rightEnd ) {
  int temp[100];
  int tempPos = leftStart;
  int numEle = ( rightEnd - leftStart ) + 1;
   while( ( leftStart <= leftEnd ) && ( rightStart <= rightEnd ) ) {
     if( arr[leftStart] < arr[rightStart] ) {
       temp[tempPos] = arr[leftStart];
       tempPos++;       leftStart++;
     }
     else {
       temp[tempPos] = arr[rightStart];
       tempPos++;       rightStart++;
     }
}
    while( leftStart <= leftEnd ) {
     temp[tempPos] = arr[leftStart];
     tempPos++;
     leftStart++;
  }
    while( rightStart <= rightEnd ) {
     temp[tempPos] = arr[rightStart];
     tempPos++;       rightStart++;
  }
    for( int i = 1; i <= numEle; i++ ) {
     arr[rightEnd] = temp[rightEnd];
     rightEnd--;
  }  }
```

Searching Algorithm

Searching:

Searching is the process of finding a given value position in a list of values. Searching algorithms are classified into two categories.

1. Linear search
2. Binary search

Linear Search:

```
int linearSearch(int arr*, int n,
int x)
{
   int i;
   for (i = 0; i < n; i++)
      if (arr[i] == x)
         return i;
   return -1;
}
```

Binary Search:

```
while(left<=right)
{
          mid=(left + right)/2;
          if(key==arr[mid])
              return mid;
          if(key<arr[mid])
              right=mid-1;
         else
              left=mid+1;
}
```

Time Complexity:

Time Complexities of Searching & Sorting Algorithms:

	Best Case	Average Case	Worst Case
Linear Search	O(1)	O(n)	O(n)
Binary Search	O(1)	O(log n)	O(log n)
Bubble Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$
Selection Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$
Insertion Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$
Merge Sort	O(n log n)	O(n log n)	O(n log n)
Quick Sort	O(n log n)	O(n log n)	$O(n^2)$

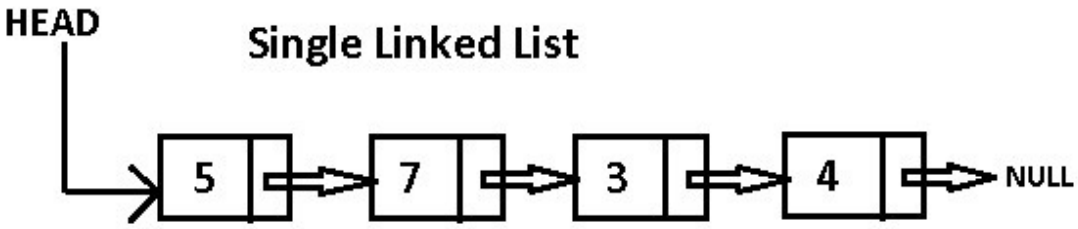
Singly Linked List

Limitations of array over linked list:

- Array does not grow dynamically (i.e length has to be known)
- Inefficient memory management.
- In ordered array insertion is slow.
- In both ordered and unordered array deletion is slow.
- Large number of data movements for insertion & deletion
- which is very expensive in case of array with large number of elements.

Linked List:

We can overcome the drawbacks of the sequential storage.
If the items are explicitly ordered, that is each item contained within itself the address of the next Item.
In Linked Lists elements are logically adjacent, need not be physically adjacent. Node is divide into two part.



Operation can be performed on linked List:

1. insert()
2. insertAtFirst()
3. insertAtLast()
4. insertByPos()
5. deleteAtFirst()
6. deleteAtLast()
7. deleteByPos()
8. deleteByVal()
9. deleteAllNode()
10. Reserve()
11. midElement()

1. Insert by value:

```
Node * newNode = new Node(data);
        if (newNode == NULL) {
                return false;
        }
        if (head == NULL) {
                head = newNode;
                return true;
        }
        Node * last = head;
        while (last->getNext() != NULL) {
                last = last->getNext();
        }
        last->setNext(newNode);
        return true;
```

Algorithm for insert node:

1. Create node
2. Check for empty list
   a) If list is empty
      Set head is equal to newnode
   b) If list is not empty,
      - Create temp node
      - Locate temp to last node
      - Set last node next to newnode

2. To Insert node at first location: O(1)

```
bool insertAtFirst()
{
if(head==NULL)
{
   head=newnode;
   return true;
}
newnode->next=head;
head=newnode;
return true;
}
```

Algorithm for insert at first

1. check for empty list
   a. if list is empty
      set head=newnode
   b. if list is not empty
      set newnode->next=head;
      head=newnode;

3. To Insert node at last location: O(n)

```
bool insertAtLast()
{
if(head==NULL)
{
   head=newnode;
   return true;
}
Node* last=head;
//locate temp to last node
while(last->next!=NULL)
{
last=last->next;
}
last->next=newnode;
return true;
```

Algorithm for insert at last

1. check for empty list
   a. if list is empty
      set head=newnode
   b. if list is not empty
      i. locate last pointer to last node
      ii. set last next to newnode
      last->next=newnode

4. Insert node at given location: O(n)

```
bool insertAtPos(int pos,int val)
{
  //check for invalid position
if (position <= 0 || ( head == NULL && position > 1 ))
  {
            return false;
  }

  Node * newNode = new Node(data);
  //check for newnode get memory
  if (newNode == NULL){
            return false;
  }
  //check for position 1
  if (position == 1){
            if (head != NULL){
                      newNode->setNext(head);
            }
            head = newNode;
            return true;
  }

  Node * prev = head;
  // position other than 1
  for (int i = 1; i < position - 1; i++){
            prev = prev->getNext();

            if (prev == NULL){
                      delete newNode;
                      return false;
            }
  }
  newNode->setNext(prev->getNext());
  prev->setNext(newNode);
  return true;
}
```

Invalid position

5. Delete node at first location: O(1)

```
bool deleteAtFirst()
{
If (head==NULL)
{
        return false;
}
Node* del =head;
head=del->next;
delete[] del;
return true;
}
```

Algorithm for delete at first

1. check for empty list
    a. if list is empty
       no node will be deleted
       return false;
    b. if list is not empty
        i. locate del pointer to first node
        ii. set head to del next
            head=del->next
        iii. delete del pointer

6. Delete node at last location: O(n)

```
bool deleteAtLast()
{
if(head==NULL)
{
   return false;
}
Node* del=head,*prev=head;
//locate temp to last node
While(del->next!=NULL)
{
prev=del;
del=del->next;
}
prev->next=NULL;
return true;
}
```

Algorithm for delete at last

1. check for empty list
    a. if list is empty
       set head=newnode
    b. if list is not empty
        i. locate last pointer to last node
        ii. set last next to newnode
            last->next=newnode

7. Delete node at given location: O(n)

```
bool LinkedList::deleteByPos(int position) {

    //Check for invalid pos
     if (position <= 0) {
           return false;
     }
    //Check for position 1
     if (position == 1) {
           Node * del = head;
           head = head->getNext();
           delete del;
           return true;
     }
     // position other than 1
     Node * prev = head;
     for (int i = 1; i < position - 1; i++) {
           prev = prev->getNext();

           if (prev == NULL) {
                 return false;
           }
     }
     Node * del = prev->getNext();
     prev->setNext( del->getNext() );
     delete del;
     return true;
}
```

8. Delete node with given value: O(n)

```
bool LinkedList::deleteByVal(int data) {
      if (head == NULL) {
            return false;
      }
      //check for first node
      if (head->getData() == data) {
            Node * del = head;
            head = del->getNext();
            delete del;
            return true;
      }
      //check for given data
      Node * del = head, * prev = head;
      while (del->getData() != data) {
            prev = del;
            del = del->getNext();
            if (del == NULL) {
                  return false;
            }
      }
      prev->setNext( del->getNext() );
      delete del;
      return true ;
}
```

Invalid data

9. Delete all node : O(n)

```
while( head!=NULL)
        deleteAtFirst();
```

10.Reverse list:

```
void LinkedList:: Reverse() {
        Node * stack[100];
        int top = -1;
        Node * temp = head;
        while (temp) {
                stack[++top] = temp;
                temp = temp->getNext();
        }
        while (top != -1) {
                cout << stack[top--]->getData()  << " ";
        }
        cout << endl;
}
```

11. Find out middle element in linked list:

Method 1(using two loop):

```
count=0;
while(temp!=NULL)
  {
        count++;
        temp=temp->getNext();
  }
  for(i=0;i<count/2;i++)
  {
        temp=temp->getNext();
  }
  return temp->getData();
```

Method 2(using one loop):

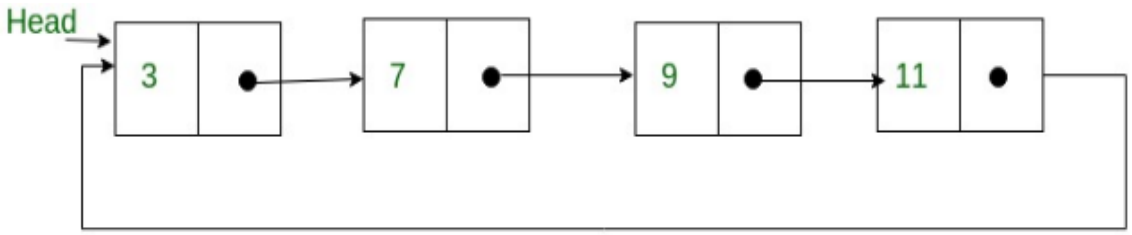
```
Node* temp=head, prev*=head;
while(temp=!NULL && temp->getNext()!=NULL)
{

        temp=temp->getNext()->getNext();
        prev=prev->getNext();
}
        return prev->getData();
```

Singly Circular Linked List

Singly circular Linked List:

A circular linked list is a linked list in which the last node points to the head or front node making the data structure to look like a circle. A circularly linked list node can be implemented using singly linked.



1. **Insert at circular list = O(n)**

```
bool CircularLinkedList :: insert(int data) {
      Node * newNode = new Node( data );
//Check for memory allocation to newnode
      if( newNode == NULL ) {
      return false;
   }
//Check for empty list  (if yes insert node at first)

    if( head == NULL ) {
      head = newNode;
      newNode->setNext( newNode );
      return true;
   }
//create temporary pointer and locate it to last node
   Node * last = head;
   while( last->getNext() != head ) {
      last = last->getNext();
   }
   newNode->setNext( head ); //set last(newnode) node next to head
   last->setNext( newNode );

   return true;
}
```

2. Insert at first location= O(1)

```
bool insertAtFirst()
{
 if(head==NULL)
    {
        head=newnode;
        newnode->next=head;
        return true;
    }
    Node* temp=head;

    while(temp->next!=Null)
    {
            temp=temp->next;
    }
    Newnode->next=head;
    head=newnode;
    temp->next=head;
    return true;
}
```

3. Insert at last location= O(1)

```
bool insertAtLast()
{
   if(head==NULL)
    {
        head=newnode;
        newnode->next=head;
        return true;
    }
    Node* temp=head;

    while(temp->next!=Null)
    {
            temp=temp->next;
    }
    temp->next=newnode;
    newnode->next=head;

    return true;
}
```

4. delete at first location= O(1)

```
bool deleteAtFirst() circular
{
   if(head==NULL)
     {
        return false;
     }
     Node* del=head;
     head=del->next;
     delete[] del;
     return true;
}
```

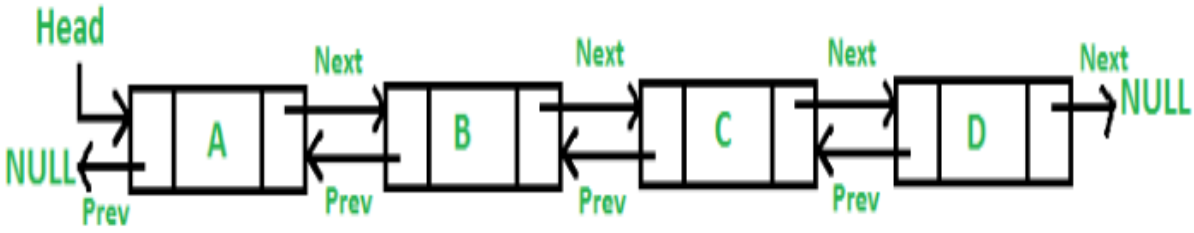
5. delete at last location= O(1)

```
bool deleteAtLast()
{
   if(head==NULL)
     {
        return false;
     }
     Node* del=head,*prev=head;
     while(del->next!=NULL)
     {
              prev=del;
              del=del->next;
     }
     Node* del=head;
     head=del->next;
     delete[] del;
     return true;
}
```

Doubly Linked List

Doubly Linked List:

A doubly linked list is a linked list data structure that includes a link back to the previous node in each node in the structure. This is contrasted with a singly linked list where each node only has a link to the next node in the list. Doubly linked lists also include a field and a link to the next node in the list.



1. **Insert in doubly list:**

```
bool DoublyLinkedList::insert(int data) {

      Node * newNode = new Node(data);

      if (newNode == NULL) {
            return false;
      }

      if (head == NULL) {
            head = newNode;
            return true;
      }

      Node * last = head;
      while (last->getNext() != NULL) {
            last = last->getNext();
      }

      last->setNext(newNode);
      newNode->setPrev(last);

      return true;

}
```

2. delete in doubly list:

```
bool DoublyLinkedList::deletebyPos(int position) {
      if (position <= 0 || head == NULL ) {
            return false;
      }
      if (position == 1) {
            Node * del = head;
            head = head->getNext();
            if (head != NULL) {
                  head->setPrev(NULL);
            }
            delete del;
            return true;
      }
      Node * del = head;
      for (int i = 1; i < position; i++) {
            del = del->getNext();
            if (del == NULL) {
                  return false;
            }
      }
      del->getPrev()->setNext(del->getNext());
      if (del->getNext() != NULL) {
            del->getNext()->setPrev(del->getPrev());
      }
      delete del;
      return true;

}
```

Stack

Stack:

Stack is a linear data structure which follows a particular order in which the operations are performed. The order may be LIFO(Last In First Out) or FILO(First In Last Out).

Following are operations are performed with stack.

1. Push()
2. Pop()
3. Peek()
4.

We can implement stack by two ways,

- Using array
- Using Linkedlist

Stack implementation using Array:

isFull() & isEmpty():

```
bool isEmpty() {
    return top == -1;
  }

 bool isFull() {
    return top == ( size - 1 );
  }
```

Push:

```
bool push( int data ) {
      if( isFull() ) {
         cout<<"List is full"<<endl;
         return false;
      }

      arr[++top] = data;
      return true;
   }
```

pop():

```
int pop() {
     if( isEmpty() ) {
              cout<<"List is empty"<<endl;
        return -999;
     }
        return arr[--top];
  }
```

peek():

```
int peek() {
         if( isEmpty() ) {
         return -999;
      }
      return arr[top];
   }
```

Stack implementation using Linked List:

push():

```
bool push(int data)
{
        node* newnode =new node(data);
        if (newnode == NULL)
        {
                return false;
        }
        newnode->setData( data);
        newnode->Setnext( head);
        head = newnode;
        return true;
}
```

pop():

```
bool pop()
{
        node* del = head;
        if (head == NULL)
        {
                return false;
        }
        head = del->getNext();
        delete [] del;
        return ture;
}
```

peek():

```
int peek()
{
        return head->getData();
}
```

Queue

Queue:

A Queue is an ordered collection of items into which new items may be inserted at rear end and items are deleted at one end called front.

Types of Queue:

1. **Linear Queue**
2. **Circular Queue**
3. **Priority Queue**
4. **Dequeue (Double Ended Queue)**
5.

Queue implementation using Array:

isFull() & isEmpty():

```
bool isEmpty() {
    return ( front == -1 && rear == -1)|| ( front > rear );
}

bool isFull()
    {
    return rear = ( size - 1 );
}
```

Insert():

```
bool insert( int data ){
    if( isFull() ) {
        return false;
    }
     arr[++rear] = data;
    if( front == -1 ) {
        front = 0;
    }
    return true;
}
```

delete() :

```
int deleteData() {
      if( isEmpty() ) {
         return -999;
      }
      return arr[front++];
   }
```

Circular Queue implementation using Array:

isFull() & isEmpty():

```
bool isEmpty() {
      return front == rear;
   }
   bool isFull() {
      return  ( front == -1 && rear ==( size - 1 ) ) ||
      ( (rear+1) % size == front );
    }
```

Insert():

```
bool insert( int data ){
      if( isFull() ){
         return false;
      }

      rear = ( rear + 1 ) % size;
      arr[rear] = data;
      return true;
   }
```

delete() :

```
int deleteData() {
      if( isEmpty() ){
         return -999;
      }
     front = ( front + 1 ) % size;
      return arr[front];
   }
```

Difference between Stack and Queue:

Sr.No	Stack	Queue
1	A Stack Data Structure works on Last In First Out (LIFO) principle.	A Queue Data Structure works on First In First Out (FIFO) principle.
2.	Push and pop operations are done from same end i.e "top"	Push and pop operations are done from same end i.e "rear" and "front" respectively
3.	You can implement multi-stack approach	Threre are four types of Queue i.e linear, circular, priority and dequeue.
4.	Application: • Used in infix to postfix conversion, • scheduling algorithms • depth first search and evaluation of an expression	Application: • Printer mainatains queue of documents to be printed • OS uses queues for many functionalities : Ready Queue, Waiting Queue, Message Queue • To implements algo like Breadth first search.

Polish Notation:

These are notations to represent math equations.

- Infix Notation: A+B
- Prefix Notation: +AB
- Postfix Notation: AB+

To convert infix to prefix /postfix considers the priorities:

Precedence	Operator	Type	Associativity
15	() [] .	Parentheses Array subscript Member selection	Left to Right
14	++ --	Unary post-increment Unary post-decrement	Right to left
13	++ -- + - ! ~ (*type*)	Unary pre-increment Unary pre-decrement Unary plus Unary minus Unary logical negation Unary bitwise complement Unary type cast	Right to left
12	* / %	Multiplication Division Modulus	Left to right
11	+ -	Addition Subtraction	Left to right
10	<< >> >>>	Bitwise left shift Bitwise right shift with sign extension Bitwise right shift with zero extension	Left to right
9	< <= > >= instanceof	Relational less than Relational less than or equal Relational greater than Relational greater than or equal Type comparison (objects only)	Left to right
8	== !=	Relational is equal to Relational is not equal to	Left to right
7	&	Bitwise AND	Left to right
6	^	Bitwise exclusive OR	Left to right
5	|	Bitwise inclusive OR	Left to right
4	&&	Logical AND	Left to right
3	||	Logical OR	Left to right
2	? :	Ternary conditional	Right to left
1	= += -= *= /= %=	Assignment Addition assignment Subtraction assignment Multiplication assignment Division assignment Modulus assignment	Right to left

Infix to postfix Evaluation rules:

1. Scan the infix exp. From left to right
2. If scan character is left parenthesis then push it into stack
3. If scan character is operand than that will display into postfix expression.
4. If scan character is operator than that will push into operator stack.
5. If scan character has higher precedence than stack operator then scanned operator will push into operator stack.
6. If scan character has less or equal precedence than stack operator then stack operator will pop out from stack to postfix expression and scanned operator will push into operator stack.
7. If scan character is right parenthesis then till left parenthesis of stack all operators will pop to postfix expression and left will remove from stack.
8. Repeat step 1 to step 6 until end of expression

Ex: A+ (B*C-(D/E^F)*G)*H

Symbol	Scanned	STACK	Postfix Expression	Description
1.		(		Start
2.	A	(	A	
3.	+	(+	A	
4.	(	(+(	A	
5.	B	(+(	AB	
6.	*	(+(*	AB	
7.	C	(+(*	ABC	
8.	-	(+(-	ABC*	'*' is at higher precedence than '-'
9.	(	(+(-(	ABC*	
10.	D	(+(-(	ABC*D	
11.	/	(+(-(/	ABC*D	
12.	E	(+(-(/	ABC*DE	
13.	^	(+(-(/^	ABC*DE	
14.	F	(+(-(/^	ABC*DEF	
15.	)	(+(-	ABC*DEF^/	Pop from top on Stack, that's why '^' Come first
16.	*	(+(-*	ABC*DEF^/	
17.	G	(+(-*	ABC*DEF^/G	
18.	)	(+	ABC*DEF^/G*-	Pop from top on Stack, that's why '^' Come first
19.	*	(+*	ABC*DEF^/G*-	
20.	H	(+*	ABC*DEF^/G*-H	
21.	)	Empty	ABC*DEF^/G*-H*+	END

Infix to prefix Evaluation rules:

1. Reserve the input string or start from right of the infix expression
2. Examine the next element in the input.
3. If it is operand , add it to output string .
4. If it is closing parenthesis ,push it on to stack.
5. If it is an operator ,then
   - If stack is empty , push operator on stack.
   - If the top of stack is closing parenthesis , push operator on stack
   - If it has same or higher priority then the top of stack push operator on stack
   - If it has lower priority the top, the pop stack and add it to post fix expression and push operator into stack
6. Else pop the operator from the stack and add it to output string If it is an opening parenthesis, pop operators from stack and ass them to output string until a closing parenthesis is encountered.pop and discard the closing parenthesis.
7. If there is more input go to step 2.
8. If there is no more input , unstack the remaining operators and them to output string.
9. Reserve the output string.

Binary Search Tree

Tree:

A tree consists of nodes connected by edges, which do not form cycle.
For collection of nodes & edges to define as tree, there must be one & only one path from the root to any other node.
A tree is a connected graph of N vertices with N-1 Edges.

Tree Terminologies:

1. **Node:** A node stands for the item of information plus the branches of other items.

2. **Siblings:** Children of the same parent are siblings.

3. **Degree:** The number of sub trees of a node is called degree. The degree of a tree is the maximum degree of the nodes in the tree.

4. **Leaf Nodes:** Nodes that have the degree as zero are called leaf nodes or terminal nodes. Other nodes are called non terminal nodes.

5. **Ancestor:** The ancestor of a node are all the nodes along the path from the root to that node.

6. **Level:** The level of a node is defined by first letting the root of the tree to be level = 1or level=0.

7. **Height/Depth:** The height or depth of the tree is defined as the maximum level of any node in the tree.

Binary Search Tree

A Binary Search Tree (BST) is a tree in which all the nodes follow the below-mentioned properties –

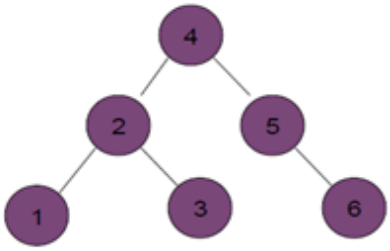
The left sub-tree of a node has a key less than or equal to its parent node's key.

The right sub-tree of a node has a key greater than to its parent node's key.

Insert() in to Binary search tree:

```
bool BST::insert(int data) {
    //create a node
        Node * newNode = new Node( data );
  //check for newnode and for duplicate data point
      if( newNode == NULL ) {
        return false;
   }
//check for tree is empty
      if( root == NULL ) {
        //if empty
      root = newNode;
      return true;
   }
//if tree is not empty  create temporary pointer
      Node * temp = root;
//compare data
      while( temp->getData() != data ) {
         if( data < temp->getData() ) {
         //insert to left
         //check if  temp has left child
         if( temp->getLeft() == NULL ) {
            temp->setLeft( newNode );
            return true;
         }
         temp = temp->getLeft();
      }
      else {
         //insert to right
         //check if  temp has right child
         if( temp->getRight() == NULL ) {
            temp->setRight( newNode );
            return true;
         }
         temp = temp->getRight();
     } }
    delete newNode;
   return false;
```

Tree traversals:



- **Preorder(Root-Left-Right)**
  421356
- **Inorder(Left-Root-Right)**
  123456
- **Postorder(Left-Right-Root)**
  132654

PreOrder:

```
void BST::preOrder() {
    Node * temp = root;
  Node * stack[100];
  int top = -1;
   cout<<"Pre : ";
  while( temp != NULL || top != -1 ) {
        while( temp ) {
        cout<<temp->getData()<<" ";
        stack[++top] = temp;
        temp = temp->getLeft();
      }
       temp = stack[top--];
      temp = temp->getRight();
    }
```

Algorithm for preorder Traversal:

1. Visit node
2. Backup its address (use stack)
3. goto left child
4. If temp is null then pop stack
5. go back to popped parent and goto it's right
6. Repeat till stack is empty or temp is not NULL

Inorder:

```
void BST::inOrder() {
   Node * temp = root;
   Node * stack[100];
   int top = -1;
   cout<<"In : ";
   while( temp != NULL || top != -1 ) {
        while( temp ) {
          stack[++top] = temp;
          temp = temp->getLeft();
        }
        temp = stack[top--];
        cout<<temp->getData()<<" ";
        temp = temp->getRight();
      }
}
```

Algorithm for Inorder Traversal:

1. Push temp to stack
2. Goto left of temp
3. Repeat till temp is NULL
4. now pop stack & get back to popped node
5. visit that popped node and then shift to its right child
6. Repeat till stack is empty or temp is not NULL

Postorder:

```
void BST::postOrder() {
      typedef struct {
      Node * address;
      char flag;
   } Pair;
   Node * temp = root;
   Pair stack[100];
   int top = -1;
   while( temp != NULL || top != -1) {
        while( temp ) {
          Pair p;
          p.address = temp; p.flag = 'L';
          stack[++top] = p;
          temp = temp->getLeft();
        }
        Pair p = stack[top--];
          if( p.flag == 'L') {
          temp = p.address->getRight();
          p.flag = 'R';
          stack[++top] = p; }
        else {
          cout<<p.address->getData()<<" ";
        } }}
```

Threaded Binary Search Tree

Insert ():

Algorithm:

Insert to left:

1. parent will become inorder successor of new node
2. parent's inorder predecessor will become inorder predecessor of newnode
3. new node will become left child of parent

Insert to right:

1. parent will become inorder predecessor of newnode
2. parent's inorder successor will become inorder successor of newnode
3. newnode will become right child of parent

```
bool TBST::insert(int data) {

    Node * newNode = new Node( data );
    if( newNode == NULL ) {
        return false;
    }

    if( root == NULL ) {
        root = newNode;
        return true;
    }

    Node * temp = root;
    while( true ) {

        if( data == temp->getData() ) {
            delete newNode;
            return true;
        }

        if( data < temp->getData() ) {
            //insert to left
            if( temp->getLFlag() == 'T' ) {
                newNode->setRight( temp );
                newNode->setLeft( temp->getLeft() );
                temp->setLeft( newNode );
                temp->setLFlag('L');
                return true;
            }
            temp = temp->getLeft();
        }
        else {
            //insert to right
            if( temp->getRFlag() == 'T') {
                newNode->setLeft( temp );
                newNode->setRight( temp->getRight() );
                temp->setRight( newNode );
                temp->setRFlag('L');
                return true;
            }
            temp = temp->getRight();
        }
    }
}
```

Delete():

```
bool TBST::deleteData(int data) {

   if( root == NULL ) {
       return false;
   }

   Node * parent = root, * del = root;

   while( del->getData() != data ) {

       if( data < del->getData() ) {

           if( del->getLFlag() == 'T' ) {
               return false;
           }

           parent = del;
           del = del->getLeft();
       }
       else {

           if( del->getRFlag() == 'T') {
               return false;
           }

           parent = del;
           del = del->getRight();
       }

   }

   while( true ) {

       if( del->getLFlag() == 'T' && del->getRFlag() == 'T') {

           if( del == root ) {
               root = NULL;
               delete del;
           }

           if ( del == parent->getLeft() ) {
               parent->setLeft( del->getLeft() );
               parent->setLFlag('T');
           }
           else {
               parent->setRight( del->getRight() );
               parent->setRFlag('T');

           }
           delete del;
           return true;

       }
```

```
//Find maximum from left and minimum from right

if( del->getLFlag() == 'L' ) {

            Node * max = del->getLeft();
            parent = del;

            while (max->getRFlag() == 'L') {
                parent = max;
                max = max->getRight();
            }

            int data = del->getData();
            del->setData( max->getData() );
            max->setData( data );

            del = max;
        }
        else {

            Node * min = del->getRight();
            parent = del;

            while( min->getLFlag() == 'L') {
                parent = min;
                min = min->getLeft();
            }

            int data = min->getData();
            min->setData( del->getData() );
            del->setData( data );

            del = min;

        }

    }
```

Preorder:

```
void TBST::preOrder() {

    Node * temp = root;
    char flag = 'L';

    cout<<"preorder : ";

    while (temp) {

       while( temp->getLFlag() == 'L' && flag == 'L' ){
            cout<<temp->getData()<<" ";
            temp = temp->getLeft();
        }

        if( flag == 'L') {
            cout<<temp->getData()<<" ";
        }
        flag = temp->getRFlag();
        temp = temp->getRight();
    }
    cout<<endl;

    }

}
```

Inorder:

```
void TBST::inOrder() {

    Node * temp = root;
    char flag = 'L';

    cout<<"Inorder : ";

    while( temp ) {

        while( temp->getLFlag() == 'L' && flag == 'L'){
            temp = temp->getLeft();
        }

        cout<<temp->getData()<<" ";
        flag = temp->getRFlag();
        temp = temp->getRight();
    }

    cout<<endl;


}
```

isRightChild:

```
bool TBST::isRightChild( Node * node ) {

    if( node == root ) {
        return false;
    }

    Node * temp = root;
    char flag = 'L';

    while( temp ) {

        while( temp->getLFlag() == 'L' && flag == 'L'){
            temp = temp->getLeft();

            if( temp == node ) {
                return false;
            }
        }

        flag = temp->getRFlag();
        temp = temp->getRight();

        if( temp == node && flag == 'L') {
            return true;
        }
    }

    return false;
}
```

PostOrder:

```
 void TBST::postOrder() {

   Node * temp = root;
   char flag = 'L';

   cout<<"Postorder : ";

   while( temp ) {

       while( temp->getLFlag() == 'L' && flag == 'L') {
           temp = temp->getLeft();
       }

       flag = temp->getRFlag();

       if( flag == 'L') {
      //temp has right child
           temp = temp->getRight();
       }
       else {
           while( true ) {

 //temp does not have right child, so visit temp
               cout<<temp->getData()<<" ";
               bool isRight = isRightChild( temp );

               if( isRight ) {
 //temp is right child, so go to it's parent and visit parent
                   while( temp->getLFlag() == 'L') {
                       temp = temp->getLeft();
                   }

                   temp = temp->getLeft();
               }
               else {
 //temp is left child, so go to it's parent and then to right of
parent**
                   while( temp->getRFlag() == 'L') {
                       temp = temp->getRight();
                   }
                   temp = temp->getRight();
                   flag = 'T';
                   break;
               }
           }
       }
   }
   cout<<endl;
 }
```

Graph

Graph:

A Graph is a collection of nodes, which are called vertices 'V', connected in pairs by line segments, called Edges E.
Sets of vertices are represented as V(G) and sets of edges are represented as E(G).
So a graph is represented as G = (V, E).
There are two types of Graphs
- Undirected Graph
- Directed Graph

Directed Graph are usually referred as Digraph for Simplicity. A directed Graph is one, where each edge is represented by a specific direction or by a directed pair <v1, v2>.Hence <v1, v2> & <v2, v1> represents two different edges.

Terminology related to Graph:

- Out – degree: The number of Arc exiting from the node is called the out degree of the node.
- In- Degree: The number of Arcs entering the node is the In degree of the node.
- Sink node: A node whose out-degree is zero is called Sink node.
- Path: path is sequence of edges directly or indirectly connected between two nodes.
- Cycle: A directed path of length at least L which originates and terminates at the same node in the graph is a cycle

The graphs can be implemented in two ways

1. Array Method
2. Linked List

Graph traversal

1. Breadth first search

```
void Graph::bfs(int v) {
        int * visited = new int[noOfVertices] ;
        int q[100];
        int front = -1, rear = -1;
        q[0] = v;
        front = rear = 0;
        cout << "BFS : ";
        while (front <= rear) {
        v = q[front++];
        if (visited[v] == 0) {
        cout << vertices[v] << " ";
        visited[v] = 1;
        for (int i = 0; i < noOfVertices; i++) {
                if (adjMat[v][i] == 1 && visited[i] == 0) {
                q[++rear] = i;
                } }}

        delete[] visited;

}
```

2. Depth first search

```
void Graph::dfs(int v) {
        int * visited = new int[noOfVertices] ;
        int stack[100];
        int top = -1;
        cout << "DFS : ";
        cout << vertices[v] << " ";
        visited[v] = 1;
        stack[++top] = v;
        while (top != -1) {
                for (int i = 0; i < noOfVertices; i++) {
                        if (adjMat[v][i] == 1 && visited[i] == 0) {
                                cout << vertices[i] << " ";
                                visited[i] = 1;
                                stack[++top] = i;
                                v = i;
                                i = -1;
                        }
                }
                v = stack[top--];}

}
```