What is Java?

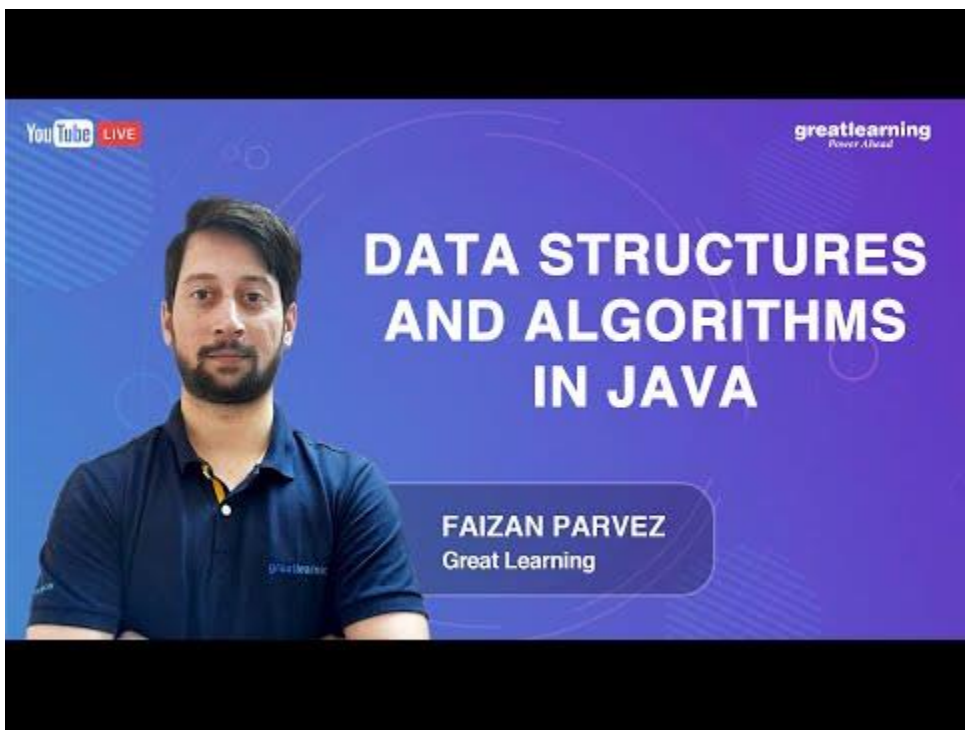
Before we learn about Data Structures using Java, let us understand what Java means.

- Java is a
    - a programming language
    - object-oriented
    - high level
    - originally developed by Sun Microsystems
- It follows the WORA principle
    - stands for “Write Once Run Anywhere”
    - you can run a java program as many times as you want on a java supported platform after it is compiled.

What are Data Structures?

- Made up of 2 words
    - “DATA” + “STRUCTURES”
- It is a way to arrange data on computers
- Example: You might want to store data in
    - Linear fashion – Array/ Linked List
    - One on the other – Stacks
    - Hierarchical Fashion – Trees
    - Connect Nodes – Graph

To learn more about this domain, check out Great Learning Academy’s Data Structures & Algorithms in Java Free Online Course. The course will cover all the basic concepts required for you to step into the world of Data Structures and Java. Taking up a free online course can help you understand the foundational concepts clearly and act as a stepping stone in your career.



List of Data Structures using Java

- Array
- Linked List
- Stack
- Queue
- Binary Tree
- Binary Search Tree
- Heap
- Hashing

- Graph

Also Read: Data Structures using C

Arrays

- Linear Data Structure
- Elements are stored in contiguous memory locations
- Can access elements randomly using index
- Stores homogeneous elements i.e, similar elements
- Syntax:
- Array declaration
    - datatype varname []=new datatype[size];
    - datatype[] varname=new datatype[size];

- Can also do declaration and initialization at once
    - Datatype varname [] = {ele1, ele2, ele3, ele4};

Advantages

- Random access
- Easy sorting and iteration
- Replacement of multiple variables

Disadvantages

- Size is fixed
- Difficult to insert and delete
- If capacity is more and occupancy less, most of the array gets wasted
- Needs contiguous memory to get allocated

Applications

- For storing information in a linear fashion
- Suitable for applications that require frequent searching

Demonstration of Array

```
import java.util.*;


class JavaDemo {

      public static void main (String[] args) {

          int[] priceOfPen= new int[5];

          Scanner in=new Scanner(System.in);

          for(int i=0;i<priceOfPen.length;i++)

              priceOfPen[i]=in.nextInt();


          for(int i=0;i<priceOfPen.length;i++)

                System.out.print(priceOfPen[i]+" ");

      }
```

```
}



Input:

23 13 56 78 10



Output:

23 13 56 78 10
```

Also Read: How to choose the right programming language for Data Science?

Linked List

- Linear Data Structure
- Elements can be stored as per memory availability
- Can access elements on linear fashion only
- Stores homogeneous elements i.e, similar elements
- Dynamic in size
- Easy insertion and deletion
- Starting element or Node is the key which is generally termed as head.

Advantages

- Dynamic in size
- No wastage as capacity and size is always equal
- Easy insertion and deletion as 1 link manipulation is required
- Efficient memory allocation

Disadvantages

- If head Node is lost, the linked list is lost
- No random access possible

Applications

- Suitable where memory is limited
- Suitable for applications that require frequent insertion and deletion

Demonstration of Linked List

```
import java.util.*;



class LLNode{



      int data;

      LLNode next;
```

```
	LLNode(int data)
	{
		this.data=data;
		this.next=null;

	}
}



class Demo{
	LLNode head;



	LLNode insertInBeg(int key,LLNode head)
	{
		LLNode ttmp=new LLNode(key);

		if(head==null)
			head=ttmp;

		else
			{
				ttmp.next=head;
				head=ttmp;
			}
		return head;
	}



	LLNode insertInEnd(int key,LLNode head)
	{
		LLNode ttmp=new LLNode(key);
		LLNode ttmp1=head;
```

```
        if(ttmp1==null)
              head=ttmp;
        else
        {
              while(ttmp1.next!=null)
                          ttmp1=ttmp1.next;
              ttmp1.next=ttmp;

        }
              return head;

    }

    LLNode insertAtPos(int key,int pos,LLNode head)
    {
          LLNode ttmp=new LLNode(key);

          if(pos==1)
          {
                ttmp.next=head;
                head=ttmp;
          }
          else
          {
                LLNode ttmp1=head;
                for(int i=1;ttmp1!=null && i<pos;i++)
                      ttmp1=ttmp1.next;
                ttmp.next=ttmp1.next;
                ttmp1.next=ttmp;
          }
```

```
	return head;
}



LLNode delete(int pos,LLNode head)
{
	LLNode ttmp=head;
	if(pos==1)
		head=ttmp.next;
	else
	{
		for(int i=1;ttmp!=null && i<pos-1;i++)
			ttmp=ttmp.next;
		ttmp.next=ttmp.next.next;
	}
	return head;
}



int length(LLNode head)
{
	LLNode ttmp=head;
	int c=0;
	if(ttmp==null)
		return 0;
	else
	{
	 while(ttmp!=null)
		{	ttmp=ttmp.next;
			c++;
		}
	}
	return c;
}
```

```
LLNode reverse(LLNode head)
{
	LLNode prevLNode=null,curLNode=head,nextLNode=null;
	while(curLNode!=null)
	{
		nextLNode=curLNode.next;
		curLNode.next=prevLNode;

		prevLNode=curLNode;
		curLNode=nextLNode;
	}

	head=prevLNode;
	return head;
}



void display(LLNode head)
{
	LLNode ttmp=head;
	while(ttmp!=null)
		{System.out.print(ttmp.data+" ");
		 ttmp=ttmp.next;
		}
}

public static void main(String[] args)
{
	LinkedListDemo l=new LinkedListDemo();
	l.head=null;
	Scanner in=new Scanner(System.in);
	 do
{
```

```
System.out.println("\n********* MENU *********");
      System.out.println("\n1.Insert In End");
      System.out.println("\n2.Insert In Beg");
      System.out.println("\n3.Insert At A  Particular Pos");
      System.out.println("\n4.Delete At a Pos");
      System.out.println("\n5.Length");
      System.out.println("\n6.Reverse");
      System.out.println("\n7.Display");
      System.out.println("\n8.EXIT");
      System.out.println("\nenter ur choice : ");
      int n=in.nextInt();
     switch(n)
          {case 1: System.out.println("\nenter the value ");
                    l.head=l.insertInEnd(in.nextInt(),l.head);
                   break;
           case 2: System.out.println("\nenter the value");
                   l.head=l.insertInBeg(in.nextInt(),l.head);
                   break;
           case 3: System.out.println("\nenter the value");
                   l.head=l.insertAtPos(in.nextInt(),in.nextInt(),l.head);
                   break;
           case 4:
                   l.head=l.delete(in.nextInt(),l.head);
                   break;
           case 5:
                System.out.println(l.length(l.head));
                 break;
           case 6:
                 l.head=l.reverse(l.head);
                 break;
           case 7:
                l.display(l.head);
                       break;
           case 8: System.exit(0);
```

```
                        break;

             default: System.out.println("\n Wrong Choice!");

                         break;

              }

       System.out.println("\n do u want to cont... ");

      }while(in.nextInt()==1);


 }

}
```

Output:

```
********* MENU *********

1.Insert In End

2.Insert In Beg

3.Insert At A  Particular Pos

4.Delete At a Pos

5.Length

6.Reverse

7.Display

8.EXIT
```

```
enter ur choice :

1


enter the value

23


 do u want to cont...

1


********* MENU *********

1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :

1


enter the value

56


 do u want to cont...
```

```
1


********* MENU *********


1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :
2


enter the value
10


 do u want to cont...
1


********* MENU *********


1.Insert In End


2.Insert In Beg
```

```
3.Insert At A  Particular Pos

4.Delete At a Pos

5.Length

6.Reverse

7.Display

8.EXIT

enter ur choice :
7
10 23 56
 do u want to cont...
1

********* MENU *********

1.Insert In End

2.Insert In Beg

3.Insert At A  Particular Pos

4.Delete At a Pos

5.Length

6.Reverse

7.Display
```

```
8.EXIT


enter ur choice :

3


enter the value

67

2


 do u want to cont...

1


********* MENU *********


1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :

7

10 23 67 56
```

```
 do u want to cont...
1


********* MENU *********


1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :
4
2


 do u want to cont...
1


********* MENU *********


1.Insert In End


2.Insert In Beg
```

```
3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :

7

10 67 56

 do u want to cont...

1


********* MENU *********


1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display
```

```
8.EXIT


enter ur choice :

6


 do u want to cont...

1


********* MENU *********


1.Insert In End


2.Insert In Beg


3.Insert At A  Particular Pos


4.Delete At a Pos


5.Length


6.Reverse


7.Display


8.EXIT


enter ur choice :

7

56 67 10

 do u want to cont...
```

Stack

- Linear Data Structures using Java
- Follows LIFO: Last In First Out
- Only the top elements are available to be accessed
- Insertion and deletion takes place from the top
- Eg: a stack of plates, chairs, etc
- 4 major operations:
    - push(ele) – used to insert element at top
    - pop() – removes the top element from stack
    - isEmpty() – returns true is stack is empty
    - peek() – to get the top element of the stack
- All operation works in constant time i.e, O(1)

Advantages

- Maintains data in a LIFO manner
- The last element is readily available for use
- All operations are of O(1) complexity

Disadvantages

- Manipulation is restricted to the top of the stack
- Not much flexible

Applications

- Recursion
- Parsing
- Browser
- Editors

Demonstration of Stack – using Array

```
import java.util.*;



class Stack

{

 int[] a;

 int top;

 Stack()

 {

    a=new int[100];

    top=-1;

 }



void push(int x)

{
```

```
    if(top==a.length-1)
      System.out.println("overflow");
    else
     a[++top]=x;
}

int pop()
{
  if(top==-1)
         {System.out.println("underflow");
        return -1;
       }
 else
    return(a[top--]);
}

void display()
{
       for(int i=0;i<=top;i++)
              System.out.print(a[i]+" ");
       System.out.println();
}

boolean isEmpty()
{
       if(top==-1)
              return true;
       else
              return false;
}

int peek()
{
       if(top==-1)
```

```
                  return -1;
            return (a[top]);
      }



}

public class Demo
{
      public static void main(String args[])
      {

       Stack s=new Stack();
       Scanner in= new Scanner(System.in);


        do
             {System.out.println("\n******** MENU *******");
              System.out.println("\n1.PUSH");
              System.out.println("\n2.POP");
              System.out.println("\n3.PEEK");
              System.out.println("\n4 IS EMPTY");
              System.out.println("\n5.EXIT");
              System.out.println("\n enter ur choice : ");
              switch(in.nextInt())
             {
              case 1:
                     System.out.println("\nenter the value ");
                     s.push(in.nextInt());
                     break;
              case 2:
                    System.out.println("\n popped element : "+ s.pop());
                     break;


             case 3:
```

```
                        System.out.println("\n top element : "+ s.peek());
                         break;
                case 4: System.out.println("\n is empty : "+ s.isEmpty());
                            break;
                case 5: System.exit(0);
                            break;
                default: System.out.println("\n Wrong Choice!");
                             break;
              }
         System.out.println("\n do u want to cont... ");
        }while(in.nextInt()==1);
       }
}
```

Output:

```
******** MENU *******

1.PUSH

2.POP

3.PEEK

4 IS EMPTY

5.EXIT
```

```
 enter ur choice :
1


enter the value
12


 do u want to cont...
1


******** MENU *******

1.PUSH


2.POP


3.PEEK


4 IS EMPTY


5.EXIT


 enter ur choice :
1


enter the value
56


 do u want to cont...
1


******** MENU *******


1.PUSH
```

```
2.POP


3.PEEK


4 IS EMPTY


5.EXIT


 enter ur choice :
2

 popped element : 56


 do u want to cont...
1


******** MENU *******


1.PUSH


2.POP


3.PEEK


4 IS EMPTY


5.EXIT


 enter ur choice :
4


 is empty : false


 do u want to cont...
```

```
1


******** MENU *******


1.PUSH


2.POP


3.PEEK


4 IS EMPTY


5.EXIT


 enter ur choice :
2


 popped element : 12


 do u want to cont...
```

Demonstration of Stack – using LinkedList

```
import java.util.*;


class LNode
{
        int data;
        LNode next;
        LNode(int d)
        {
             data=d;
        }

}
```

```
 class Stack

{

       LNode push(int d,LNode head){

                          LNode tmp1 = new LNode(d);

                          if(head==null)

                                head=tmp1;

                          else
                          {
                                tmp1.next=head;

                                head=tmp1;
                          }
                          return head;
                    }


     LNode pop(LNode head){

               if(head==null)
                    System.out.println("underflow");
                 else
                          head=head.next;
                    return head;
               }


     void display(LNode head){

                          System.out.println("\n list is : ");
                          if(head==null){
```

```
                System.out.println("no LNodes");


                return;

                }


        LNode tmp=head;


        while(tmp!=null){


        System.out.print(tmp.data+" ");

                        tmp=tmp.next;



                        }
         }


boolean isEmpty(LNode head)
  {
        if(head==null)
              return true;
        else
              return false;
      }


      int peek(LNode head)
      {
            if(head==null)
                  return -1;
            return head.data;
      }


}
```

```
public class Demo{

            public static void main(String[] args)
            {
            Stack s=new Stack();
            LNode head=null;
            Scanner in=new Scanner(System.in);

             do
                {System.out.println("\n******** MENU *******");
                 System.out.println("\n1.PUSH");
                 System.out.println("\n2.POP");
                 System.out.println("\n3.PEEK");
                 System.out.println("\n4 IS EMPTY");
                 System.out.println("\n5 DISPLAY");
                 System.out.println("\n6.EXIT");
                 System.out.println("\n enter ur choice : ");
                 switch(in.nextInt())
                      {
                       case 1:
                              System.out.println("\nenter the value ");
                              head=s.push(in.nextInt(),head);
                              break;
                        case 2:
                              head=s.pop(head);
                              break;

                       case 3:
                       System.out.println("\n top element : "+ s.peek(head));
                              break;
                        case 4:
System.out.println("\n is empty : "+ s.isEmpty(head));
```

```
                        break;
                case 5: s.display(head);
                        break;
                case 6: System.exit(0);
                        break;
                default: System.out.println("\n Wrong Choice!");
                         break;
              }
         System.out.println("\n do u want to cont... ");
        }while(in.nextInt()==1);
       }
}
```

Output

```
******** MENU *******


1.PUSH


2.POP


3.PEEK


4 IS EMPTY


5 DISPLAY


6.EXIT


 enter ur choice :
```

```
1



enter the value

12



 do u want to cont...

1



******** MENU *******



1.PUSH

2.POP

3.PEEK

4 IS EMPTY

5 DISPLAY

6.EXIT

 enter ur choice :

1



enter the value

56



 do u want to cont...

1



******** MENU *******



1.PUSH
```

```
2.POP

3.PEEK

4 IS EMPTY

5 DISPLAY

6.EXIT

 enter ur choice :
5

 list is :
56 12
 do u want to cont...
1

******** MENU *******

1.PUSH

2.POP

3.PEEK

4 IS EMPTY

5 DISPLAY

6.EXIT

 enter ur choice :
```

```
3


 top element : 56


 do u want to cont...

1


******** MENU *******


1.PUSH


2.POP


3.PEEK


4 IS EMPTY


5 DISPLAY


6.EXIT


 enter ur choice :

4


 is empty : false



 do u want to cont...

1
```

Queue

- Linear Data Structure
- Follows FIFO: First In First Out
- Insertion can take place from the rear end.
- Deletion can take place from the front end.
- Eg: queue at ticket counters, bus station
- 4 major operations:
    - enqueue(ele) – used to insert element at top
    - dequeue() – removes the top element from queue

    - peekfirst() – to get the first element of the queue
    - peeklast() – to get the last element of the queue
- All operation works in constant time i.e, O(1)

Advantages

- Maintains data in FIFO manner
- Insertion from beginning and deletion from end takes O(1) time

Applications

- Scheduling
- Maintaining playlist
- Interrupt handling

Demonstration of Queue- using Array

```
import java.util.*;


class Queue{


 int front;

 int rear;

 int[] arr;


 Queue()

 {

   front=rear=-1;

   arr=new int[10];

  }


void enqueue(int a)

{

  if(rear==arr.length-1)

          System.out.println("overflow");

    else

          arr[++rear]=a;


    if(front==-1)

          front++;
```

```
}


int dequeue()

{

  int x=-1;

    if(front==-1)

         System.out.println("underflow");

    else

         x=arr[front++];

    if(rear==0)

        rear--;

       return x;

    }


      void display()

      {

        for(int i=front;i<=rear;i++)

             System.out.print(arr[i]+" ");


       System.out.println();



      }

}


public class QueueDemo{


      public static void main(String[] args)

      {

        Queue ob=new Queue();

        ob.enqueue(1);

        ob.enqueue(2);

        ob.enqueue(3);

        ob.enqueue(4);
```

```
        ob.enqueue(5);

        ob.display();

        ob.dequeue();

        ob.display();

       }

}
```

```
Output:




1 2 3 4 5

2 3 4 5
```

Demonstration of Queue- using LinkedList

```
class LNode{


      int data;

      LNode next;


      LNode(int d)

      {

            data=d;

      }

}



class Queue{


      LNode enqueue(LNode head,int a)

      {

            LNode tmp=new LNode(a);
```

```
        if(head==null)
              head=tmp;
        else
         {
              LNode tmp1=head;
              while(tmp1.next!=null)
                    tmp1=tmp1.next;

              tmp1.next=tmp;
        }
        return head;
    }



    LNode dequeue(LNode head)
    {
          if(head==null)
                  System.out.println("underflow");
             else
                       head=head.next;
                return head;
    }

    void display(LNode head)
    {

                          System.out.println("\n list is : ");
                          if(head==null){

                                System.out.println("no LNodes");

                                return;
                                }
```

```
                        LNode tmp=head;


                        while(tmp!=null){


                        System.out.print(tmp.data+" ");


                        tmp=tmp.next;



                        }
    }


    }


    public class QueueDemoLL{


          public static void main(String[] args)
          {
                Queue ob=new Queue();
                LNode head=null;


                head=ob.enqueue(head,1);
                head=ob.enqueue(head,2);
                head=ob.enqueue(head,3);
                head=ob.enqueue(head,4);
                head=ob.enqueue(head,5);
                ob.display(head);
                head=ob.dequeue(head);
                ob.display(head);
          }
    }
```

```
Output



list is :

1 2 3 4 5

list is :

2 3 4 5
```

Binary Tree

- Hierarchical Data Structure
- Topmost element is known as the root of the tree
- Every Node can have at most 2 children in the binary tree
- Can access elements randomly using index
- Eg: File system hierarchy
- Common traversal methods:
    - preorder(root) : print-left-right
    - postorder(root) : left-right-print
    - inorder(root) : left-print-right

Advantages

- Can represent data with some relationship
- Insertion and search are much efficient

Disadvantages

- Sorting is difficult
- Not much flexible

Applications

- File system hierarchy
- Multiple variations of the binary tree have a wide variety of applications

Demonstration of Binary Tree

```
class TLNode

{

 int data;

 TLNode left,right;



 TLNode(int d)

 {

   data=d;

  }

 }
```

```
public class BinaryTree
{
   static void preorder(TLNode r)
   {
            if(r==null)
                return;

            System.out.print(r.data+" ");
            preorder(r.left);
            preorder(r.right);

   }
   static void inorder(TLNode r)
   {
            if(r==null)
                return;


            inorder(r.left);
            System.out.print(r.data+" ");
            inorder(r.right);

   }
   static void postorder(TLNode r)
   {
            if(r==null)
                return;


            postorder(r.left);
            postorder(r.right);
```

```
        System.out.print(r.data+" ");


}


 public static void main(String[] args)
    {
        TLNode root=new TLNode(1);


        root.left=new TLNode(2);
        root.right=new TLNode(3);

        root.left.left=new TLNode(4);
        root.left.right=new TLNode(5);


        root.right.left=new TLNode(6);
        root.right.right=new TLNode(7);
        preorder(root);
        System.out.println();


        inorder(root);
        System.out.println();


        postorder(root);
        System.out.println();




       }
}
```

Output

```
1 2 4 5 3 6 7

4 2 5 1 6 3 7

4 5 2 6 7 3 1
```

Binary Search Tree

- Binary tree with the additional restriction
- Restriction:
    - The left child must always be less than the root node
    - The right child must always be greater than the root node
- Insertion, Deletion, Search is much more efficient than a binary tree

Advantages

- Maintains order in elements
- Can easily find the min and max Nodes in the tree
- Inorder traversal gives sorted elements

Disadvantages

- Random access not possible
- Ordering adds complexity

Applications

- Suitable for sorted hierarchical data

Demonstration of Binary Search Tree

```
class TLNode{



      int data;

      TLNode left,right;



      TLNode(int d)

      {

            data=d;

      }

}



public class BST{



      TLNode root;



      TLNode insert(int d,TLNode root)
```

```
{
  if(root==null)
    root=new TLNode(d);

else if(d<=root.data)
      root.left=insert(d,root.left);

  else
      root.right=insert(d,root.right);

  return root;
}

TLNode search(int d,TLNode root)
{
      if(root.data==d)
            return root;
      else if(d<root.data)
            return search(d,root.left);
    else
            return search(d,root.right);
}

   void inorder(TLNode r)
{
          if(r==null)
              return;

          inorder(r.left);
          System.out.println(r.data);
          inorder(r.right);
```

```
   }



TLNode delete(TLNode root, int data)
    {

        if (root == null)  return root;

        if (data < root.data)
            root.left = delete(root.left, data);
        else if (data > root.data)
            root.right = delete(root.right, data);

        else
        {

            if (root.left == null)
                return root.right;
            else if (root.right == null)
                return root.left;



            root.data = minValue(root.right);

            root.right = delete(root.right, root.data);
        }

        return root;
    }
   int minValue(TLNode root)
    {
        int minv = root.data;
        while (root.left != null)
```

```
      {
          minv = root.left.data;
          root = root.left;
      }
      return minv;
  }


public static void main(String[] args)
{
          BST ob=new BST();
        ob.root=ob.insert(50,ob.root);
            ob.root=ob.insert(30,ob.root);
            ob.root=ob.insert(20,ob.root);
            ob.root=ob.insert(20,ob.root);
            ob.root=ob.insert(70,ob.root);
            ob.root=ob.insert(60,ob.root);
            ob.root=ob.insert(80,ob.root);
        ob.root=ob.delete(ob.root,50);
        System.out.println("******" +ob.root.data);
        ob.inorder(ob.root);

        TLNode find=ob.search(30,ob.root);
        if(find==null)
                System.out.println("not found");
             else
                System.out.println("found : "+find.data);


      }
}
```

Output:

```
******60

20

20

30

60

70

80

found : 30
```

Heap

- Binary Heap can be visualized array as a complete binary tree
- Arr[0] element will be treated as root
- length(A) – size of array
- heapSize(A) – size of heap
- Generally used when we are dealing with minimum and maximum elements
- For ith node

(i-1)/2	Parent
(2*i)+1	Left child
(2*i)+2	Right Child

Advantages

- Can be of 2 types: min heap and max heap
- Min heap keeps smallest and element and top and max keeps largest
- O(1) for dealing with min or max elements

Disadvantages

- Random access not possible
- Only min or max element is available for accessibility

Applications

- Suitable for applications dealing with priority
- Scheduling algorithm
- caching

Demonstration of Max Heap

```
import java.util.*;




class Heap{


      int heapSize;
```

```
void build_max_heap(int[] a)
{
	heapSize=a.length;
	for(int i=(heapSize/2);i>=0;i--)
		max_heapify(a,i);

}

void max_heapify(int[] a,int i)
{
	int l=2*i+1;
	int r=2*i+2;
	int largest=i;
	if(l<heapSize &&a[l]>a[largest])
		largest=l;
	if(r<heapSize &&a[r]>a[largest])
		largest=r;
	if(largest!=i)
	{
		int t=a[i];
		a[i]=a[largest];
		a[largest]=t;
	    max_heapify(a,largest);
	}

}

//to delete the max element

int extract_max(int[] a)
{
	if(heapSize<0)
		System.out.println("underflow");
```

```
		int max=a[0];
		a[0]=a[heapSize-1];
		heapSize--;
		max_heapify(a,0);
		return max;
	}

	void increase_key(int[] a,int i,int key)
	{
		if(key<a[i])
			System.out.println("error");
		a[i]=key;
		while(i>=0 && a[(i-1)/2]<a[i])
		{
			int t=a[(i-1)/2];
			a[(i-1)/2]=a[i];
			a[i]=t;

			i=(i-1)/2;
		}
	}

	void print_heap(int a[])
	{
		for(int i=0;i<heapSize;i++)
		    System.out.println(a[i]+" ");
	}
}

public class HeapDemo{

	public static void main(String[] args)
	{
		Scanner in=new Scanner(System.in);
```

```
        int n=in.nextInt();

        int a[]=new int[n];


        System.out.println("enter the elements of array");


        for(int i=0;i<n;i++)

          a[i]=in.nextInt();

           Heap ob=new Heap();


        ob.build_max_heap(a);

        ob.print_heap(a);



                System.out.println("maximum element is : "+ob.extract_max(a));

                ob.print_heap(a);

                System.out.println("maximum element is : "+ob.extract_max(a));

                ob.increase_key(a,6,800);

                ob.print_heap(a);


      }


}
```

Output

```
7

enter the elements of array

50 100 10 1 3 20 5

100

50

20

1

3

10

5
```

```
maximum element is : 100

50

5

20

1

3

10

maximum element is : 50

800

5

20

1

3
```

Hashing

- Uses special Hash function
- A hash function maps element to an address for storage
- This provides constant-time access
- Collision is handled by collision resolution techniques
- Collision resolution technique
    - Chaining
    - Open Addressing

Advantages

- The hash function helps in fetching element in constant time
- An efficient way to store elements

Disadvantages

- Collision resolution increases complexity

Applications

- Suitable for the application needs constant time fetching

Demonstration of HashSet – to find string has unique characters

```
import java.util.*;



class HashSetDemo1{



      static boolean isUnique(String s)

      {
```

```
        HashSet<Character> set =new HashSet<Character>();


        for(int i=0;i<s.length();i++)
            {
                    char c=s.charAt(i);
                    if(c==' ')
                          continue;
                    if(set.add(c)==false)
                          return false;

              }

              return true;
        }


        public static void main(String[] args)
        {
              String s="helo wqty ";
              boolean ans=isUnique(s);
              if(ans)
                    System.out.println("string has unique characters");
              else
                    System.out.println("string does not have unique characters");



              }
        }


Output:

string has unique characters
```

Demonstration of HashMap – count the characters in string

```
import java.util.*;
```

```
class HashMapDemo
{

      static void check(String s)
      {
            HashMap<Character,Integer> map=new HashMap<Character,Integer>();
            for(int i=0;i<s.length();i++)
                  {char c=s.charAt(i);
                   if(!map.containsKey(c))
                        map.put(c,1);
                   else
                        map.put(c,map.get(c)+1);
                  }



       Iterator<Character> itr = map.keySet().iterator();
       while (itr.hasNext()) {
             Object x=itr.next();
             System.out.println("count of "+x+" : "+map.get(x));
       }
 }

      public static void main(String[] args)
      {
            String s="hello";
            check(s);
      }
}


Output

count of e : 1

count of h : 1
```

```
count of l : 2

count of o : 1
```

Demonstration of HashTable – to find string has unique characters

```
import java.util.*;

class hashTabledemo {

      public static void main(String[] arg)

      {

            // creating a hash table

            Hashtable<Integer, String> h =

                              new Hashtable<Integer, String>();


            Hashtable<Integer, String> h1 =

                              new Hashtable<Integer, String>();


            h.put(3, "Geeks");

            h.put(2, "forGeeks");

            h.put(1, "isBest");


            // create a clone or shallow copy of hash table h

            h1 = (Hashtable<Integer, String>)h.clone();


            // checking clone h1

            System.out.println("values in clone: " + h1);


            // clear hash table h

            h.clear();


            // checking hash table h

            System.out.println("after clearing: " + h);

                        System.out.println("values in clone: " + h1);



      }

}
```

```
Output

values in clone: {3=Geeks, 2=forGeeks, 1=isBest}

after clearing: {}

values in clone: {3=Geeks, 2=forGeeks, 1=isBest}
```

Graph

- Basically it is a group of edges and vertices
- Graph representation
    - G(V, E); where V(G) represents a set of vertices and E(G) represents a set of edges
- The graph can be directed or undirected
- The graph can be connected or disjoint

Advantages

- finding connectivity
- Shortest path
- min cost to reach from 1 pt to other
- Min spanning tree

Disadvantages

- Storing graph(Adjacency list and Adjacency matrix) can lead to complexities

Applications

- Suitable for a circuit network
- Suitable for applications like Facebook, LinkedIn, etc
- Medical science

Demonstration of Graph

```
import java.util.*;



class Graph

{

	int v;

	LinkedList<Integer> adj[];



	Graph(int v)

	{

		this.v=v;

		adj=new LinkedList[v];

		for(int i=0;i<v;i++)

			adj[i]=new LinkedList<Integer>();

	}
```

```
void addEdge(int u,int v)
{
      adj[u].add(v);
}

void BFS(int s)
{
      boolean[] visited=new boolean[v];
      LinkedList<Integer> q=new LinkedList<Integer>();
      q.add(s);
      visited[s]=true;

      while(!q.isEmpty())
      {
            int x=q.poll();
            System.out.print(x+" ");

            Iterator<Integer> itr=adj[x].listIterator();
            while(itr.hasNext())
            {
              int p=itr.next();
              if(visited[p]==false)
                        {
                              visited[p]=true;
                              q.add(p);
                        }
                  }
            }
      }

void DFSUtil(int s,boolean[] visited)
```

```
    {
          visited[s]=true;
          System.out.println(s);

          Iterator<Integer> itr=adj[s].listIterator();
          while(itr.hasNext())
          {
                int x=itr.next();
                if(visited[x]==false)
                {
                      //visited[x]=true;
                      DFSUtil(x,visited);
                }
          }
    }

    void DFS(int s){
          boolean visited[]=new boolean[v];
          DFSUtil(s,visited);
    }

    public static void main(String[] args)
          {
                Graph g=new Graph(4);
                g.addEdge(0,1);
                g.addEdge(0,2);
                g.addEdge(1,2);
                g.addEdge(2,0);
                g.addEdge(2,3);
                g.addEdge(3,3);

                g.BFS(2);
```

```
                    g.DFS(2);



            }
}
```

Output:

```
2 0 3 1 2

0

1

3
```