Bharatiya Vidya Bhavan's
SARDAR PATEL INSTITUTE OF TECHNOLOGY
(Autonomous Institute Affiliated to University of Mumbai)
Munshi Nagar, Andheri (W), Mumbai – 400 058.
Department of Master of Computer Application

Experiment	1
Aim	Understand sorting algorithms on the basis of Divide and Conquer approach
Objective	1) Learn Divide and Conquer strategy in sorting algorithms 2) Learn Merge Sort and Quick Sort 3) Compare the Time complexity of Merge Sort and Quick Sort
Name	Durgesh Dilip Mandge
UCID	2023510032
Class	FYMCA
Batch	B
Date of Submission	30-01-2-24

Algorithm and Explanation of the technique used

1. **MergeSort :**

PseudoCode :

```
function mergeSort(array)
  If length of array <= 1
    return array
  middle = length of array / 2
  leftArray = mergeSort(first half of array)
  rightArray = mergeSort(second half of array)
  return merge(leftArray, rightArray)
```

2. **QuickSort:**

PseudoCode:

```
function quickSort(arr, l, r)
  if l < r
    pivotIndex = partition(arr, l, r)
    quickSort(arr, l, pivotIndex - 1)
    quickSort(arr, pivotIndex + 1, r)
function partition(arr, l, r)
    pivot = arr[r]
    i = l - 1
    for j = l to r - 1
        if arr[j] < pivot
            i = i + 1
            swap arr[i] and arr[j]
    swap arr[i + 1] and arr[r]
    return i + 1
```

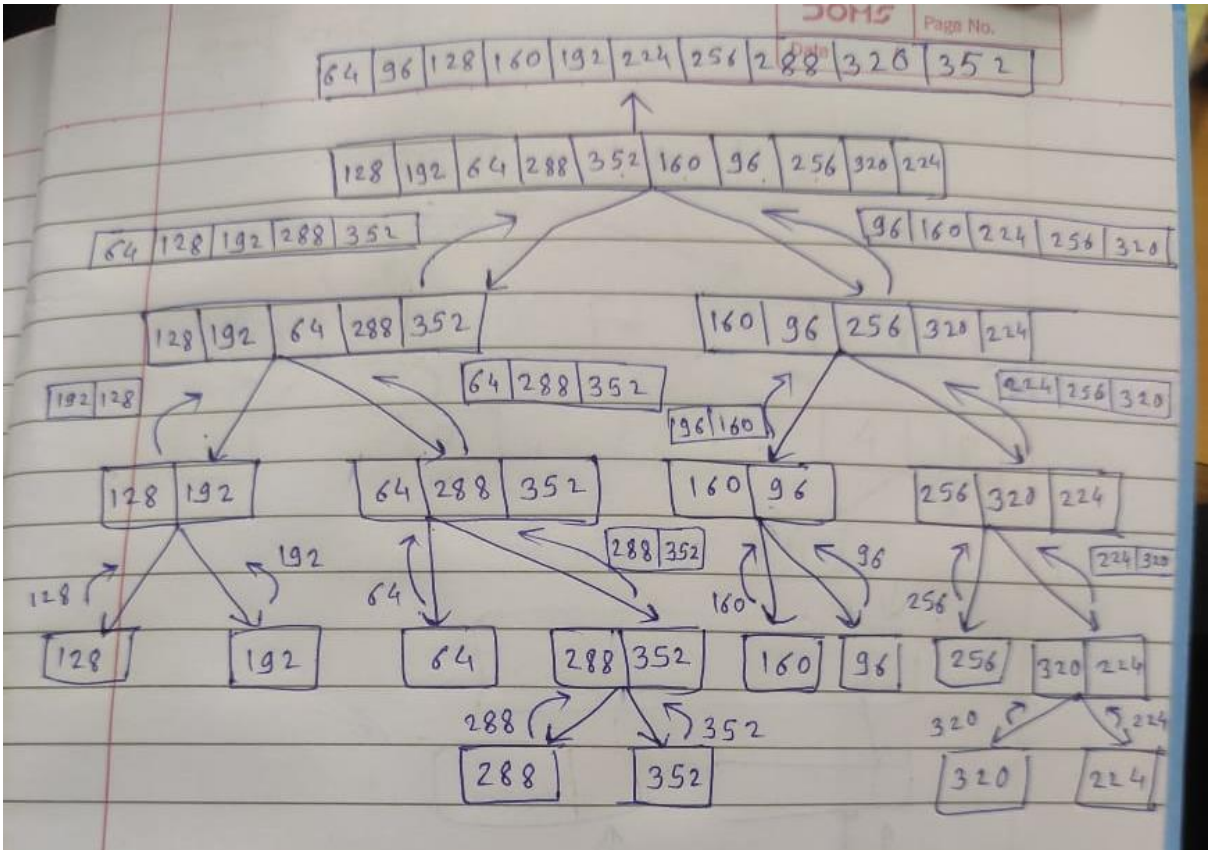
Program(Code)

1.Merge Sort

```java
package Lab1;

import java.util.Arrays;

public class MergeSort {

    // r + (r+1)*i
    // 32 + 33*i
    // = [ 64 96 128 160 192 224 256 288 320 352 ]
    public static void main(String[] args) {
        int[] arr = { 128, 192, 64, 288, 352, 160, 96, 256, 320, 224};
        int[] ans = mergeSort(arr);
        System.out.println(Arrays.toString(ans));
    }

    private static int[] mergeSort(int[] arr) {
        if(arr.length<=1){
            return arr;
        }
        int s = 0, e = arr.length;
        int m = (e+s)/2;
        int[] left = mergeSort(Arrays.copyOfRange(arr, 0, m));
        int[] right = mergeSort(Arrays.copyOfRange(arr, m, e));
        return merge(left,right);
    }

    private static int[] merge(int[] left, int[] right) {
        int[] ans = new int[left.length+right.length];
        int i=0, j=0, k=0;
        while(i < left.length && j < right.length){
            if(left[i] < right[j]){
                ans[k]=left[i]; i++; k++;
            }else{
                ans[k]=right[j] ; j++; k++;
            }
        }
        while(i < left.length){
            ans[k] = left[i]; i++; k++;
        }
        while (j < right.length) {
            ans[k] = right[j]; j++; k++;
        }
        return ans;
    }
}
```

2.QuickSort

```java
package Lab1;

import java.util.Arrays;

public class QuickSort {

    public static void main(String[] args){
        int[] arr = { 10, 7, 8, 9, 1, 5 };
        int N = arr.length;

        quickSort(arr, 0, N - 1);
        System.out.println(Arrays.toString(arr));
    }

    static void swap(int[] arr, int i, int j){
        int temp = arr[i];
        arr[i] = arr[j];
        arr[j] = temp;
    }

    static int partition(int[] arr, int low, int high){
        int pivot = arr[high];
        int i = (low - 1);
        for (int j = low; j <= high - 1; j++) {
            if (arr[j] < pivot) {
                i++;
                swap(arr, i, j);
            }
        }
        swap(arr, i + 1, high);
        return (i + 1);
    }

    static void quickSort(int[] arr, int low, int high){
        if (low < high) {
            int pi = partition(arr, low, high);
            quickSort(arr, low, pi - 1);
            quickSort(arr, pi + 1, high);
        }
    }

}
```

Output	**1.mergeSort(128, 192, 64, 288, 352, 160, 96, 256, 320, 224);** PROBLEMS 2 OUTPUT DEBUG CONSOLE TERMINAL PORTS GITLENS Install the latest PowerShell for new features and improvements! https://aka.ms/PSWindows PS C:\Users\smart\Documents\SPIT-lab\Sem 2\DAA\Lab1> & 'C:\Program Files\Java\jdk-21\bin\j ilsInExceptionMessages' '-cp' 'C:\Users\smart\AppData\Roaming\Code\User\workspaceStorage\86 _ws\jdt.ls-java-project\bin' 'Lab1.MergeSort' [64, 96, 128, 160, 192, 224, 256, 288, 320, 352] PS C:\Users\smart\Documents\SPIT-lab\Sem 2\DAA\Lab1> **2.quickSort(128, 192, 64, 288, 352, 160, 96, 256, 320, 224)** PROBLEMS 2 OUTPUT DEBUG CONSOLE TERMINAL PORTS GITLENS PS C:\Users\smart\Documents\SPIT-lab\Sem 2\DAA\Lab1> c:; cd 'c:\Users\smart\Documents\S \jdk-21\bin\java.exe' '--enable-preview' '-XX:+ShowCodeDetailsInExceptionMessages' '-cp' aceStorage\86a17b1b4c0252b9bf3938210292e98a\redhat.java\jdt_ws\jdt.ls-java-project\bin' [64, 96, 128, 160, 192, 224, 256, 288, 320, 352] PS C:\Users\smart\Documents\SPIT-lab\Sem 2\DAA\Lab1>
Justification of the complexity calculated	**Merge Sort (128, 192, 64, 288, 352, 160, 96, 256, 320, 224)** 

① Merge Sort

- Best Case: Sorted Array
  It will still divides array into halves and merges them back.
  ∴ Complexity: O(nlogn)

- Average Case: Randomly shuffled Array
  Average case scenario will be randomly shuffled array
  ∴ Complexity: O(nlogn)

- Worst Case: When Reverse Sorted
  Each element is to compared to be moved to the end
  ∴ Complexity: O(nlogn)

Merge Sort

$T(n) = 2T(n/2) + n$

Comparing above equation with $[T(n) = aT(n/b) + f(n)]$

$a = 2, b = 2, f(n) = n$

$n^{\log_b^a} = n^{\log_2^2} = n = f(n)$

$\therefore n^{\log_b^a} = f(n)$

$\therefore T(n) = \Theta(n \log_b^a \log n)$

$= \Theta(n \log n)$

QuickSort (128, 192, 64, 288, 352, 160, 96, 256, 320, 224)

Quick Sort

Pivot

[128, 192, 64, 288, 352, 160, 96, 256, 320, (224)]

↓

[128, 192, 64, 160, 96, 224, 288, 352, 256, 320]

[128, 192, 64, 160, (96)] [288, 352, 256, (320)]

[64, 96, 128, 192, 160] [288, 256, 320, 352]

[64] [128, 192, (160)] [288, (256)] [352]

[128, 160, 192] [288]

[128] [192]

↓ : Partition
↙↘ : Recursion

After swapping :

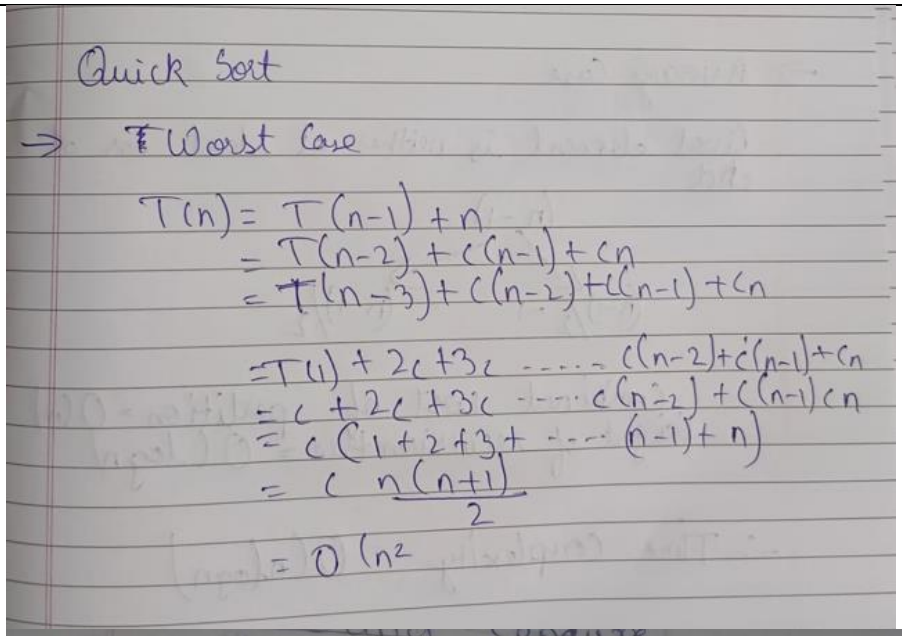
[64, 96, 128, 160, 192, 224, 256, 288, 320, 352]

Quick Sort

→ Worst Case

$$T(n) = T(n-1) + n$$
$$= T(n-2) + c(n-1) + cn$$
$$= T(n-3) + c(n-2) + c(n-1) + cn$$

$$= T(1) + 2c + 3c \cdots c(n-2) + c(n-1) + cn$$
$$= c + 2c + 3c \cdots c(n-2) + c(n-1)cn$$
$$= c(1 + 2 + 3 + \cdots (n-1) + n)$$
$$= c\,\frac{n(n+1)}{2}$$
$$= O(n^2$$



Quick Sort

→ Worst Case

$T(n) = T(n-1) + n$

$= T(n-2) + c(n-1) + cn$

$= T(n-3) + c(n-2) + c(n-1) + cn$

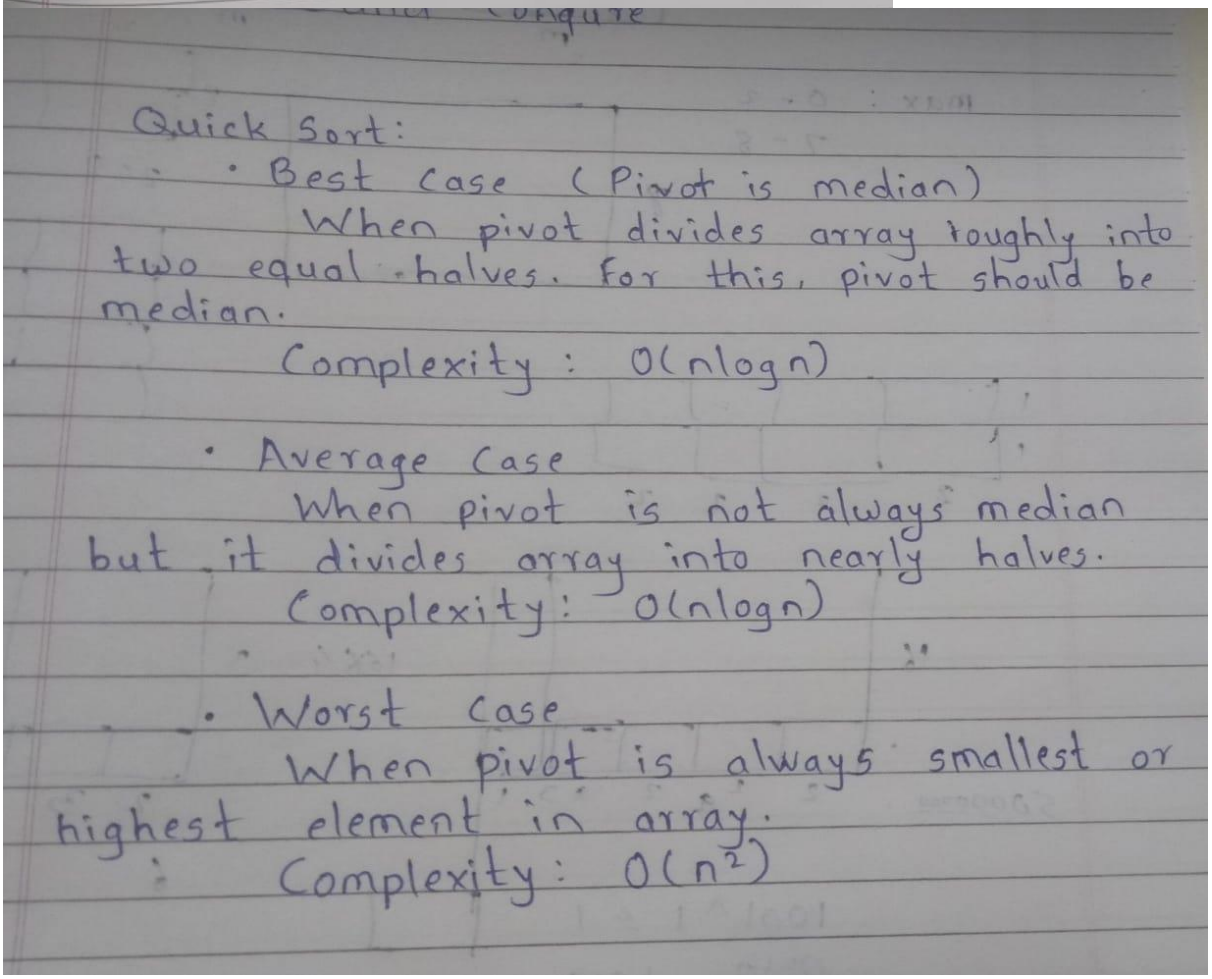
$= T(1) + 2c + 3c \cdots c(n-2) + c(n-1) + cn$

$= c + 2c + 3c \cdots c(n-2) + c(n-1) cn$

$= c(1 + 2 + 3 + \cdots (n-1) + n)$

$= c \frac{n(n+1)}{2}$

$= O(n^2$



Quick Sort:

- Best case (Pivot is median)

When pivot divides array roughly into two equal halves. For this, pivot should be median.

Complexity: O(nlogn)

- Average case

When pivot is not always median but it divides array into nearly halves.

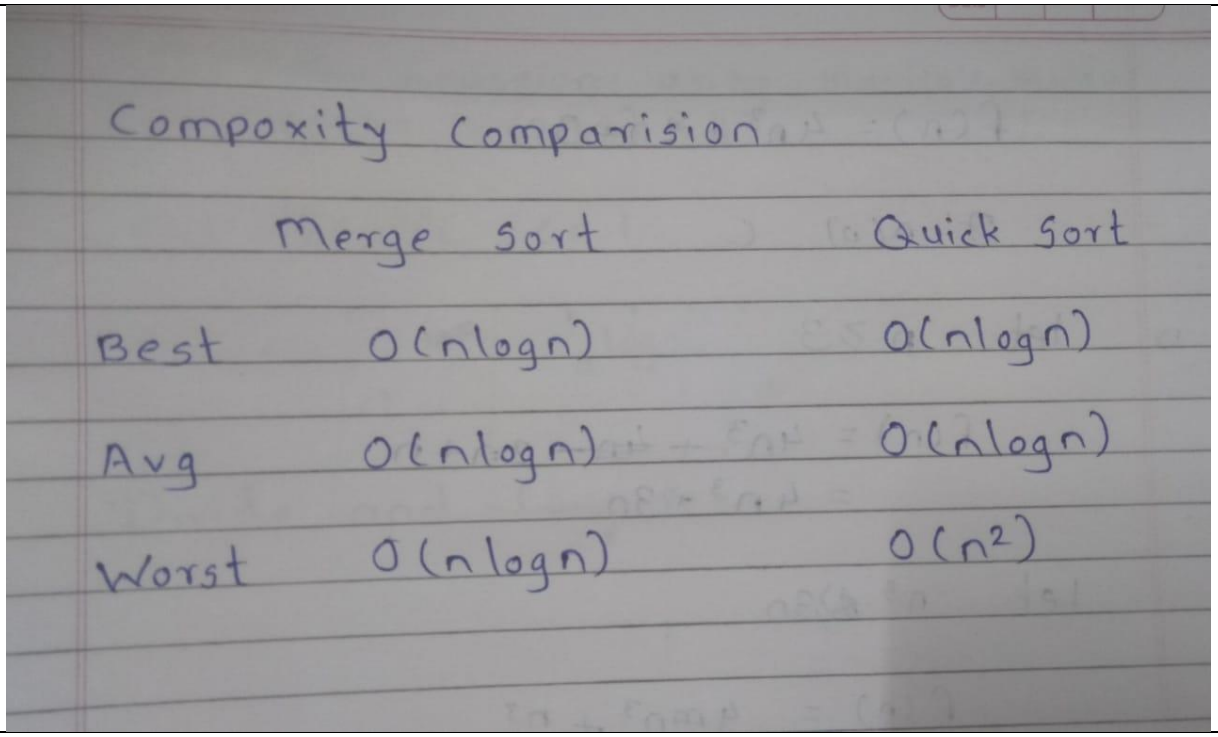
Complexity: O(nlogn)

- Worst case

When pivot is always smallest or highest element in array.

Complexity: $O(n^2)$

Complexity Comparision

	
Conclusion	Worst case complexity of MergeSort (Array is reverse sorted) is less than the Worst case complexity of QuickSort (Choosed Pivot is either highest or smallest element). For sorted Array given Merge Sort follows all steps alike unsorted array, but QuickSort do not follow all computations if the array is already sorted. For practically use Quick Sort will more effective than the merge sort as its worst case complexity do not depend on the input it depends on selection of pivot.