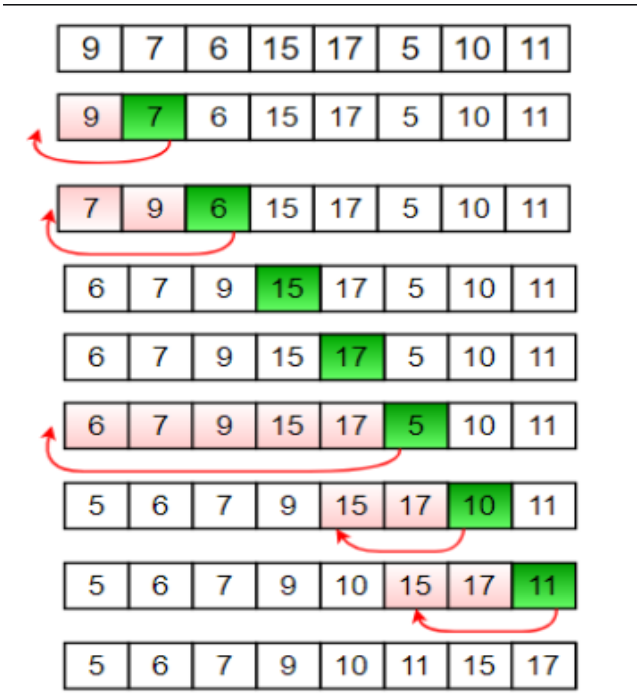
Experiment No: 1

Aim

Write a Program to demonstrate Insertion Sort and analyse the Time Complexity with different range of inputs

Introduction

Insertion Sort is one of the simplest Sorting Technique. The array is virtually split into a sorted and an unsorted part. Values from the unsorted part are picked and placed at the correct position in the sorted part.



Algorithm

It is a **STABLE** (i.e , it maintains the relative order of the items with equal sort keys) and **IN-PLACE ALGORITHM** (does not need an extra space and produces an output in the same memory that contains the data) .

Steps to sort the array of size N in Asceding Order :

- Iterate from **arr[1] to arr[N-1]** over the array.
- Compare the current element (key) to its predecessor.
- If the key element is smaller than its predecessor, compare it to the elements before. Move the greater elements one position up to make space for the swapped element.

Program

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <stdbool.h>


#define N 10000
int i, j, key;

bool isSorted ( int *arr )
{
    for (i = 0; i < N - 1; i++)
    {
        if ( arr[i + 1] < arr[i] )
        {
            return false;
        }
        return true;
    }
}

void insertion_sort ( int *arr )
{
    long long int Comparisons = 0;
    for (i = 1; i < N; i++)
    {
        key = arr[i];
        for (j = i - 1; j >= 0; j--)
        {
            Comparisons++;
            if (key < arr[j])
            {
                arr[j + 1] = arr[j];
            }
```

```
            else
            {
                break;
            }
        }
        arr[j + 1] = key;
    }
    printf("\nNo of Comparisons is %llu\n", Comparisons);
}

void calculateTime (  int *arr  )
{
    clock_t time;
    time = clock();

    insertion_sort(arr);

    time = clock() - time;
    double time_taken = ((double)time) / CLOCKS_PER_SEC;

    printf("The Time taken is equal to %.12lf seconds\n", time_taken);
}

int  main ( )
{

    int arr[N];

// using random() function to assign random values to the array elements

    for (i = 0; i < N; i++)
    {
        arr[i] = rand();
    }


// ****************************   A V E R A G E   C A S E   **********************

calculateTime(arr);

isSorted(arr) ? printf("\nThe Array is Sorted , All is Well\n ") : printf("The Array is not Sorted :( ");


 // *************************   B E S T   C A S E   ***************************


    calculateTime(arr);

// ****************************   W O R S T   C A S E   ***************************
```

```
// reversing the array  ( Worst Case ) ( By Swapping )
for (i = 0; i < N / 2; i++)
   {
      arr[i] = arr[i] + arr[N - i - 1];
      arr[N - i - 1] = arr[i] - arr[N - i - 1];
      arr[i] = arr[i] - arr[N - i - 1];
   }
   reverse(arr);
   calculateTime(arr);
}
```

Output

Comparisons" refers the total number of checks of a[i-1] > a[i] for all i >= 1 to i < n .

INPUT SIZE (N)	AVERAGE CASE TIME COMPLEXITY (in ms)	BEST CASE TIME COMPLEXITY (in ms)	WORST CASE TIME COMPLEXITY (in ms)
	RunTime , Comparisons	RunTime , Comparisons	RunTime , Comparisons
10	0 ms 22	0 ms 9	0 ms 45
100	0 ms 2459	0 ms 99	0 ms 4950
1000	2 ms 249143	0 ms 999	10 ms 499500
10000	80ms 24962883	0 ms 9999	156 ms 49994850
100000	7530 ms , 2506144504	6 ms 99999	15318 ms 4999866158

Analysis

Best Case (Sorted Array) takes the least time since it undergoes only (N-1) Comparisons. (Time Complexity ≈ O(N))

Average Case (Random Input Array) takes on an average of the time of Best and Worst Cases. (Time Complexity ≈ O(N^2 / 4) ≈ O(N^2))

Worst Case (Reversed Array) undergoes the most number of Comparsions and hence it takes the most time of all of cases.

No.of Comparisons = (n-1) + (n-2) + (n-3) + …. 3 + 2 + 1

= **(n^2 – n) / 2 ;**

∴ Time Complexity ≈ O(N^2 / 2) ≈ O(N^2)

CASES	**AVERAGE**	**BEST**	**WORST**
TIME COMPLEXITY	O(N^2)	O(N)	O(N^2)

Applications

1) Sorting a small list of numbers:

If you have a small list of numbers that needs to be sorted, insertion sort can be an efficient option. It's simple to implement and its time complexity is O(n^2) which make it good for small lists.

2) Sorting Linked List :

Insertion sort is also good for sorting linked list, when compared to other sorting algorithms like merge sort which needs extra space for merge operations

References

1) https://www.geeksforgeeks.org/insertion-sort/
(Press Ctrl + Click to open)

2) Image
https://www.geeksforgeeks.org/recursive-insertion-sort/