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Subject: - Complexity Theory & Algorithms

Practical-1

Aim: Perform Selection Sort, Quick Sort, Bubble Sort and Insertion Sort for the input size 10000, 50000 and 100000 for Ascending, Descending & Random order array. Plot the chart of the output data and do the analysis which algorithm is best and justify your reason.

Code-

```
#include <bits/stdc++.h>
using namespace std;
using namespace std::chrono;

void random_array(int *arr, int n)
{
    for (int i = 0; i < n; i++)
    {
        arr[i] = rand() % n;
    }
}
// For Quick Sort
void random(vector<int> &array, int n)
{
    for (int i = 0; i < n; i++)
    {
        array[i] = rand() % n;
    }
}
void acending_array(int *arr, int n)
{
    for (int i = 0; i < n; i++)
    {
        arr[i] = i;
    }
}
// For Quick Sort
void acending(vector<int> &array, int n)
{
    for (int i = 0; i < n; i++)
    {
        array[i] = i;
    }
}
void decending_array(int *arr, int n)
{
    for (int i = 0; i < n; i++)
    {
        arr[i] = n - i - 1;
    }
}
// For Quick Sort
void decending(vector<int> &array, int n)
{
    for (int i = 0; i < n; i++)
    {
        array[i] = n - i - 1;
    }
}
// BubbleSort Algorithm
void bubblesort(int *arr, int n)
{
    for (int i = n - 1; i >= 0; i--)
    {
        for (int j = 0; j <= i - 1; j++)
        {
            if (arr[j] > arr[j + 1])
            {
                int temp = arr[j + 1];
                arr[j + 1] = arr[j];
                arr[j] = temp;
            }
        }
    }
}
void bubblesortcode_a(int *arr, int n)
{
    acending_array(arr, n);
    auto start = high_resolution_clock::now();
    bubblesort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Bubble sort for " << n << " elements in "
        << "Acending Order is: " << total_time.count() << endl;
}
void bubblesortcode_d(int *arr, int n)
{
    decending_array(arr, n);
    auto start = high_resolution_clock::now();
    bubblesort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Bubble sort for " << n << " elements in "
        << "Decending Order is: " << total_time.count() << endl;
}
void bubblesortcode_r(int *arr, int n)
{
    random_array(arr, n);
    auto start = high_resolution_clock::now();
    bubblesort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Bubble sort for " << n << " elements in "
        << "Random Order is: " << total_time.count() << endl;
}

// InsertionSort Algorithm
void insertionsort(int *arr, int n)
{
    for (int i = 0; i < n - 1; i++)
    {
        int j = i;
        while (j > 0 && arr[j - 1] > arr[j])
        {
            int temp = arr[j - 1];
            arr[j - 1] = arr[j];
            arr[j] = temp;
            j--;
        }
    }
}
void insertionsort_a(int *arr, int n)
{
    acending_array(arr, n);
    auto start = high_resolution_clock::now();
    insertionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
```

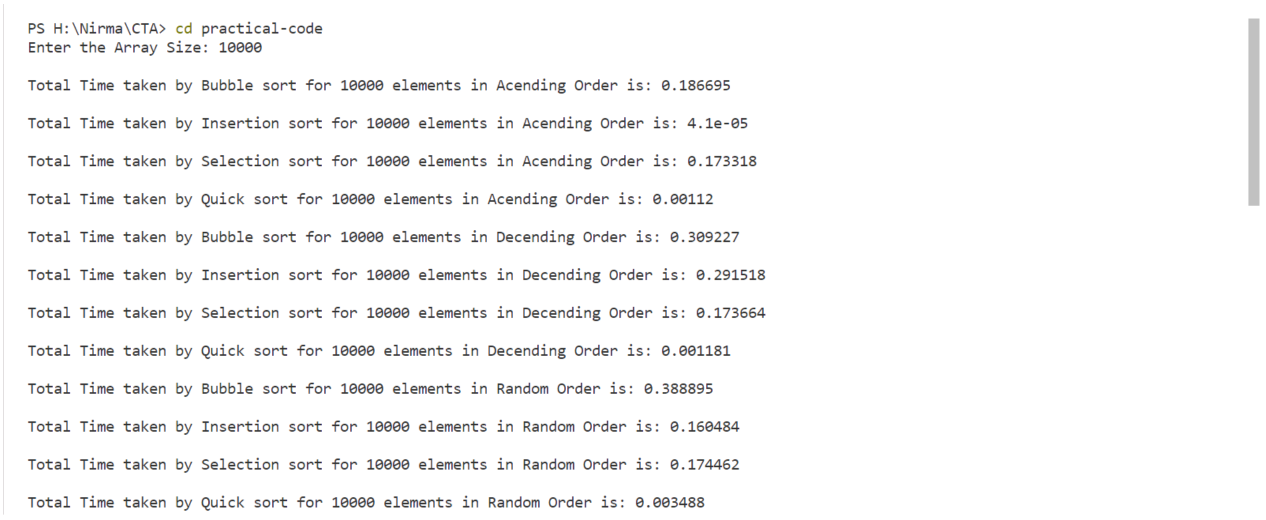
```
            << "Total Time taken by Insertion sort for " << n << " elements in "
            << "Acending Order is: " << total_time.count() << endl;
}
void insertionsort_d(int *arr, int n)
{
    decending_array(arr, n);
    auto start = high_resolution_clock::now();
    insertionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Insertion sort for " << n << " elements in "
        << "Decending Order is: " << total_time.count() << endl;
}
void insertionsort_r(int *arr, int n)
{
    random_array(arr, n);
    auto start = high_resolution_clock::now();
    insertionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Insertion sort for " << n << " elements in "
        << "Random Order is: " << total_time.count() << endl;
}

// Selection Sort Algorithm
void selectionsort(int *arr, int n)
{
    for (int i = 0; i <= n - 2; i++)
    {
        int min = i;
        for (int j = i; j <= n - 1; j++)
        {
            if (arr[j] < arr[min])
            {
                min = j;
            }
        }
        int temp = arr[min];
        arr[min] = arr[i];
        arr[i] = temp;
    }
```

```
}
void selectionsort_a(int *arr, int n)
{
    acending_array(arr, n);
    auto start = high_resolution_clock::now();
    selectionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Selection sort for " << n << " elements in "
        << "Acending Order is: " << total_time.count() << endl;
}
void selectionsort_d(int *arr, int n)
{
    decending_array(arr, n);
    auto start = high_resolution_clock::now();
    selectionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Selection sort for " << n << " elements in "
        << "Decending Order is: " << total_time.count() << endl;
}
void selectionsort_r(int *arr, int n)
{
    random_array(arr, n);
    auto start = high_resolution_clock::now();
    selectionsort(arr, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Selection sort for " << n << " elements in "
        << "Random Order is: " << total_time.count() << endl;
}

// Quicksort Algorithm
int part(vector<int> &arr, int low, int high)
{
    int midIndex = low + (high - low) / 2;
    int pivot = arr[midIndex];
    int i = low;
    int j = high;
    while (i < j)
    {
        while (arr[i] <= pivot && i <= high - 1)
        {
            i++;
        }
        while (arr[j] > pivot && j >= low + 1)
        {
            j--;
        }
        if (i < j)
        {
            swap(arr[i], arr[j]);
        }
    }
    swap(arr[midIndex], arr[j]);
    return j;
}

void qs(vector<int> &array, int low, int high)
{
    if (low < high)
    {
        int pIndex = part(array, low, high);
        qs(array, low, pIndex - 1);
        qs(array, pIndex + 1, high);
    }
}
vector<int> quicksort(vector<int> array, int n)
{
    qs(array, 0, array.size() - 1);
    return array;
}
void quicksort_a(vector<int> &array, int n)
{
    acending(array, n);
    auto start = high_resolution_clock::now();
    quicksort(array, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Quick sort for " << n << " elements in "
        << "Acending Order is: " << total_time.count() << endl;
}
```

```
void quicksort_d(vector<int> &array, int n)
{
    decending(array, n);
    auto start = high_resolution_clock::now();
    quicksort(array, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Quick sort for " << n << " elements in "
        << "Decending Order is: " << total_time.count() << endl;
}
void quicksort_r(vector<int> &array, int n)
{
    random(array, n);
    auto start = high_resolution_clock::now();
    quicksort(array, n);
    auto end = high_resolution_clock::now();

    duration<double> total_time = end - start;
    cout << endl
        << "Total Time taken by Quick sort for " << n << " elements in "
        << "Random Order is: " << total_time.count() << endl;
}

// Main Function
int main()
{
    int n;
    cout << "Enter the Array Size: ";
    cin >> n;
    int *arr = new int[n];
    //For QUickSort
    vector<int> array(n);
    for (int i = 1; i <= 3; i++)
    {
        if (i == 1)
        {
            bubblesortcode_a(arr, n);
            insertionsort_a(arr, n);
            selectionsort_a(arr, n);
            quicksort_a(array, n);
        }
        else if (i == 2)
        {
            bubblesortcode_d(arr, n);
            insertionsort_d(arr, n);
            selectionsort_d(arr, n);
            quicksort_d(array, n);
        }
        else if (i == 3)
        {
            bubblesortcode_r(arr, n);
            insertionsort_r(arr, n);
            selectionsort_r(arr, n);
            quicksort_r(array, n);
        }
    }
    return 0;
}
```

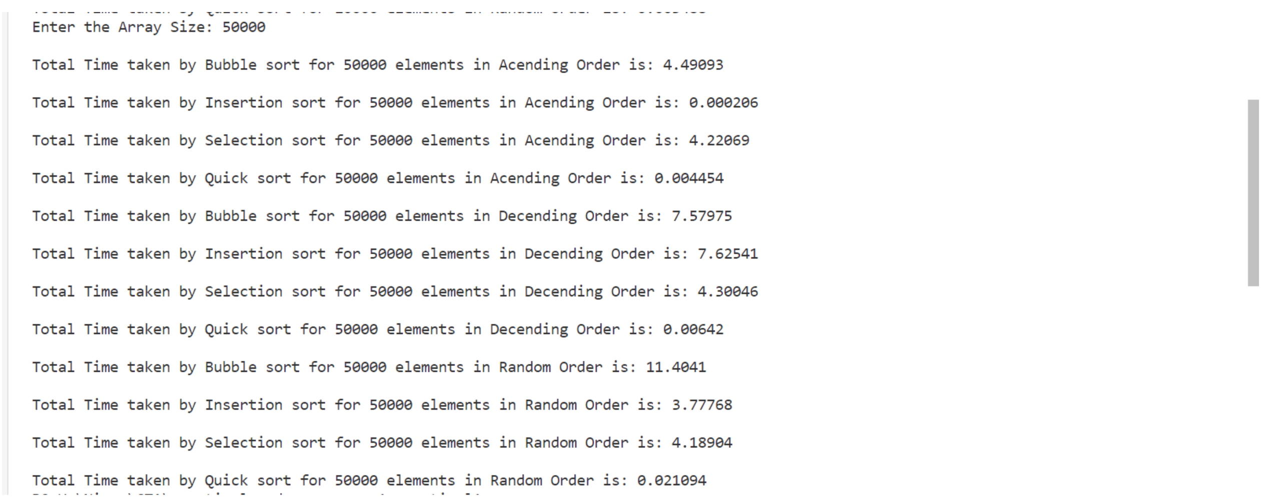
- **Output**

For array size = 10000



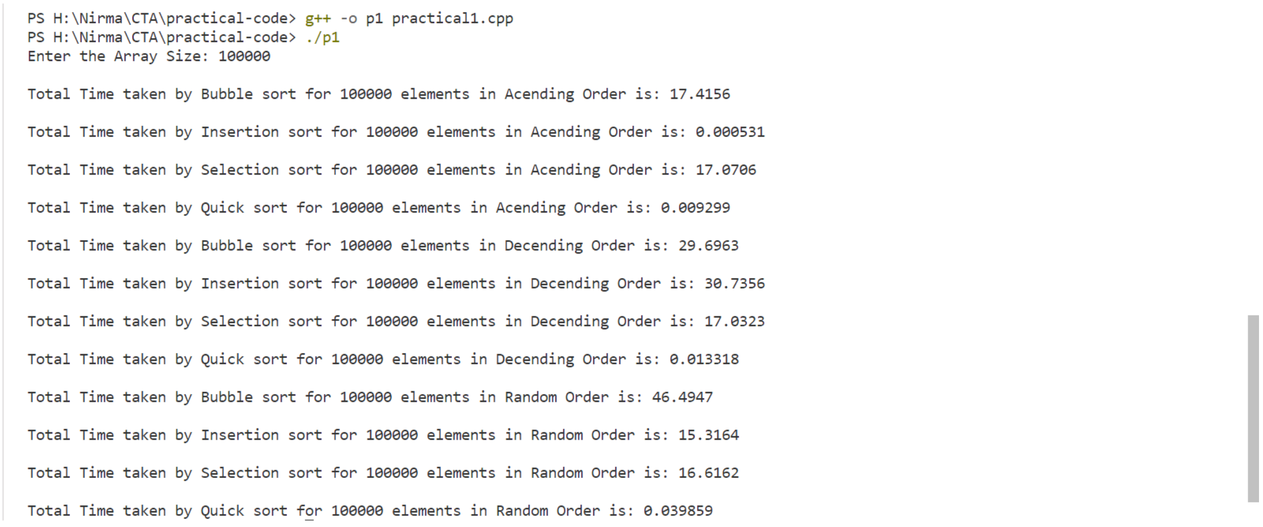
```
PS H:\Nirma\CTA> cd practical-code
Enter the Array Size: 10000

Total Time taken by Bubble sort for 10000 elements in Acending Order is: 0.186695

Total Time taken by Insertion sort for 10000 elements in Acending Order is: 4.1e-05

Total Time taken by Selection sort for 10000 elements in Acending Order is: 0.173318

Total Time taken by Quick sort for 10000 elements in Acending Order is: 0.00112

Total Time taken by Bubble sort for 10000 elements in Decending Order is: 0.309227

Total Time taken by Insertion sort for 10000 elements in Decending Order is: 0.291518

Total Time taken by Selection sort for 10000 elements in Decending Order is: 0.173664

Total Time taken by Quick sort for 10000 elements in Decending Order is: 0.001181

Total Time taken by Bubble sort for 10000 elements in Random Order is: 0.388895

Total Time taken by Insertion sort for 10000 elements in Random Order is: 0.160484

Total Time taken by Selection sort for 10000 elements in Random Order is: 0.174462

Total Time taken by Quick sort for 10000 elements in Random Order is: 0.003488
```

For array size = 50000



```
Enter the Array Size: 50000

Total Time taken by Bubble sort for 50000 elements in Acending Order is: 4.49093

Total Time taken by Insertion sort for 50000 elements in Acending Order is: 0.000206

Total Time taken by Selection sort for 50000 elements in Acending Order is: 4.22069

Total Time taken by Quick sort for 50000 elements in Acending Order is: 0.004454

Total Time taken by Bubble sort for 50000 elements in Decending Order is: 7.57975

Total Time taken by Insertion sort for 50000 elements in Decending Order is: 7.62541

Total Time taken by Selection sort for 50000 elements in Decending Order is: 4.30046

Total Time taken by Quick sort for 50000 elements in Decending Order is: 0.00642

Total Time taken by Bubble sort for 50000 elements in Random Order is: 11.4041

Total Time taken by Insertion sort for 50000 elements in Random Order is: 3.77768

Total Time taken by Selection sort for 50000 elements in Random Order is: 4.18904

Total Time taken by Quick sort for 50000 elements in Random Order is: 0.021094
```

For array size = 100000



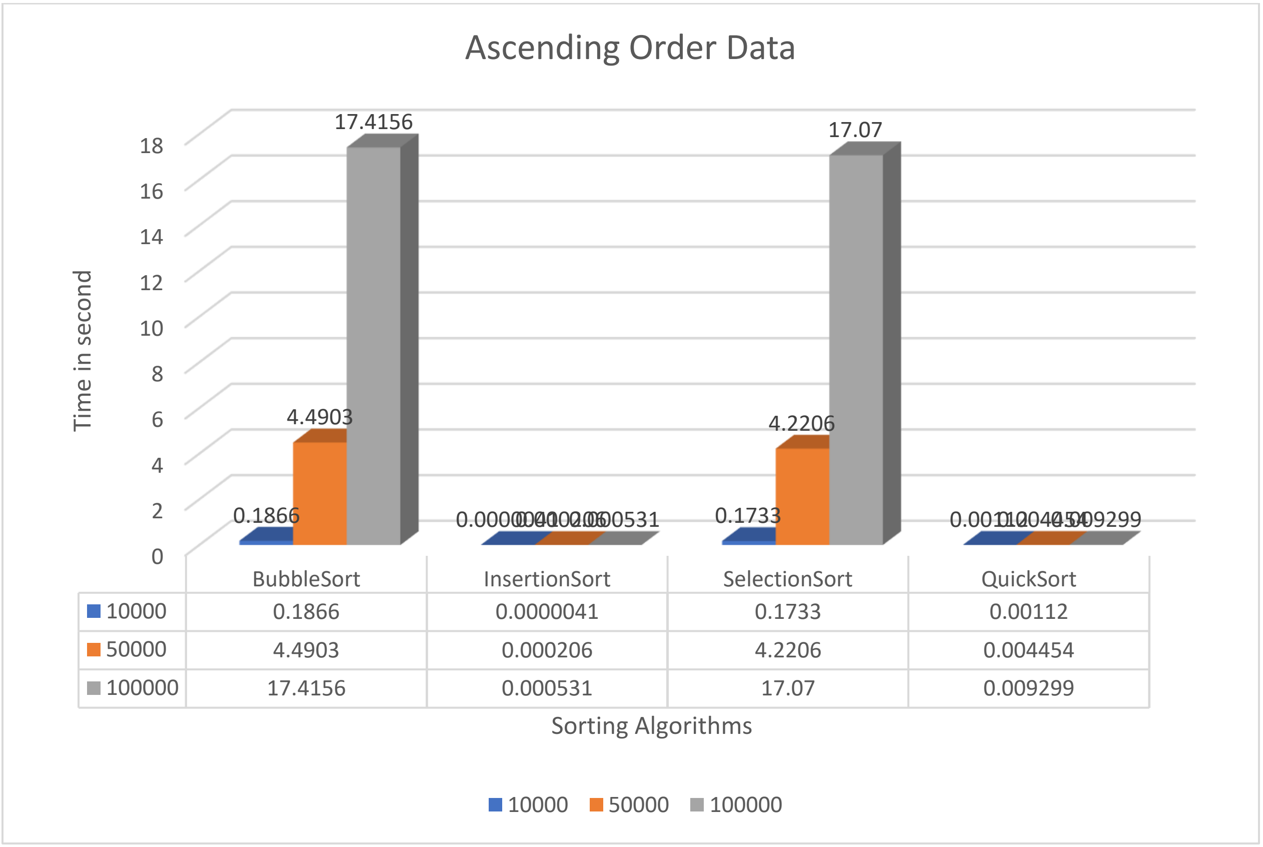
```
PS H:\Nirma\CTA\practical-code> g++ -o p1 practical1.cpp
PS H:\Nirma\CTA\practical-code> ./p1
Enter the Array Size: 100000

Total Time taken by Bubble sort for 100000 elements in Acending Order is: 17.4156

Total Time taken by Insertion sort for 100000 elements in Acending Order is: 0.000531

Total Time taken by Selection sort for 100000 elements in Acending Order is: 17.0706

Total Time taken by Quick sort for 100000 elements in Acending Order is: 0.009299

Total Time taken by Bubble sort for 100000 elements in Decending Order is: 29.6963

Total Time taken by Insertion sort for 100000 elements in Decending Order is: 30.7356

Total Time taken by Selection sort for 100000 elements in Decending Order is: 17.0323

Total Time taken by Quick sort for 100000 elements in Decending Order is: 0.013318

Total Time taken by Bubble sort for 100000 elements in Random Order is: 46.4947

Total Time taken by Insertion sort for 100000 elements in Random Order is: 15.3164

Total Time taken by Selection sort for 100000 elements in Random Order is: 16.6162

Total Time taken by Quick sort for 100000 elements in Random Order is: 0.039859
```

- **Graphs & Output Data**

Here are the three tables that describes the output generated by the above code for ascending, descending and random array for size 10000, 50000 & 100000.

ASCENDING ORDER:

	BubbleSort	InsertionSort	SelectionSort	QuickSort
10000	0.1866	0.0000041	0.1733	0.00112
50000	4.4903	0.000206	4.2206	0.004454
100000	17.4156	0.000531	17.07	0.009299

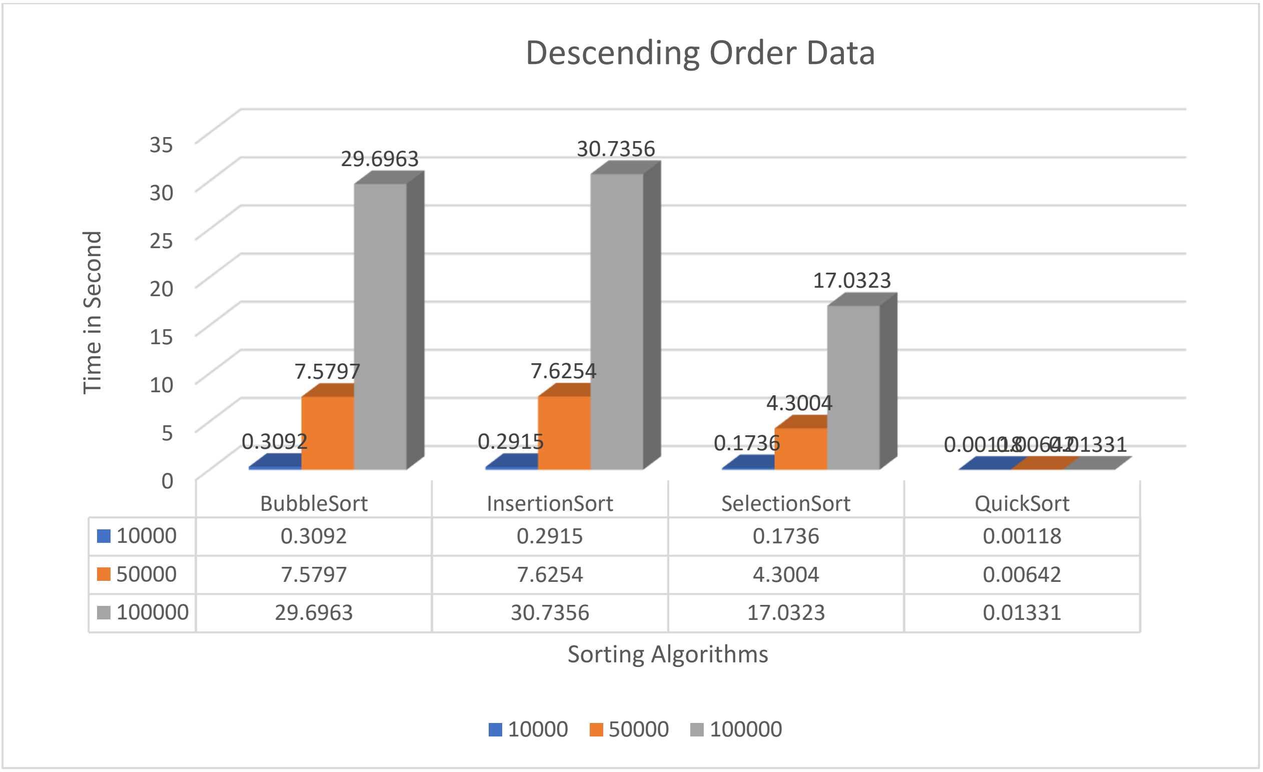


	BubbleSort	InsertionSort	SelectionSort	QuickSort
10000	0.1866	0.0000041	0.1733	0.00112
50000	4.4903	0.000206	4.2206	0.004454
100000	17.4156	0.000531	17.07	0.009299

- In above graph x-axis contains the time in second, y-axis contains the sorting algorithms and the graph compares the time taken by sorting algorithms for 10000, 50000 & 100000 array size in **ascending order** only.

DESCENDING ORDER:

	BubbleSort	InsertionSort	SelectionSort	QuickSort
10000	0.3092	0.2915	0.1736	0.00118
50000	7.5797	7.6254	4.3004	0.00642
100000	29.6963	30.7356	17.0323	0.01331

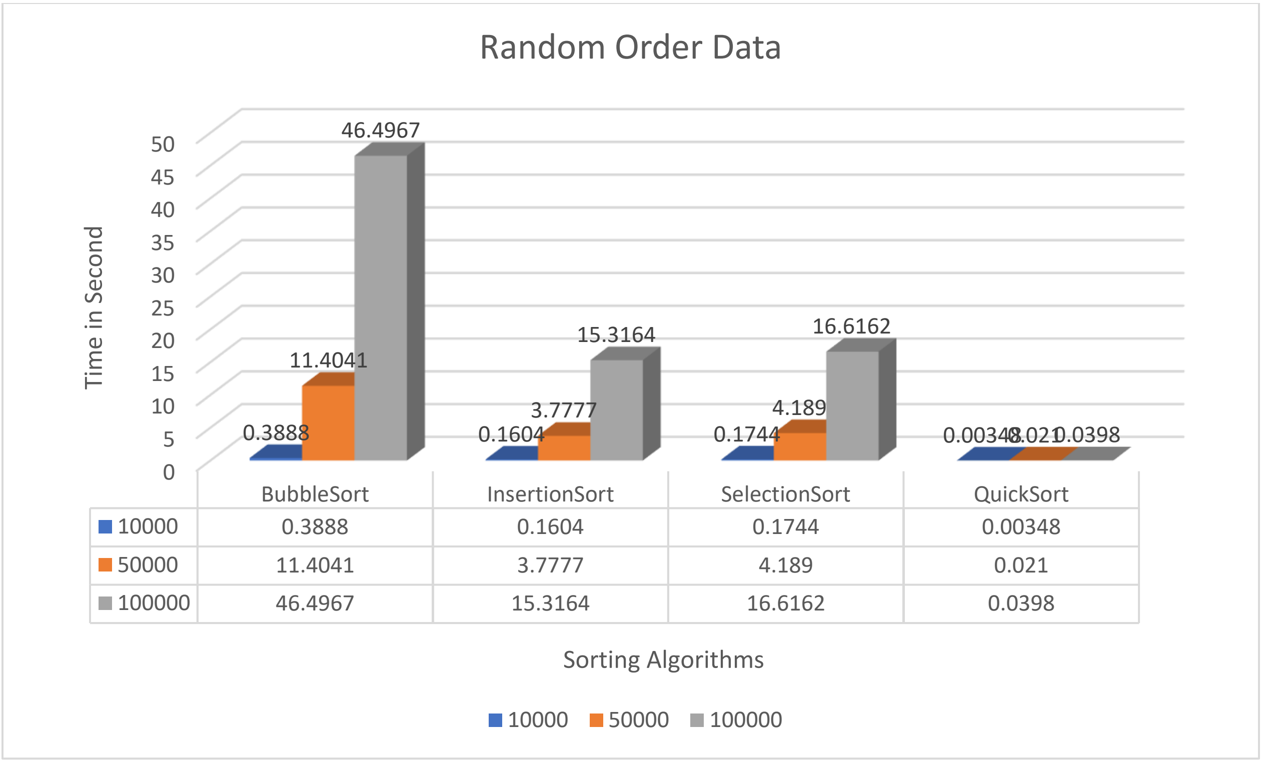


	BubbleSort	InsertionSort	SelectionSort	QuickSort
■ 10000	0.3092	0.2915	0.1736	0.00118
■ 50000	7.5797	7.6254	4.3004	0.00642
■ 100000	29.6963	30.7356	17.0323	0.01331

- In above graph x-axis contains the time in second, y-axis contains the sorting algorithms and the graph compares the time taken by sorting algorithms for 10000, 50000 & 100000 array size in **descending order** only.

RANDOM ORDER:

	BubbleSort	InsertionSort	SelectionSort	QuickSort
10000	0.3888	0.1604	0.1744	0.00348
50000	11.4041	3.7777	4.189	0.021
100000	46.4967	15.3164	16.6162	0.0398



	BubbleSort	InsertionSort	SelectionSort	QuickSort
🟦 10000	0.3888	0.1604	0.1744	0.00348
🟧 50000	11.4041	3.7777	4.189	0.021
⬜ 100000	46.4967	15.3164	16.6162	0.0398

- In above graph x-axis contains the time in second, y-axis contains the sorting algorithms and the graph compares the time taken by sorting algorithms for 10000, 50000 & 100000 array size in **random order** only.

- **Analysis**

The first thing I notice that the running time of all four algorithm increases as the input size increases. The reason behind this is as the array size is bigger the number of elements in the array are more so the number of comparisons and swaps that the algorithm need to sort an array is increases with the size of input.

BUBBLE SORT

The bubble sort algorithm works by repeatedly comparing the neighboring elements in the array and swap the largest element at the end of an array. In our case the worst-case time complexity is O(n^2), the reason behind this is in the worst-case array is in the **descending order** so all the elements in the array are in reverse order, so the bubble sort algorithm will have to make n comparisons and n-1 swaps for each n elements in the array. So, the bubble sort takes more time to sort an array in descending order.

In **ascending order** bubble sort require only comparisons there is no swap required because in ascending order array the array elements are already in sorted manner so there is no need to swap the elements so it takes less time than the descending order array.

In **Random order,** the elements are not placed in any specific order, so generally bubble sort is worse for random order array, as it needs to perform continuous number of swaps and comparisons to rearrange the array elements and sometimes it compares the element twice due to random array, so it takes more time than the descending order array.

So, from our data also we can clarify that for the 10000 elements the bubble sort takes 0.1866s in ascending order, 0.3092s in descending order and 0.3888s in the random order.

INSERTION SORT

Insertion sort performs comparatively faster then the bubble sort in all cases because in insertion sort it compares only its adjacent elements it consider the first element as already sorted element and from index-1 it checks its previous elements and put the smaller element at the first position of an array, so in the ascending order array is already sorted so it takes less amount of time, in descending order it takes more amount of time because of the array is in reverse order so it needs more comparisons and in random order it is dependent on the randomness.

Insertion sort is more efficient when array is already sorted. Because insertion sort is stable algorithm.

SELECTION SORT

Selection sort behaves same as the bubble sort. Because it considers first element as a minimum and then check every element in the array and find the minimum which is less than the default minimum so the number of comparisons and swaps are similar to the bubble sort because it checks all the elements in the array and then swaps.

QUICK SORT

Quick sort is the fastest algorithm among the selection, bubble and insertion sort. In some **cases, insertion sort** is better than the **quick sort**, when the array is smaller and partially sorted in such cases insertion sort is better than the quick sort because the insertion sort is stable algorithm means it does not swap the equal elements so it takes less time than quick sort while quicksort recursively solves the problem so it takes slightly more time than the insertion sort for the smaller size array.

But in other cases, and the array size increases quick sort is best searching algorithm among all others. Because quick sort is a divide and conquer technique, it divides the larger array into smaller subarrays and recursively sort that array so that's the reason that quick sort is better algorithm then other for the larger arrays. And other algorithms not perform well because of the other algorithms like bubble, selection and insertion are sequential sorting algorithms means sequentially iterations performs while quick sort recursively sort the array.

Pivot element selection is also matters for sorting the array.