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SUBJECT	Design and Analysis of Algorithms
EXPERIMENT No.	1B
Date of Performance	30/01/2023
Date of Submission	06/01/2023

AIM:	**Experiment on finding the running time of an algorithm.**
Program 1	
PROBLEM STATEMENT :	For this experiment, you need to implement two sorting algorithms namely Insertion and Selection sort methods. Compare these algorithms based on time and space complexity. Time required to sorting algorithms can be performed using high_resolution_clock::now() under namespace std::chrono. You have togenerate1,00,000 integer numbers using C/C++ Rand function and save them in a text file. Both the sorting algorithms uses these 1,00,000 integer numbers as input as follows. Each sorting algorithm sorts a block of 100 integers numbers with array indexes numbers A[0..99], A[0..199], A[0..299],..., A[0..99999]. You need to use high_resolution_clock::now() function to find the time required for 100, 200, 300.... 100000 integer numbers. Finally, compare two algorithms namely Insertion and Selection by plotting the time required to sort 100000 integers using LibreOffice Calc/MS Excel. The x-axis of 2-D plot represents the block no. of 1000 blocks. The y-axis of 2-D plot representsthe tunning time to sort 1000 blocks of 100,200,300,...,100000 integer numbers. Note – You have to use C/C++ file processing functions for reading and writing randomly generated 100000 integer numbers.
ALGORITHM/ THEORY:	**Sorting Algorithms** Sorting Algorithms are a class of algorithms which are used to arrange the elements of a list or anarray in a particular order. There are a lot of sorting algorithms including bubble sort, selection sort, quick sort, insertion sort,heap sort, etc. This experiment focuses on insertion and selection sort. For

our examples, we will consider sorting in ascending order.

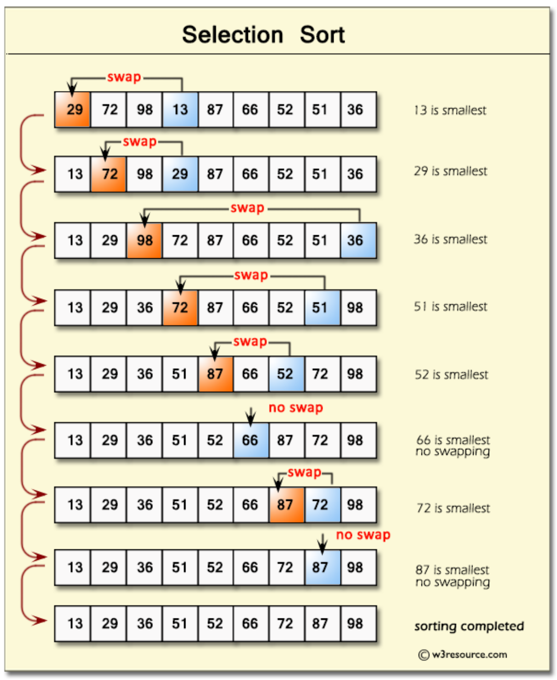
Selection Sort

The selection sort algorithm sorts an array by repeatedly finding the minimum element (consideringascending order) from unsorted part and putting it at the beginning. The algorithm maintains two subarrays in a given array.

1) The subarray which is already sorted.
2) Remaining subarray which is unsorted.

In every iteration of selection sort, the minimum element (considering ascending order) from theunsorted subarray is picked and moved to the sorted subarray.

Following example explains the above steps:



The time complexities for selection sort are given below:

Best	**Average**	**Worst**
$\Omega(n^2)$	$\theta(n^2)$	$O(n^2)$

Since it always has an n^2 time complexity, it is inefficient

for large lists.We will discuss its algorithm later.

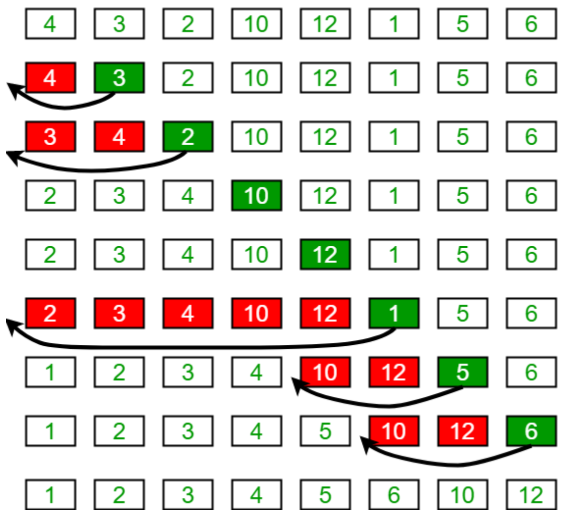
Insertion Sort

Insertion sort is a simple sorting algorithm that works similar to the way you sort playing cards in your hands. The array is virtually split into a sorted and an unsorted part. Values from the unsortedpart are picked and placed at the correct position in the sorted part.

To sort an array of size n in ascending order:

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

Insertion Sort Execution Example



The time complexities for insertion sort are given below:

Best	**Average**	**Worst**
$\Omega(n)$	$\theta(n^2)$	$O(n^2)$

Since it always has a best-case time complexity of n, it is more efficient compared to selection sort.

Algorithms:

Selection Sort:

1) START
2) For i = 0 to n-2:
   a. minIndex = i
   b. For j = i+1 to n-1
      i. If arr[minIndex] > arr[j]
         1. minIndex = j
   c. Swap elements of array at positions i and minIndex
3) END

	Insertion Sort: 1) START 2) For i = 1 to n-1 a. Key = arr[i] b. j = i – 1 c. While j >= 0 and arr[j] > Key: i. arr[j+1] = arr[j] ii. j = j – 1 d. arr[j+1] = Key 3) STOP
PROGRAM:	(code below)

```
#include <stdio.h>
#include <time.h>
#include <stdlib.h>
#include <iostream>
#include <random>
using namespace std;

//gcc test.cpp -lstdc++

double numberGenertor(int a[], int b[], int n)
{
    clock_t start, end;
    double cpu_time_used;
    start = clock();

    random_device rd; //random number function
    for (int i = 0; i < 100000; i++)  // generator random number between
1 to 100000 consisting of 1000 block each
    {
        uniform_int_distribution<int> dist(1,10000000000);
        a[i] = b[i] = dist(rd);
    }
    end = clock();
    cpu_time_used = ((double) (end - start)) / CLOCKS_PER_SEC;
    FILE *fp = fopen("./selection.txt", "w+");
    for(int i = 0; i < n; i++) {
        fprintf(fp, "%d\n", a[i]);
    }
    fclose(fp);
    fp = fopen("./insertion.txt", "w+");
    for(int i = 0; i < n; i++) {
```

```
        fprintf(fp, "%d\n", b[i]);
    }
    fclose(fp);
    return cpu_time_used;
}

double selectionSort(int a[], int n)
{
    FILE *fp = fopen("./selection.csv", "w+");
    double totalTime = 0;
    if(!fp) {
        printf("Error in opening file\n");
        return -1;
    }
    fprintf(fp, "n, time\n");
    for (int y = 100; y <= n; y+=100)
    {
        clock_t start, end;
        double iterationTime;
        start = clock();
        for (int i = 0; i < y-1; i++)
        {
            int k = i;
            for (int j = i+1; j < y; j++)
            {
                if (a[j]<a[k])
                {
                    k = j;
                }
            }
            int temp = a[k];
            a[k] = a[i];
            a[i] = temp;
        }
        end = clock();
        iterationTime = ((double) (end - start)) / CLOCKS_PER_SEC;
        totalTime += iterationTime;
        fprintf(fp, "%d, %f\n", y, iterationTime);

        printf("Array[0...%d99] sorted in %.4fs\n", (y/100),
iterationTime);
    }
    fclose(fp);
    return totalTime;
}
```

```c
double insertionSort(int a[], int n)
{
    FILE *fp = fopen("./insertion.csv", "w+");

    double totalTime = 0;
    if(!fp) {
        printf("Error in opening file\n");
        return -1;
    }
    fprintf(fp, "n, time\n");
    for (int y = 100; y <= n; y+=100)
    {
        clock_t start, end;
        double iterationTime;
        start = clock();
        int j, x;
        for (int i = 1; i < y; i++)
        {
            j = i-1;
            x = a[i];
            while (j>-1 && a[j]>x)
            {
                a[j+1] = a[j];
                j--;
            }
            a[j+1] = x;
        }
        end = clock();
        iterationTime = ((double) (end - start)) / CLOCKS_PER_SEC;
        totalTime += iterationTime;
        fprintf(fp, "%d, %f\n", y, iterationTime);

        printf("Array[0...%d99] sorted in %.4fs\n", (y/100),
iterationTime);

    }
    fclose(fp);
    return totalTime;
}

int main()
{
    int n = 100000;
    int a[n],b[n];
    printf("Clock per second of the computer : %d\n",CLOCKS_PER_SEC);
    double timeToFill = numberGenertor(a, b, n);
    printf("Time to generate random number : %f\n", timeToFill);
```

```
    printf("Insertion sort\n");
    //insertion sort from 0 to 100000
    double insertionTime = insertionSort(a, n);
    printf("Selection sort\n");
    //selection sort from 0 to 100000
    double selectionTime = selectionSort(b, n);
    printf("Time taken by insertion sort :  %.4f\n", insertionTime);
    printf("Time taken by selection sort :  %.4f\n", selectionTime);
    printf("Total time taken by program : %f\n", insertionTime +
selectionTime);

    return 0;
}
#include <stdio.h>
#include <time.h>
#include <stdlib.h>
#include <iostream>
#include <random>
using namespace std;

//gcc test.cpp -lstdc++

double numberGenertor(int a[], int b[], int n)
{
    clock_t start, end;
    double cpu_time_used;
    start = clock();

    random_device rd; //random number function
    for (int i = 0; i < 100000; i++)  // generator random number between
1 to 100000 consisting of 1000 block each
    {
        uniform_int_distribution<int> dist(1,10000000000);
        a[i] = b[i] = dist(rd);
    }
    end = clock();
    cpu_time_used = ((double) (end - start)) / CLOCKS_PER_SEC;
    FILE *fp = fopen("./selection.txt", "w+");
    for(int i = 0; i < n; i++) {
        fprintf(fp, "%d\n", a[i]);
    }
    fclose(fp);
    fp = fopen("./insertion.txt", "w+");
    for(int i = 0; i < n; i++) {
        fprintf(fp, "%d\n", b[i]);
    }
    fclose(fp);
```

	`` return cpu_time_used; } double selectionSort(int a[], int n) { FILE *fp = fopen("./selection.csv", "w+"); double totalTime = 0; if(!fp) { printf("Error in opening file\n"); return -1; } fprintf(fp, "n, time\n"); for (int y = 100; y <= n; y+=100) { clock_t start, end; double iterationTime; start = clock(); for (int i = 0; i < y-1; i++) { int k = i; for (int j = i+1; j < y; j++) { if (a[j]<a[k]) { k = j; } } int temp = a[k]; a[k] = a[i]; a[i] = temp; } end = clock(); iterationTime = ((double) (end - start)) / CLOCKS_PER_SEC; totalTime += iterationTime; fprintf(fp, "%d, %f\n", y, iterationTime); printf("Array[0...%d99] sorted in %.4fs\n", (y/100), iterationTime); } fclose(fp); return totalTime; } double insertionSort(int a[], int n) { FILE *fp = fopen("./insertion.csv", "w+"); ```

```
    double totalTime = 0;
    if(!fp) {
        printf("Error in opening file\n");
        return -1;
    }
    fprintf(fp, "n, time\n");
    for (int y = 100; y <= n; y+=100)
    {
        clock_t start, end;
        double iterationTime;
        start = clock();
        int j, x;
        for (int i = 1; i < y; i++)
        {
            j = i-1;
            x = a[i];
            while (j>-1 && a[j]>x)
            {
                a[j+1] = a[j];
                j--;
            }
            a[j+1] = x;
        }
        end = clock();
        iterationTime = ((double) (end - start)) / CLOCKS_PER_SEC;
        totalTime += iterationTime;
        fprintf(fp, "%d, %f\n", y, iterationTime);

        printf("Array[0...%d99] sorted in %.4fs\n", (y/100),
iterationTime);

    }
    fclose(fp);
    return totalTime;
}

int main()
{
    int n = 100000;
    int a[n],b[n];
    printf("Clock per second of the computer : %d\n",CLOCKS_PER_SEC);
    double timeToFill = numberGenertor(a, b, n);
    printf("Time to generate random number : %f\n", timeToFill);
    printf("Insertion sort\n");
    //insertion sort from 0 to 100000
    double insertionTime = insertionSort(a, n);
```

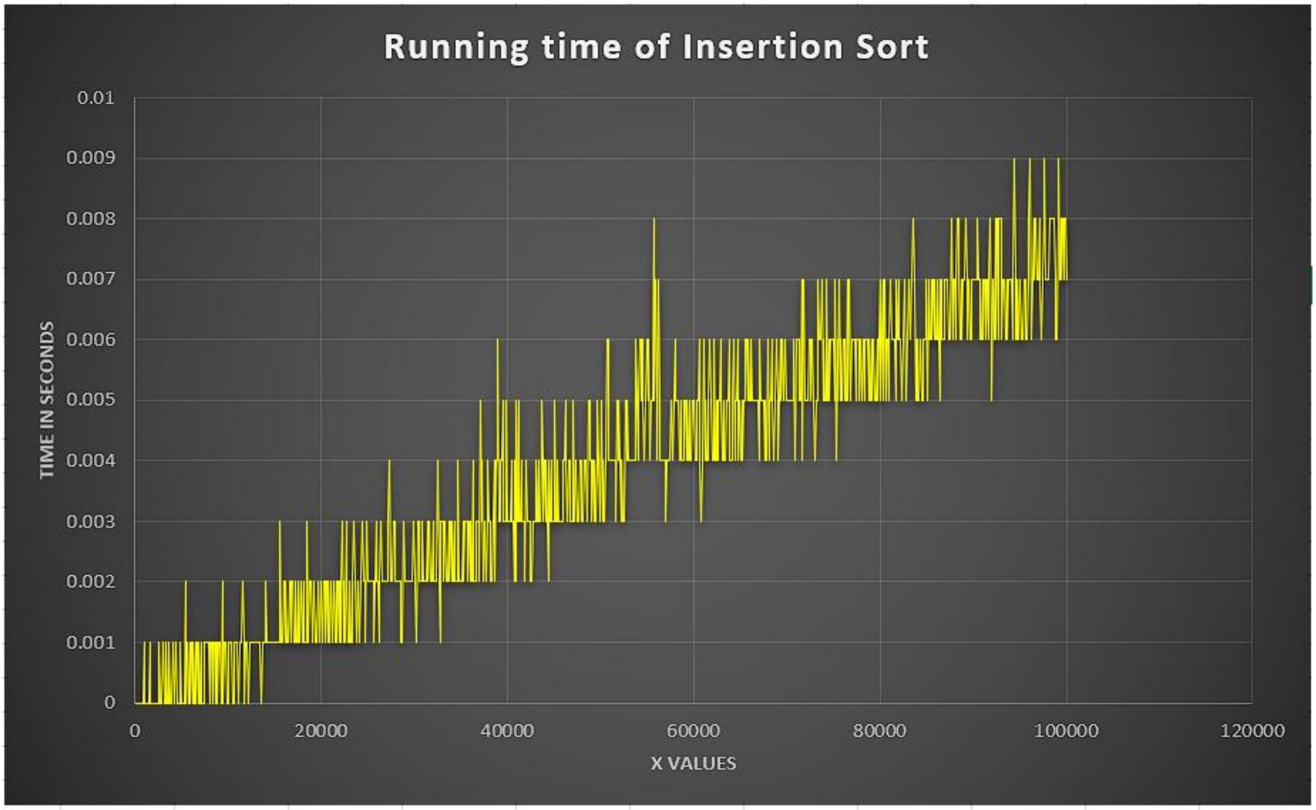
```c
    printf("Selection sort\n");
    //selection sort from 0 to 100000
    double selectionTime = selectionSort(b, n);
    printf("Time taken by insertion sort :  %.4f\n", insertionTime);
    printf("Time taken by selection sort :  %.4f\n", selectionTime);
    printf("Total time taken by program : %f\n", insertionTime +
selectionTime);

    return 0;
}
```

RESULT:

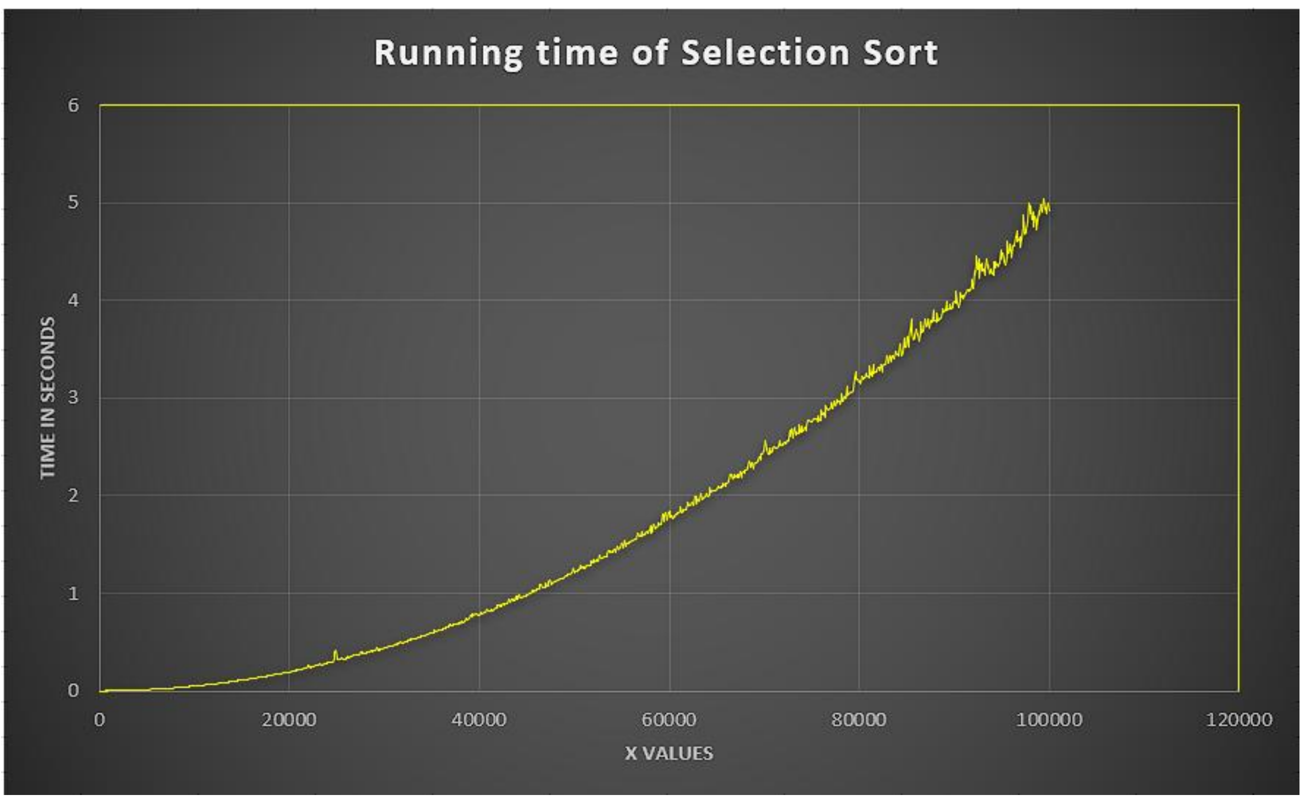
```
PS C:\Users\smsha\Desktop\SEM 4\DAA\Practicals\exp1> & .\"exp1b.exe"
Clock per second of the computer : 1000
Time to generate random number : 0.002000
Insertion sort
Array[0...199] sorted in 0.0000s
Array[0...299] sorted in 0.0000s
Array[0...399] sorted in 0.0000s
Array[0...499] sorted in 0.0000s
Array[0...599] sorted in 0.0000s
Array[0...699] sorted in 0.0000s
Array[0...799] sorted in 0.0000s
Array[0...899] sorted in 0.0000s
Array[0...999] sorted in 0.0000s
Array[0...1099] sorted in 0.0010s
Array[0...1199] sorted in 0.0000s
Array[0...1299] sorted in 0.0000s
```

```
Array[0...99499] sorted in 5.0430s
Array[0...99599] sorted in 4.9320s
Array[0...99699] sorted in 4.9580s
Array[0...99799] sorted in 4.8890s
Array[0...99899] sorted in 4.9370s
Array[0...99999] sorted in 4.9940s
Array[0...100099] sorted in 4.9200s
Time taken by insertion sort :  3.7830
Time taken by selection sort :  1645.3610
Total time taken by program : 1649.144000
PS C:\Users\smsha\Desktop\SEM 4\DAA\Practicals\exp1>
```

GRAPH:



Running time of Insertion Sort
TIME IN SECONDS
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
20000
40000
60000
80000
100000
120000
X VALUES



Running time of Selection Sort
TIME IN SECONDS
6
5
4
3
2
1
0
0
20000
40000
60000
80000
100000
120000
X VALUES

	Best	**Average**	**Worst**
Selection Sort	$\Omega(n^2)$	$\theta(n^2)$	$O(n^2)$
Insertion Sort	$\Omega(n)$	$\theta(n^2)$	$O(n^2)$

The time complexity for all 3 cases of selection sort is n^2. Meanwhile in insertion sort, the average and worst-case time complexity is the same – n^2 but the best-case time complexity is linear (in the case where the input is already sorted).

Hence, we can say that in general, insertion sort is more efficient compared to selection sort.

CONCLUSION :	In this experiment, we wrote a program which given 100000 integers in 1000 blocks of 100 numbers, uses the selection andinsertion sort algorithms to sort them in ascending order. In selection sort, during every iteration, we move the minimum element of the unsorted subarray tothe end of the sorted subarray. In insertion sort, during every iteration, we move the first element of the unsorted subarray to the appropriate position in the sorted subarray. We compared the running time of insertion and selection sort by comparing the running time graph of 2 algorithms. We also analyzed the 2 algorithms in which we found that while the time complexity of selection sort is n^2, the best-case time complexity of insertion sort is linear (in the case where the input is already sorted). Hence, we concluded that in general, insertion sort is more efficient compared to selection sort. Thus, we successfully accomplished the aim of this experiment.