| **Experiment No. 2** |
|---|
| **To implement Insertion Sort** |
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## Experiment No. 2

**Title:** Insertion Sort

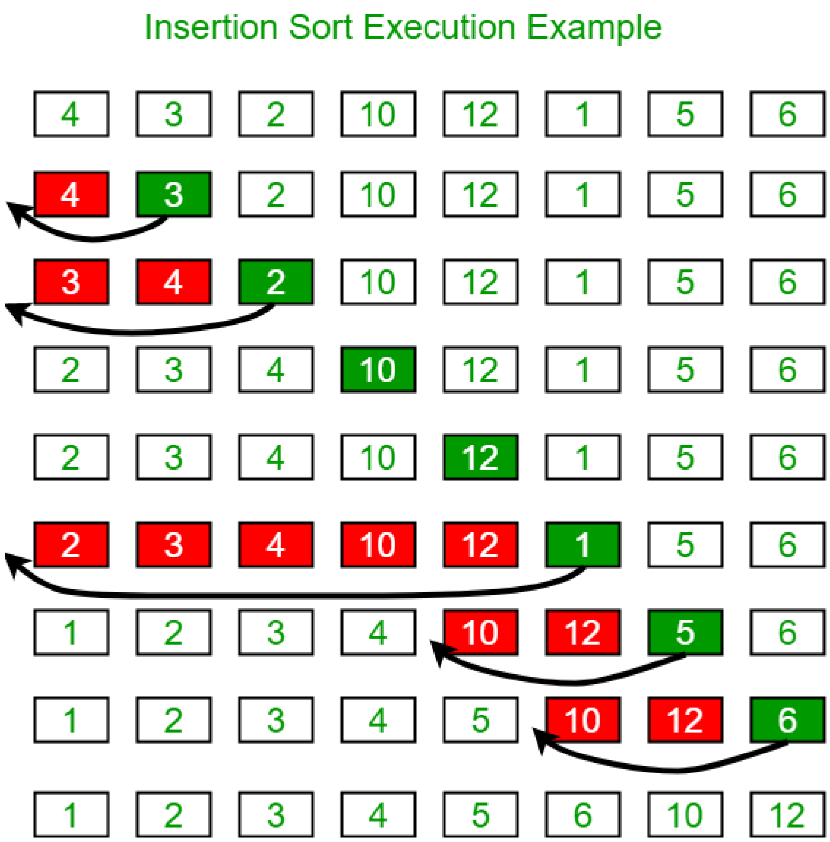
**Aim:** To study, implement and Analyze Insertion Sort Algorithm

**Objective:** To introduce the methods of designing and analyzing algorithms

**Theory:**

Insertion sort is a simple sorting algorithm that works similar to the way you sort the playing cards in your hands. 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.

**Example:**



**Algorithm and Complexity:**

| **Algorithm** Insertion Sort (A) | **Cost** | **Time** |
|---|---|---|
| *// A is an array of size n* | | |
| **for** j ← 2 to n **do** | $c_1$ | n |
| key ← A[ j ] | $c_2$ | n – 1 |
| i ← j – 1 | $c_3$ | n – 1 |
| **while** (i > 0 && A[i] > key) **do** | $c_4$ | $\sum_{j=2}^{n} t_j$ |
| A [i + 1] ← A[i] | $c_5$ | $\sum_{j=2}^{n}(t_j - 1)$ |
| i ← i - 1 | $c_6$ | $\sum_{j=2}^{n}(t_j - 1)$ |
| **end** | – | – |
| A[i + 1] ← key | $c_7$ | n – 1 |
| **end** | | |

**Best case analysis:**

- Let size of the input array is n. Total time taken by algorithm is the summation of time taken by each of its instruction.

$$T(n) = c_1 \cdot n + c_2 \cdot (n-1) + c_3 \cdot (n-1) + c_4 \cdot \left(\sum_{j=2}^{n} t_j\right) + c_5 \cdot \sum_{j=2}^{n} (t_j - 1) + c_6 \cdot \sum_{j=2}^{n} (t_j - 1) + c_7 \cdot (n-1)$$

- The best case offers the lower bound of the algorithm's running time.
- When data is already sorted, the best scenario for insertion sort happens.
- In this case, the condition in the while loop will never be satisfied, resulting in tj = 1.

$$T(n) = c_1 \cdot n + c_2 \cdot (n-1) + c_3 \cdot (n-1) + c_4 \sum_{j=2}^{n} 1 + c_5 \sum_{j=2}^{n} 0 + c_6 \sum_{j=2}^{n} 0 + c_7 \cdot (n-1)$$

Where,

$$\sum_{j=2}^{n} 1 = 1 + 1 + \dots + 1 \ (n-1 \text{ times}) = n-1$$

$$= c_1 \times n + c_2 \times n - c_2 + c_3 \times n - c_3 + c_4 \times n - c_4 + c_7 \times n - c_7$$

$$= (c_1 + c_2 + c_3 + c_7)\, n - (c_3 + c_4 + c_4 + c_7)$$

$= a\,n + b$ Which is linear function of n

$= O(n)$

**Worst case analysis:**

- The worst-case running time gives an upper bound of running time for any input.
- The running time of algorithm cannot get worse than its worst-case running time.
- Worst case for insertion sort occurs when data is sorted in reverse order.
- So we must have to compare A[j] with each element of sorted array A[1 … j – 1]. So, $t_j = j$

$$\sum_{j=2}^{n} j = 2 + 3 + 4 + \dots + n$$
$$= (1 + 2 + 3 + \dots + n) - 1 = \sum n - 1$$
$$= \frac{n(n+1)}{2} - 1$$

$$\sum_{j=2}^{n} (j-1) = 1 + 2 + 3 + \dots + n - 1 = \Sigma\,(n-1) = \frac{n(n-1)}{2}$$

$$T(n) = c_1 \cdot n + c_2 \cdot (n-1) + c_3 \cdot (n-1) + c_4 \cdot \left(\sum_{j=2}^{n} j\right) + c_5 \cdot \sum_{j=2}^{n} (j-1) + c_6 \cdot \sum_{j=2}^{n} (j-1) + c_7 \cdot (n-1)$$

$$= c_1 \cdot n + c_2 \cdot (n-1) + c_3 \cdot (n-1) + c_4 \cdot \left(\frac{n(n+1)}{2} - 1\right) + c_5 \cdot \frac{n(n-1)}{2} + c_6 \cdot \frac{n(n-1)}{2} + c_7 \cdot (n-1)$$

$$= \left(\frac{c_4}{2} + \frac{c_5}{2} + \frac{c_6}{2}\right) \cdot n^2 + \left(c_1 + c_2 + c_3 + \frac{c_4}{2} - \frac{c_5}{2} - \frac{c_6}{2} + c_7\right) \cdot n - (c_2 + c_3 + c_4 + c_7)$$

$= an^2 + bn + c$ which is quadratic function of n

$= O(n^2)$

**Average Case Analysis**

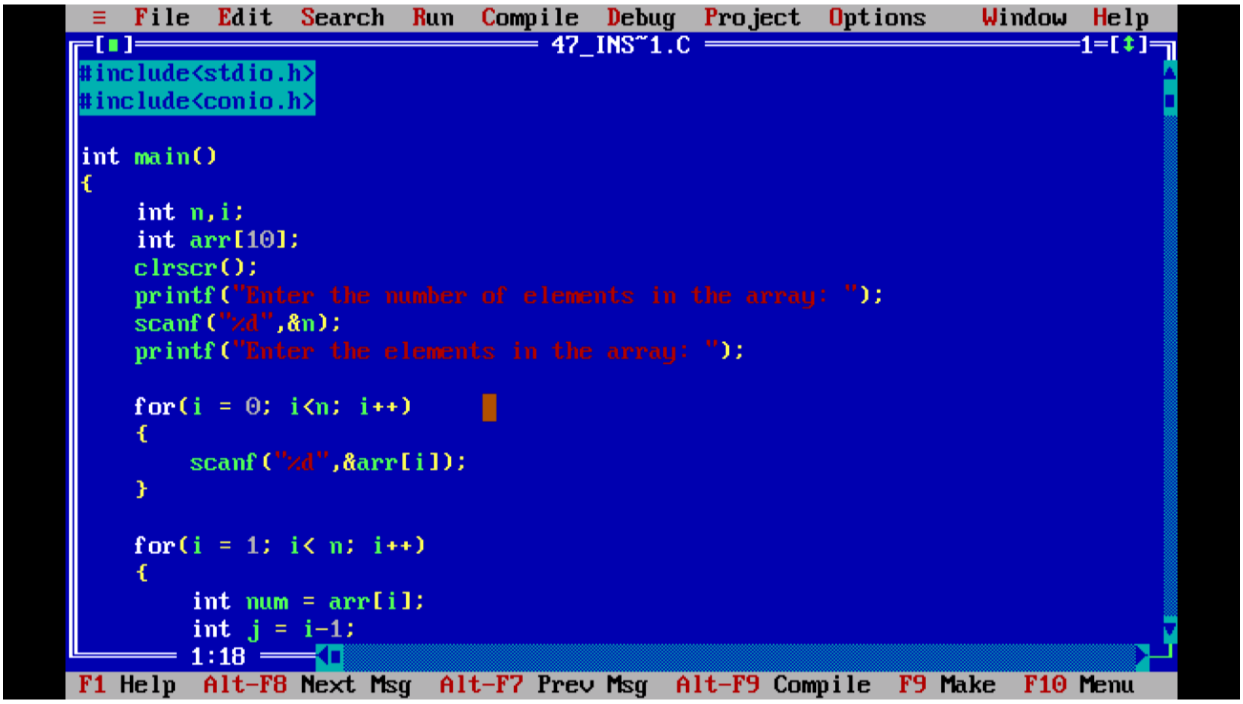
- Let's assume that $t_j = (j-1)/2$ to calculate the average case
  Therefore,
  $T(n) = C_1 * n + (C_2 + C_3) * (n - 1) + C_4/2 * (n - 1)(n) / 2 + (C_5 + C_6)/2 * ((n - 1)(n) / 2 - 1) + C_8 * (n - 1)$

further simplified has dominating factor of $\mathbf{n^2}$ and gives $T(n) = C * (n^2)$ or $O(n^2)$

## Code:

```
#include<stdio.h>
#include<conio.h>
int main()
{
   int n,i;
   int arr[10];
   clrscr();
   printf("Enter the number of elements in the array: ");
   scanf("%d",&n);
   printf("Enter the elements in the array: ");
   for(i = 0; i<n; i++)
   {
       scanf("%d",&arr[i]);
   }
   for(i = 1; i< n; i++)
   {
       int num = arr[i];
       int j = i-1;
       while(arr[j]>num  && j>=0 )
       {
          arr[j+1] = arr[j];
          j--;
       }
       arr[j+1] = num;

   printf("Sorted array: ");
   for(i = 0; i<n; i++)
   {
       printf("%d ",arr[i]);
   }
   getch();
   return 0;
}
```

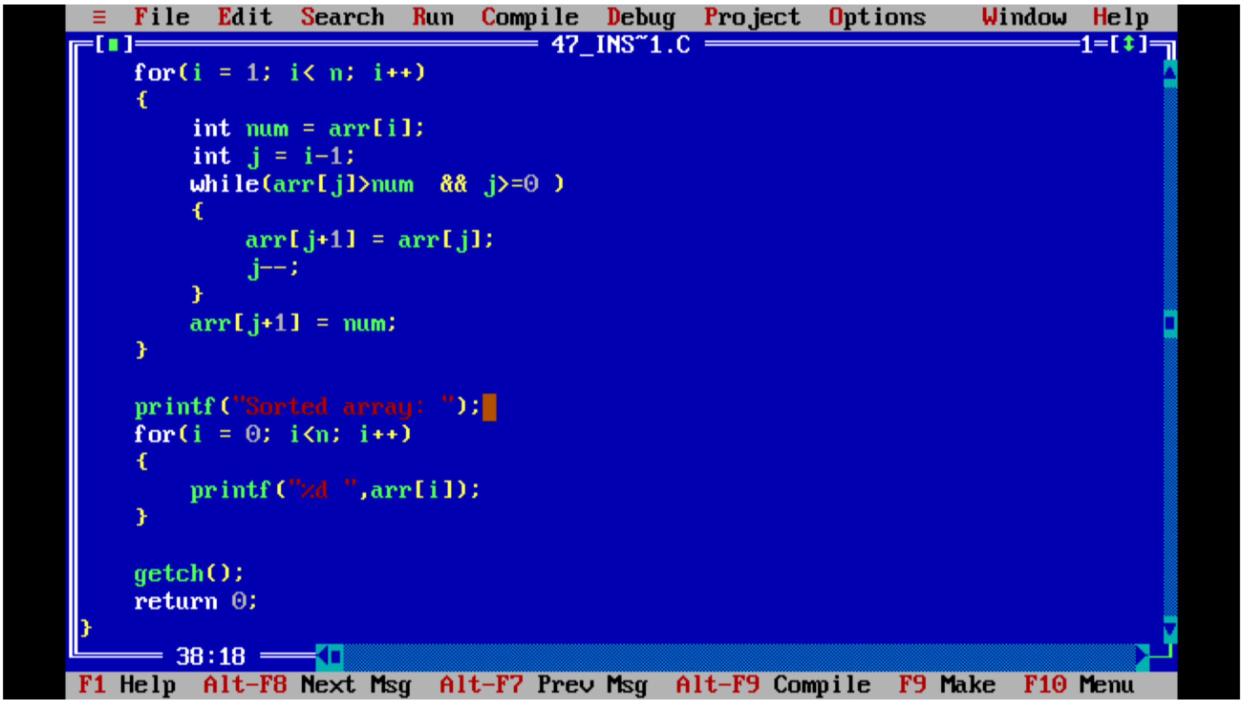



```c
#include<stdio.h>
#include<conio.h>

int main()
{
    int n,i;
    int arr[10];
    clrscr();
    printf("Enter the number of elements in the array: ");
    scanf("%d",&n);
    printf("Enter the elements in the array: ");

    for(i = 0; i<n; i++)
    {
        scanf("%d",&arr[i]);
    }

    for(i = 1; i< n; i++)
    {
        int num = arr[i];
        int j = i-1;
```




```c
    for(i = 1; i< n; i++)
    {
        int num = arr[i];
        int j = i-1;
        while(arr[j]>num  && j>=0 )
        {
            arr[j+1] = arr[j];
            j--;
        }
        arr[j+1] = num;
    }

    printf("Sorted array: ");
    for(i = 0; i<n; i++)
    {
        printf("%d ",arr[i]);
    }

    getch();
    return 0;
}
```

**Output:**

Enter the number of elements in the array: 7

Enter the elements in the array: 9 4 8 18 13 30 1

Sorted array: 1 4 8 9 13 18 30


**Conclusion:**

In conclusion, insertion sort is a simple and intuitive sorting algorithm that builds a sorted array one item at a time, by repeatedly swapping the current element with the elements in the sorted part that are larger. It is efficient for small data sets and has the advantage of being a stable, in-place sorting algorithm. However, it can be less efficient on large lists compared to more advanced algorithms.