Insertion Sort Algorithm

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> ***Insertion sort*** *is a simple sorting algorithm that works by iteratively inserting each element of an unsorted list into its correct position in a sorted portion of the list. It is a* ***stable sorting*** *algorithm, meaning that elements with equal values maintain their relative order in the sorted output.*

Insertion sort is like sorting playing cards in your hands. You split the cards into two groups: the sorted cards and the unsorted cards. Then, you pick a card from the unsorted group and put it in the right place in the sorted group.

Insertion Sort Algorithm:

Insertion sort is a simple sorting algorithm that works by building a sorted array one element at a time. It is considered an ” **in-place** ” sorting algorithm, meaning it doesn’t require any additional memory space beyond the original array.

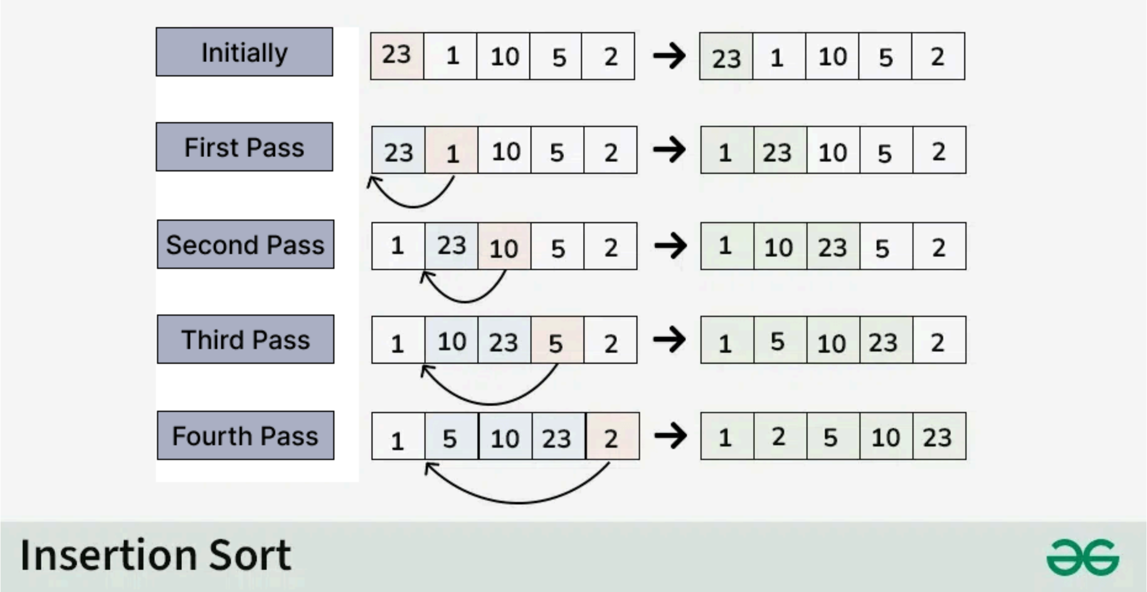
To achieve insertion sort, follow these steps:

- We start with second element of the array as first element in the array is assumed to be sorted.
- Compare second element with the first element and check if the second element is smaller then swap them.
- Move to the third element and compare it with the second element, then the first element and swap as necessary to put it in the correct position among the first three elements.

- Continue this process, comparing each element with the ones before it and swapping as needed to place it in the correct position among the sorted elements.
- Repeat until the entire array is sorted.

Working of Insertion Sort Algorithm:

Consider an array having elements ***: {23, 1, 10, 5, 2}***



Initial:

- *Current element is* ***23***
- *The first element in the array is assumed to be sorted.*
- *The sorted part until* ***0th*** *index is :* ***[23]***

First Pass:

- *Compare* ***1*** *with* ***23*** *(current element with the sorted part).*
- *Since* ***1*** *is smaller, insert* ***1*** *before* ***23*** *.*
- *The sorted part until* ***1st*** *index is:* ***[1, 23]***

Second Pass:

- *Compare **10** with **1** and **23** (current element with the sorted part).*
- *Since **10** is greater than **1** and smaller than **23** , insert **10** between **1** and **23** .*
- *The sorted part until **2nd** index is: **[1, 10, 23]***

Third Pass:

- *Compare **5** with **1** , **10** , and **23** (current element with the sorted part).*
- *Since **5** is greater than **1** and smaller than **10** , insert **5** between **1** and **10***
- *The sorted part until **3rd** index is **: [1, 5, 10, 23]***

Fourth Pass:

- *Compare **2** with **1, 5, 10** , and **23** (current element with the sorted part).*
- *Since **2** is greater than **1** and smaller than **5** insert **2** between **1** and **5** .*
- *The sorted part until **4th** index is: **[1, 2, 5, 10, 23]***

Final Array:

- *The sorted array is: **[1, 2, 5, 10, 23]***

Implementation of Insertion Sort:

C++ C Java Python C# JavaScript PHP

```
// C# program for implementation of Insertion Sort
using System;

class InsertionSort {
    /* Function to sort array using insertion sort */
    void sort(int[] arr) {
        int n = arr.Length;
        for (int i = 1; i < n; ++i) {
            int key = arr[i];
            int j = i - 1;

            /* Move elements of arr[0..i-1], that are
               greater than key, to one position ahead
               of their current position */
            while (j >= 0 && arr[j] > key) {
                arr[j + 1] = arr[j];
                j = j - 1;
            }
            arr[j + 1] = key;
        }
    }

    /* A utility function to print array of size n */
    static void printArray(int[] arr) {
        int n = arr.Length;
        for (int i = 0; i < n; ++i)
            Console.Write(arr[i] + " ");

        Console.WriteLine();
    }
```

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```
        int[] arr = { 12, 11, 13, 5, 6 };

        InsertionSort ob = new InsertionSort();
        ob.sort(arr);

        printArray(arr);
    }
}

/* This code is contributed by Hritik Shah. */
```

Output

```
Number of passes: 4
5 6 11 12 13
```

Time Complexity: O(N^2)

Auxiliary Space: O(1)

Complexity Analysis of Insertion Sort :

Time Complexity of Insertion Sort

- **Best case: O(n)** , If the list is already sorted, where n is the number of elements in the list.
- **Average case: O(n ^{2})** , If the list is randomly ordered
- **Worst case: O(n ^{2})** , If the list is in reverse order

Space Complexity of Insertion Sort

- **Auxiliary Space:** O(1), Insertion sort requires **O(1)** additional space, making it a space-efficient sorting algorithm.

Advantages of Insertion Sort:

- Simple and easy to implement.
- Stable sorting algorithm.
- Efficient for small lists and nearly sorted lists.
- Space-efficient.
- Adoptive. the number of inversions is directly proportional to number of swaps. For example, no swapping happens for a sorted array and it takes O(n) time only.

Disadvantages of Insertion Sort:

- Inefficient for large lists.
- Not as efficient as other sorting algorithms (e.g., merge sort, quick sort) for most cases.

Applications of Insertion Sort:

Insertion sort is commonly used in situations where:

- The list is small or nearly sorted.
- Simplicity and stability are important.
- Used as a subroutine in Bucket Sort
- Can be useful when array is already almost sorted (very few inversions)

- Since Insertion sort is suitable for small sized arrays, it is used in Hybrid Sorting algorithms along with other efficient algorithms like Quick Sort and Merge Sort. When the subarray size becomes small, we switch to insertion sort in these recursive algorithms. For example IntroSort and TimSort use insertions sort.

Frequently Asked Questions on Insertion Sort

Q1. What are the Boundary Cases of the Insertion Sort algorithm?

> *Insertion sort takes the maximum time to sort if elements are sorted in reverse order. And it takes minimum time (Order of n) when elements are already sorted.*

Q2. What is the Algorithmic Paradigm of the Insertion Sort algorithm?

> *The Insertion Sort algorithm follows an incremental approach.*

Q3. Is Insertion Sort an in-place sorting algorithm?

> *Yes, insertion sort is an in-place sorting algorithm.*

Q4. Is Insertion Sort a stable algorithm?

> *Yes, insertion sort is a stable sorting algorithm.*

Q5. When is the Insertion Sort algorithm used?

> *Insertion sort is used when number of elements is small. It can also be useful when the input array is almost sorted, and only a few elements are misplaced in a complete big array.*

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