Sorting

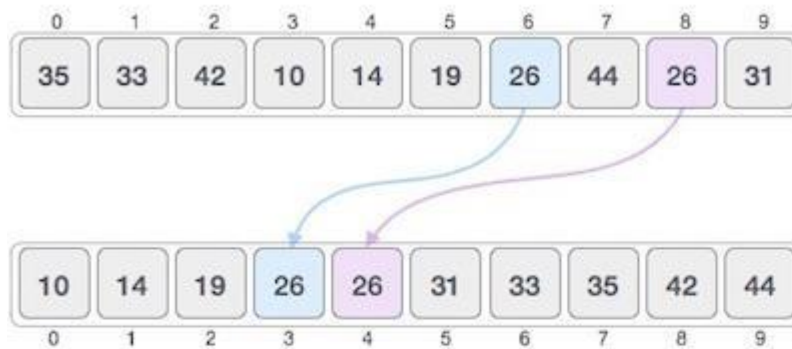
Sorting is a process of ordering or placing a list of elements from a collection in some kind of order. It is nothing but storage of data in sorted order. Sorting can be done in ascending and descending order. It arranges the data in a sequence which makes searching easier.

For example: The below list of characters is sorted in increasing order of their ASCII values. That is, the character with lesser ASCII value will be placed first than the character with higher ASCII value.

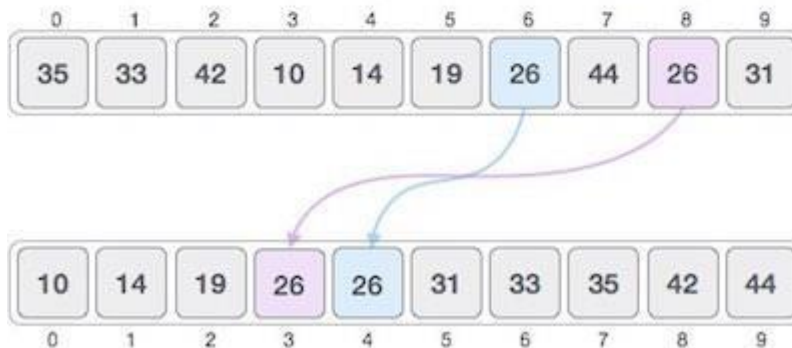
d a t a s t r u c t u r e	**a a c d e r r s t t t u u**
Input	**Output**

Stable and Not Stable Sorting

If a sorting algorithm, after sorting the contents, does not change the sequence of similar content in which they appear, it is called **stable sorting**.



If a sorting algorithm, after sorting the contents, changes the sequence of similar content in which they appear, it is called **unstable sorting**.



Adaptive and Non-Adaptive Sorting Algorithm

A sorting algorithm is said to be **adaptive**, if it takes advantage of already 'sorted' elements in the list that is to be sorted. That is, while sorting if the source list has some element already sorted, adaptive algorithms will take this into account and will try not to re-order them.

A **non-adaptive** algorithm is one which does not take into account the elements which are already sorted. They try to force every single element to be re-ordered to confirm their sorted-ness.

Important Terms

Some terms are generally coined while discussing sorting techniques, here is a brief introduction to them −

Increasing Order

A sequence of values is said to be in **increasing order**, if the successive element is greater than the previous one. For example, 1, 3, 4, 6, 8, 9 are in increasing order, as every next element is greater than the previous element.

Decreasing Order

A sequence of values is said to be in **decreasing order**, if the successive element is less than the current one. For example, 9, 8, 6, 4, 3, 1 are in decreasing order, as every next element is less than the previous element.

Non-Increasing Order

A sequence of values is said to be in **non-increasing order**, if the successive element is less than or equal to its previous element in the sequence. This order occurs when the sequence contains duplicate values. For example, 9, 8, 6, 3, 3, 1 are in non-increasing order, as every next element is less than or equal to (in case of 3) but not greater than any previous element.

Non-Decreasing Order

A sequence of values is said to be in **non-decreasing order**, if the successive element is greater than or equal to its previous element in the sequence. This order occurs when the sequence contains duplicate values. For example, 1, 3, 3, 6, 8, 9 are in non-decreasing order, as every next element is greater than or equal to (in case of 3) but not less than the previous one.

Some important sorting algorithms

The Bubble Sort

The **bubble sort** makes multiple passes through a list. It compares adjacent items and exchanges those that are out of order. Each pass through the list places the next largest value in its proper place. In essence, each item "bubbles" up to the location where it belongs.

Example: Sort {5, 1, 12, -5, 16} using bubble sort.

5	1	12	-5	16	unsorted
5	1	12	-5	16	5 > 1, swap
1	5	12	-5	16	5 < 12, ok
1	5	12	-5	16	12 > -5, swap
1	5	-5	12	16	12 < 16, ok
1	5	-5	12	16	1 < 5, ok
1	5	-5	12	16	5 > -5, swap
1	-5	5	12	16	5 < 12, ok
1	-5	5	12	16	1 > -5, swap
-5	1	5	12	16	1 < 5, ok
-5	1	5	12	16	-5 < 1, ok
-5	1	5	12	16	sorted

Table 1: Comparisons for Each Pass of Bubble Sort

Pass	Comparisons
1	n−1
2	n−2
3	n−3
…	…
n−1	1

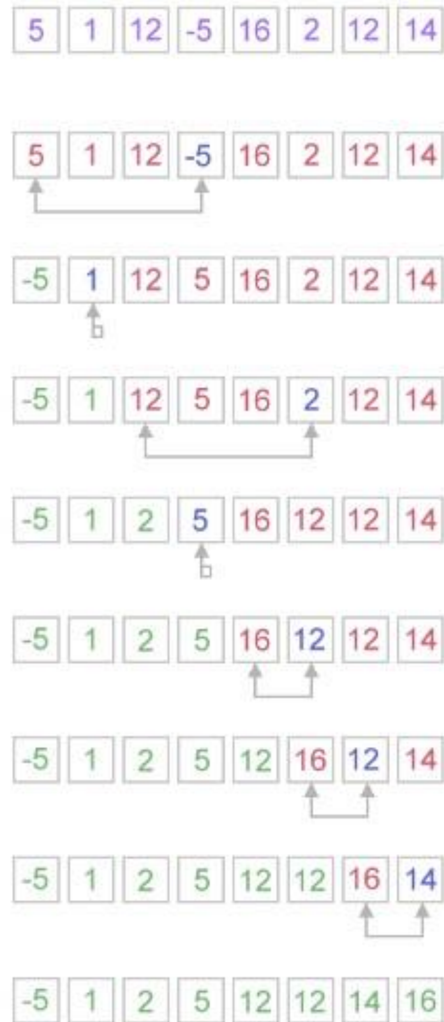
Algorithm for bubble sort

```
1. Input array A[1….n]
2. for (i = 0; i<= n – 1; i++)
   {
    for (j= 0; j<=n - i – 1; j++)
    {
     if (A[j] > A[j+1])
      {
        temp = A[j];
        A[j] = A[j+1];
        A[j+1] = temp;
      }
    }
  }
3. Output: Sorted list
```

The Selection Sort

In this method, at first, we select the smallest data of the list. After selecting, we place the smallest data in the first position and the data in first position is placed in the position where the smallest data was. After that we consider the list except the data in the first position. Again we select the (second) smallest data from the list and place it in the second position of the list and place the data in the in the second position, in the position where the second smallest data was. By repeating the process, we can sort the whole list.

Example: Sort {5, 1, 12, -5, 16, 2, 12, 14} using selection sort.

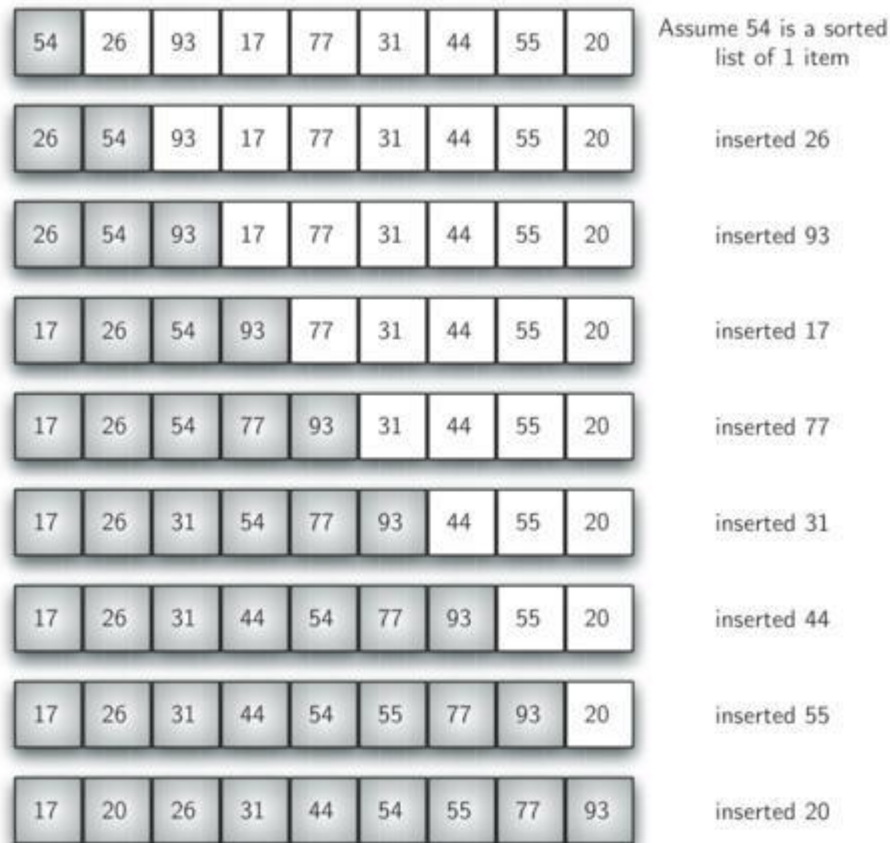


Algorithm for selection sort

```
1. Input array A[1…..n]
2. for(i=1; i<=n-1; i++)
          {
           small_index=i;
           for(j=i+1; j<=n; j++)
          {
            if(A[j] < A[small_index])
            small_index=j;
          }
           temp=A[i];
           A[i]=A[small_index];
           A[small_index]=temp;
          }
3. Output: Sorted list
```

The Insertion Sort

It always maintains a sorted sublist in the lower positions of the list. Each new item is then "inserted" back into the previous sublist such that the sorted sublist is one item larger. Figure shows the insertion sorting process. The shaded items represent the ordered sublists as the algorithm makes each pass. We can derive simple steps by which we can achieve insertion sort.



Algorithm for insertion sort

1. Input array arr[1….n]
2. for (i = 1; i < n; i++)

```
{
   key = arr[i];
   j = i - 1;
   while (j >= 0 && arr[j] > key)
   {
      arr[j + 1] = arr[j];
      j = j - 1;
   }
   arr[j + 1] = key;
}
```

3. Output: Sorted list.

The Merge Sort

Merge sort is a recursive algorithm that continually splits a list in half. If the list is empty or has one item, it is sorted by definition (the base case). If the list has more than one item, we split the list and recursively invoke a merge sort on both halves. Once the two halves are sorted, the fundamental operation, called a **merge**, is performed. Merging is the process of taking two smaller sorted lists and combining them together into a single, sorted, new list.

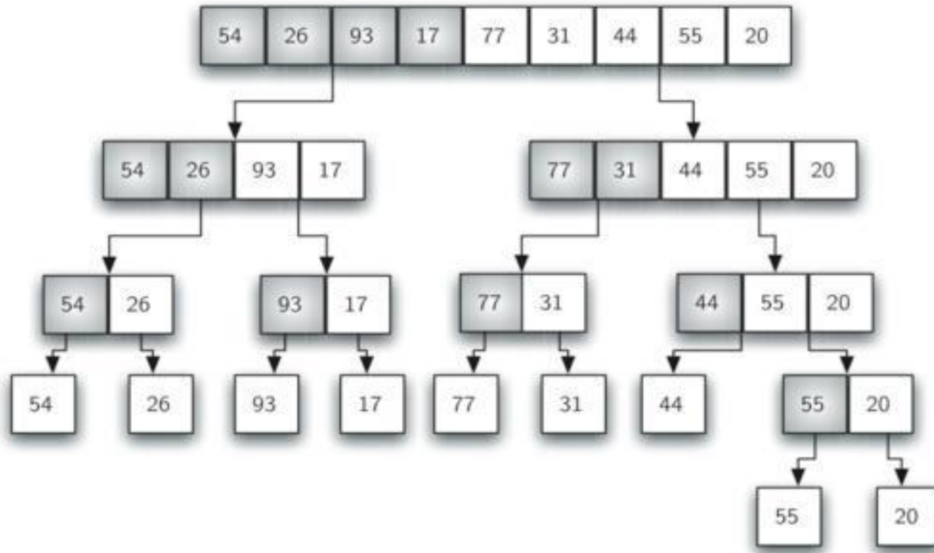


Figure 1: Splitting the List in a Merge Sort

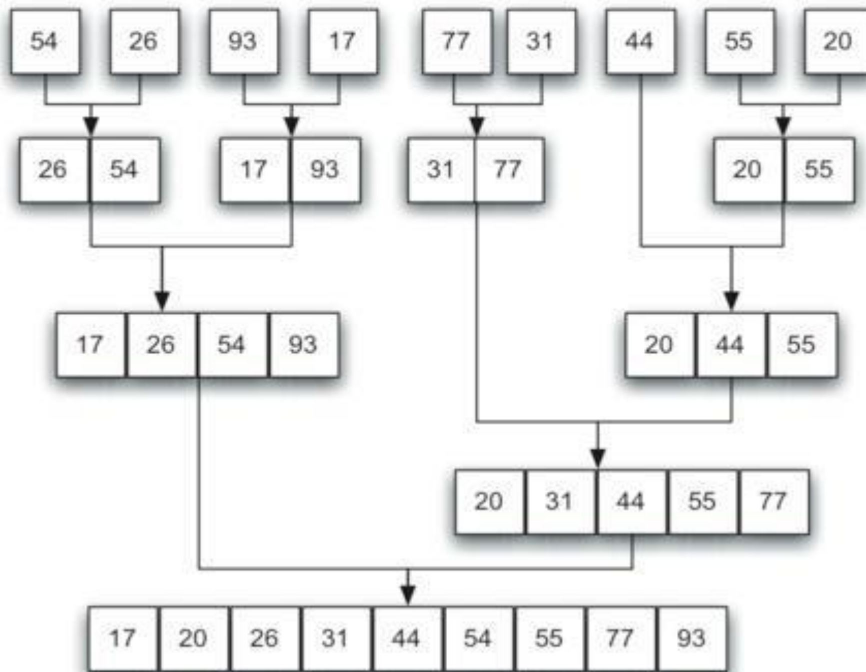
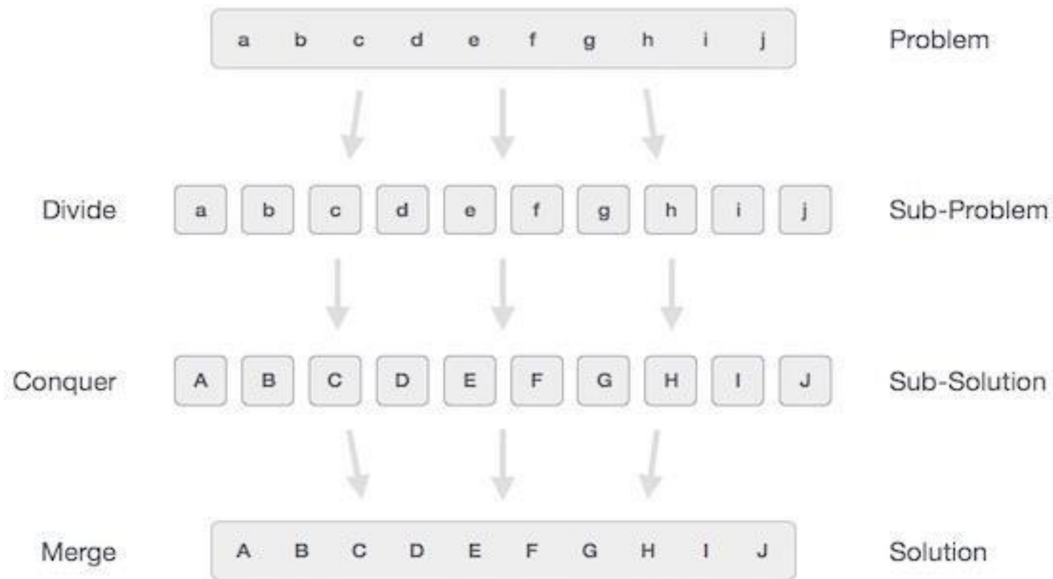


Figure 2: Lists as They Are Merged Together

Divide and Conquer Method

In divide and conquer approach, the problem in hand, is divided into smaller sub-problems and then each problem is solved independently. When we keep on dividing the subproblems into even smaller sub-problems, we may eventually reach a stage where no more division is possible. Those "atomic" smallest possible sub-problem (fractions) is solved. The solution of all sub-problems is finally merged in order to obtain the solution of an original problem.



Broadly, we can understand **divide-and-conquer** approach in a three-step process.

Divide/Break

This step involves breaking the problem into smaller sub-problems. Sub-problems should represent a part of the original problem. This step generally takes a recursive approach to divide the problem until no sub-problem is further divisible. At this stage, sub-problems become atomic in nature but still represent some part of the actual problem.

Conquer/Solve

This step receives a lot of smaller sub-problems to be solved. Generally, at this level, the problems are considered 'solved' on their own.

Merge/Combine

When the smaller sub-problems are solved, this stage recursively combines them until they formulate a solution of the original problem. This algorithmic approach works recursively and conquer & merge steps works so close that they appear as one.

Complexity of Sorting Algorithm

Array Sorting Algorithms

Algorithm	Time Complexity			Space Complexity
	Best	Average	Worst	Worst
Quicksort	Ω(n log(n))	Θ(n log(n))	O(n^2)	O(log(n))
Mergesort	Ω(n log(n))	Θ(n log(n))	O(n log(n))	O(n)
Timsort	Ω(n)	Θ(n log(n))	O(n log(n))	O(n)
Heapsort	Ω(n log(n))	Θ(n log(n))	O(n log(n))	O(1)
Bubble Sort	Ω(n)	Θ(n^2)	O(n^2)	O(1)
Insertion Sort	Ω(n)	Θ(n^2)	O(n^2)	O(1)
Selection Sort	Ω(n^2)	Θ(n^2)	O(n^2)	O(1)
Tree Sort	Ω(n log(n))	Θ(n log(n))	O(n^2)	O(n)
Shell Sort	Ω(n log(n))	Θ(n(log(n))^2)	O(n(log(n))^2)	O(1)
Bucket Sort	Ω(n+k)	Θ(n+k)	O(n^2)	O(n)
Radix Sort	Ω(nk)	Θ(nk)	O(nk)	O(n+k)
Counting Sort	Ω(n+k)	Θ(n+k)	O(n+k)	O(k)
Cubesort	Ω(n)	Θ(n log(n))	O(n log(n))	O(n)

Advantages And disadvantages

Bubble Sort

Advantages	Disadvantages
The primary advantage of the bubble sort is that it is popular and easy to implement.	The main disadvantage of the bubble sort is the fact that it does not deal well with a list containing a huge number of items.
In the bubble sort, elements are swapped in place without using additional temporary storage.	The bubble sort requires n-squared processing steps for every n number of elements to be sorted.
The space requirement is at a minimum	The bubble sort is mostly suitable for academic teaching but not for real-life applications.

Insertion Sort

Advantages	Disadvantages
The main advantage of the insertion sort is its simplicity.	The disadvantage of the insertion sort is that it does not perform as well as other, better sorting algorithms
It also exhibits a good performance when dealing with a small list.	With n-squared steps required for every n element to be sorted, the insertion sort does not deal well with a huge list.
The insertion sort is an in-place sorting algorithm so the space requirement is minimal.	The insertion sort is particularly useful only when sorting a list of few items.

Selection Sort

Advantages	Disadvantages
The main advantage of the selection sort is that it performs well on a small list.	The primary disadvantage of the selection sort is its poor efficiency when dealing with a huge list of items.
Because it is an in-place sorting algorithm, no additional temporary storage is required beyond what is needed to hold the original list.	The selection sort requires n-squared number of steps for sorting n elements.
Its performance is easily influenced by the initial ordering of the items before the sorting process.	Quick Sort is much more efficient than selection sort

Quick Sort

Advantages	Disadvantages
The quick sort is regarded as the best sorting algorithm.	The slight disadvantage of quick sort is that its worst-case performance is similar to average performances of the bubble, insertion or selections sorts.
It is able to deal well with a huge list of items.	If the list is already sorted than bubble sort is much more efficient than quick sort
Because it sorts in place, no additional storage is required as well	If the sorting element is integers than radix sort is more efficient than quick sort.

Merge Sort

Advantages	Disadvantages
It can be applied to files of any size.	Requires extra space »N
Reading of the input during the run-creation step is sequential ==> Not much seeking.	Merge Sort requires more space than other sort.
If heap sort is used for the in-memory part of the merge, its operation can be overlapped with I/O	Merge sort is less efficient than other sort