Selection Sort Algorithm

Selection Sort algorithm is used to arrange a list of elements in a particular order (Ascending or Descending). In selection sort, the first element in the list is selected and it is compared repeatedly with all the remaining elements in the list.

If any element is smaller than the selected element (for Ascending order), then both are swapped so that first position is filled with the smallest element in the sorted order.

Next, we select the element at a second position in the list and it is compared with all the remaining elements in the list.

If any element is smaller than the selected element, then both are swapped. This procedure is repeated until the entire list is sorted.

Step by Step Process

The selection sort algorithm is performed using the following steps...

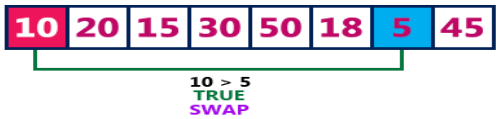
- **Step 1 -** Select the first element of the list (i.e., Element at first position in the list).
- **Step 2:** Compare the selected element with all the other elements in the list.
- **Step 3:** In every comparison, if any element is found smaller than the selected element (for Ascending order), then both are swapped.
- **Step 4:** Repeat the same procedure with element in the next position in the list till the entire list is sorted.

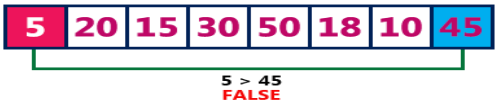
Consider the following example to understand the working process of Selection Sort :

Consider the following unsorted list of elements...

Iteration #1

Select the first position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.





List after 1st iteration

Iteration #2

Select the second position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 2nd iteration

Iteration #3

Select the third position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 3rd iteration

Iteration #4

Select the fourth position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 4th iteration

Iteration #5

Select the fifth position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 5th iteration

Iteration #6

Select the sixth position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 6th iteration

Iteration #7

Select the seventh position element in the list, compare it with all other elements in the list and whenever we found a smaller element than the element at first position then swap those two elements.

List after 7th iteration

Final sorted list

Complexity of the Selection Sort Algorithm

To sort an unsorted list with **'n'** number of elements, we need to make **((n-1)+(n-2)+(n-3)+.....+1) = (n (n-1))/2** number of comparisons in the worst case. If the list is already sorted then it requires **'n'** number of comparisons.

Worst Case : $O(n^2)$
Best Case : $\Omega(n^2)$
Average Case : $\Theta(n^2)$

Radix Sort Algorithm

Radix sort is one of the sorting algorithms used to sort a list of integer numbers in order. In radix sort algorithm, a list of integer numbers will be sorted based on the digits of individual numbers. Sorting is performed from **least significant digit to the most significant digit**.

Radix sort algorithm requires the number of passes which are equal to the number of digits present in the largest number among the list of numbers. For example, if the largest number is a 3 digit number then that list is sorted with 3 passes.

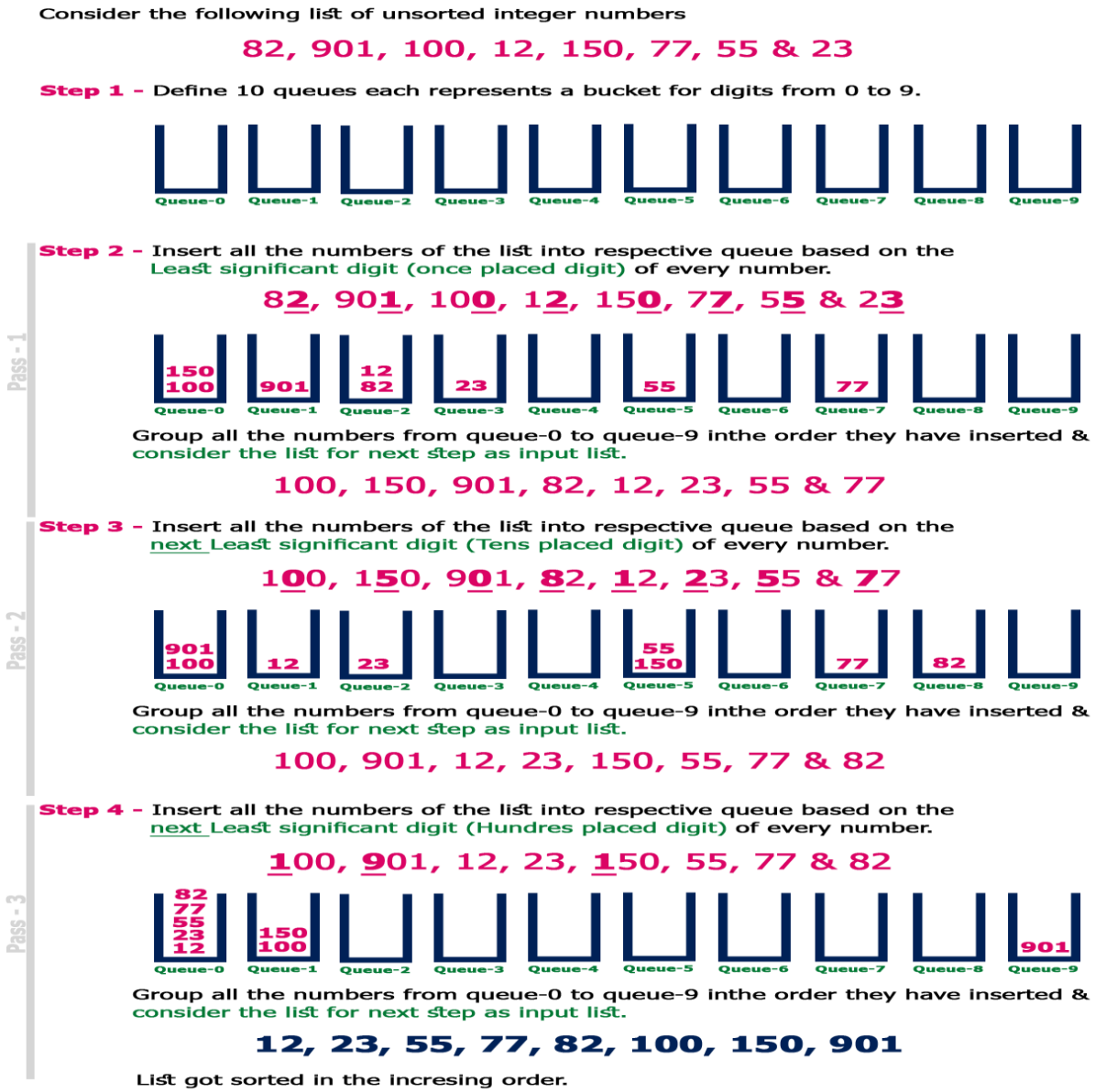
Step by Step Process

The Radix sort algorithm is performed using the following steps...

- **Step 1 -** Define 10 queues each representing a bucket for each digit from 0 to 9.
- **Step 2 -** Consider the least significant digit of each number in the list which is to be sorted.
- **Step 3 -** Insert each number into their respective queue based on the least significant digit.
- **Step 4 -** Group all the numbers from queue 0 to queue 9 in the order they have inserted into their respective queues.
- **Step 5 -** Repeat from step 3 based on the next least significant digit.

- **Step 6 -** Repeat from step 2 until all the numbers are grouped based on the most significant digit.

Let us understand the following Example:



Complexity of the Radix Sort Algorithm

To sort an unsorted list with 'n' number of elements, Radix sort algorithm needs the following complexities...

Worst Case : O(n)
Best Case : O(n)
Average Case : O(n)

Quick Sort Algorithm

Quick sort is a fast sorting algorithm used to sort a list of elements. Quick sort algorithm is invented by **C. A. R. Hoare**.

The quick sort algorithm attempts to separate the list of elements into two parts and then sort each part recursively. That means it use **divide and conquer** strategy. In quick sort, the partition of the list is performed based on the element called ***pivot***. Here pivot element is one of the elements in the list.

The list is divided into two partitions such that **"all elements to the left of pivot are smaller than the pivot and all elements to the right of pivot are greater than or equal to the pivot"**.

Step by Step Process

In Quick sort algorithm, partitioning of the list is performed using following steps...

- **Step 1 -** Consider the first element of the list as **pivot** (i.e., Element at first position in the list).

- **Step 2 -** Define two variables i and j. Set i and j to first and last elements of the list respectively.
- **Step 3 -** Increment i until list[i] > pivot then stop.
- **Step 4 -** Decrement j until list[j] < pivot then stop.
- **Step 5 -** If i < j then exchange list[i] and list[j].
- **Step 6 -** Repeat steps 3,4 & 5 until i > j.
- **Step 7 -** Exchange the pivot element with list[j] element.
-

Let us understand the process of Quick Sort with the following example:

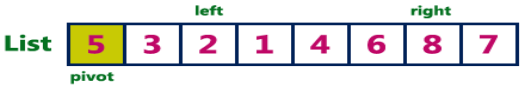
Consider the following unsorted list of elements...

Define pivot, left & right. Set pivot = 0, left = 1 & right = 7. Here '7' indicates 'size-1'.

Compare List[left] with List[pivot]. If **List[left]** is greater than **List[pivot]** then stop left otherwise move left to the next.
Compare List[right] with List[pivot]. If List[right] is smaller than List[pivot] then stop right otherwise move right to the previous.
Repeat the same until **left>=right**.
If both left & right are stoped but left<right then swap List[left] with List[right] and countinue the process.
If left>=right then swap List[pivot] with List[right].

Compare List[left]<List[pivot] as it is true increment left by one and repeat the same, left will stop at 8.
Compare List[right]>List[pivot] as it is true decrement right by one and repeat the same, right will stop at 2.

Here left & right both are stoped and left is not greater than right so we need to swap List[left] and List[right]



Compare List[left]<List[pivot] as it is true increment left by one and repeat the same, left will stop at 6.
Compare List[right]>List[pivot] as it is true decrement right by one and repeat the same, right will stop at 4.

Here left & right both are stoped and left is greater than right so we need to swap List[pivot] and List[right]

Here we can observe that all the numbers to the left side of 5 are smaller and right side are greater. That means 5 is placed in its correct position.
Repeat the same process on the left sublist and right sublist to the number 5.

In the left sublist as there are no smaller number than the pivot left will keep on moving to the next and stops at last number. As the List[right] is smaller, right stops at same position. Now left and right both are equal so we swap pivot with right.

In the right sublist left is grester than the pivot, left will stop at same position.
As the List[right] is greater than List[pivot], right moves towords left and stops at pivot number position.
Now left > right so we swap pivot with right. (6 is swap by itself).

Repeat the same recursively on both left and right sublists until all the numbers are sorted.
The final sorted list will be as follows...

Complexity of the Quick Sort Algorithm

To sort an unsorted list with **'n'** number of elements, we need to make

((n-1)+(n-2)+(n-3)+.....+1) = (n (n-1))/2 number of comparisons in the worst case. If the list is already sorted, then it requires **'n'** number of comparisons.

Worst Case : O(n^2)

Best Case : O (n log n)

Average Case : O (n log n)

Heap Sort Algorithm

Heap sort is one of the sorting algorithms used to arrange a list of elements in order Heap-sort algorithm uses one of the tree concepts called **Heap Tree**. In this sorting algorithm, we use **Max Heap** to arrange list of elements in Descending order and **Min Heap** to arrange list elements in Ascending order.

Step by Step Process

The Heap sort algorithm to arrange a list of elements in ascending order is performed using following steps...

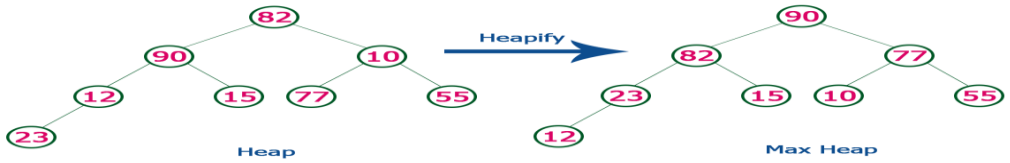
- **Step 1 -** Construct a **Binary Tree** with given list of Elements.
- **Step 2 -** Transform the Binary Tree into **Min Heap.**
- **Step 3 -** Delete the root element from Min Heap using **Heapify** method.
- **Step 4 -** Put the deleted element into the Sorted list.
- **Step 5 -** Repeat the same until Min Heap becomes empty.
- **Step 6 -** Display the sorted list.

Let us understand the working Process of Heap Sort with an example

Consider the following list of unsorted numbers which are to be sort using Heap Sort

82, 90, 10, 12, 15, 77, 55, 23

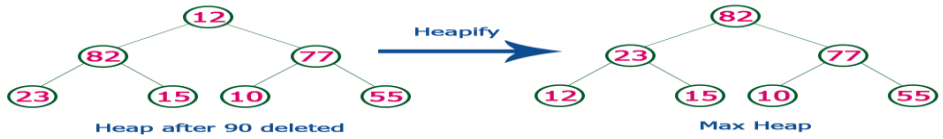
Step 1 - Construct a Heap with given list of unsorted numbers and convert to Max Heap



list of numbers after heap converted to Max Heap

90, 82, 77, 23, 15, 10, 55, 12

Step 2 - Delete root (**90**) from the Max Heap. To delete root node it needs to be swapped with last node (**12**). After delete tree needs to be heapify to make it Max Heap.



list of numbers after swapping 90 with 12.

12, 82, 77, 23, 15, 10, 55, 90

Step 3 - Delete root (**82**) from the Max Heap. To delete root node it needs to be swapped with last node (**55**). After delete tree needs to be heapify to make it Max Heap.

list of numbers after swapping 82 with 55.

12, 55, 77, 23, 15, 10, 82, 90

Step 4 - Delete root (**77**) from the Max Heap. To delete root node it needs to be swapped with last node (**10**). After delete tree needs to be heapify to make it Max Heap.

list of numbers after swapping 77 with 10.

12, 55, 10, 23, 15, 77, 82, 90

Step 5 - Delete root (**55**) from the Max Heap. To delete root node it needs to be swapped with last node (**15**). After delete tree needs to be heapify to make it Max Heap.

list of numbers after swapping 55 with 15.

12, 15, 10, 23, 55, 77, 82, 90

Step 6 - Delete root (**23**) from the Max Heap. To delete root node it needs to be swapped with last node (**12**). After delete tree needs to be heapify to make it Max Heap.

list of numbers after swapping 23 with 12.

12, 15, 10, 23, 55, 77, 82, 90

Step 7 - Delete root (**15**) from the Max Heap. To delete root node it needs to be swapped with last node (**10**). After delete tree needs to be heapify to make it Max Heap.

list of numbers after Deleting 15, 12 & 10 from the Max Heap.

10, 12, 15, 23, 55, 77, 82, 90

Whenever Max Heap becomes Empty, the list get sorted in Ascending order

Complexity of the Heap Sort Algorithm

To sort an unsorted list with **'n'** number of elements, following are the complexities...

Worst Case : O(n log n)

Best Case : O(n log n)

Average Case : O(n log n)

Insertion Sort Algorithm

Sorting is the process of arranging a list of elements in a particular order (Ascending or Descending).

Insertion sort algorithm arranges a list of elements in a particular order. In insertion sort algorithm, every iteration moves an element from unsorted portion to sorted portion until all the elements are sorted in the list.

Step by Step Process

The insertion sort algorithm is performed using the following steps...

- **Step 1 -** Assume that first element in the list is in sorted portion and all the remaining elements are in unsorted portion.
- **Step 2:** Take first element from the unsorted portion and insert that element into the sorted portion in the order specified.
- **Step 3:** Repeat the above process until all the elements from the unsorted portion are moved into the sorted portion.

Consider the following unsorted list of elements...

Asume that sorted portion of the list empty and all elements in the list are in unsorted portion of the list as shown in the figure below...

Move the first element 15 from unsorted portion to sorted portion of the list.

To move element 20 from unsorted to sorted portion, Compare 20 with 15 and insert it at correct position

To move element 10 from unsorted to sorted portion, Compare 10 with 20 and it is smaller so swap. Then compare 10 with 15 again smaller swap. And 10 is insert at its correct position in sorted portion of the list.

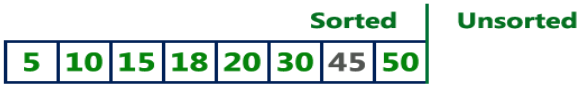
To move element 30 from unsorted to sorted portion, Compare 30 with 20, 15 and 10. And it is larger than all these so 30 is directly inserted at last position in sorted portion of the list.

To move element 50 from unsorted to sorted portion, Compare 50 with 30, 20, 15 and 10. And it is larger than all these so 50 is directly inserted at last position in sorted portion of the list.

To move element 18 from unsorted to sorted portion, Compare 18 with 30, 20 and 15. Since 18 is larger than 15, move 20, 30 and 50 one position to the right in the list and insert 18 after 15 in the sorted portion.

To move element 5 from unsorted to sorted portion, Compare 5 with 50, 30, 20, 18, 15 and 10. Since 5 is smaller than all these element, move 10, 15, 18, 20, 30 and 50 one position to the right in the list and insert 5 at first position in the sorted list.

To move element 45 from unsorted to sorted portion, Compare 45 with 50 and 30. Since 45 is larger than 30, move 50 one position to the right in the list and insert 45 after 30 in the sorted list.



Unsorted portion of the list has became empty. So we stop the process. And the final sorted list of elements is as follows...

Comparison of Sorting Methods

The comparison of sorting methods is performed based on the **Time complexity** and **Space complexity** of sorting methods. The following table provides the time and space complexities of sorting methods. These Time and Space complexities are defined for **'n'** number of elements.

Sorting Method	Time Complexity Worst Case	Time Complexity Average Case	Time Complexity Best Case	Space Complexity
Bubble Sort	**$n(n-1)/2 = O(n^2)$**	**$n(n-1)/2 = O(n^2)$**	**$n(n-1)/2 = O(n^2)$**	**Constant**
Insertion Sort	**$n(n-1)/2 = O(n^2)$**	**$n(n-1)/4 = O(n^2)$**	**O(n)**	**Constant**
Selection Sort	**$n(n-1)/2 = O(n^2)$**	**$n(n-1)/2 = O(n^2)$**	**$n(n-1)/2 = O(n^2)$**	**Constant**
Quick Sort	**$n(n+3)/2 = O(n^2)$**	**O(n log n)**	**O(n log n)**	**Constant**
Heap Sort	**O(n log n)**	**O(n log n)**	**O(n log n)**	**Constant**
Merge Sort	**O(n log n)**	**O(n log n)**	**O(n log n)**	**Depends**