Sorting Algorithms in Java

1. Merge Sort
2. Heap Sort
3. Insertion Sort
4. Selection Sort
5. Bubble Sort

1) Merge Sort

Merge sort is one of the most flexible sorting algorithms in java known to mankind (yes, no kidding). It uses the divide and conquers strategy for sorting elements in an array. It is also a stable sort, meaning that it will not change the order of the original elements in an array concerning each other. The underlying strategy breaks up the array into multiple smaller segments till segments of only two elements (or one element) are obtained. Now, elements in these segments are sorted and the segments are merged to form larger segments. This process continues till the entire array is sorted.

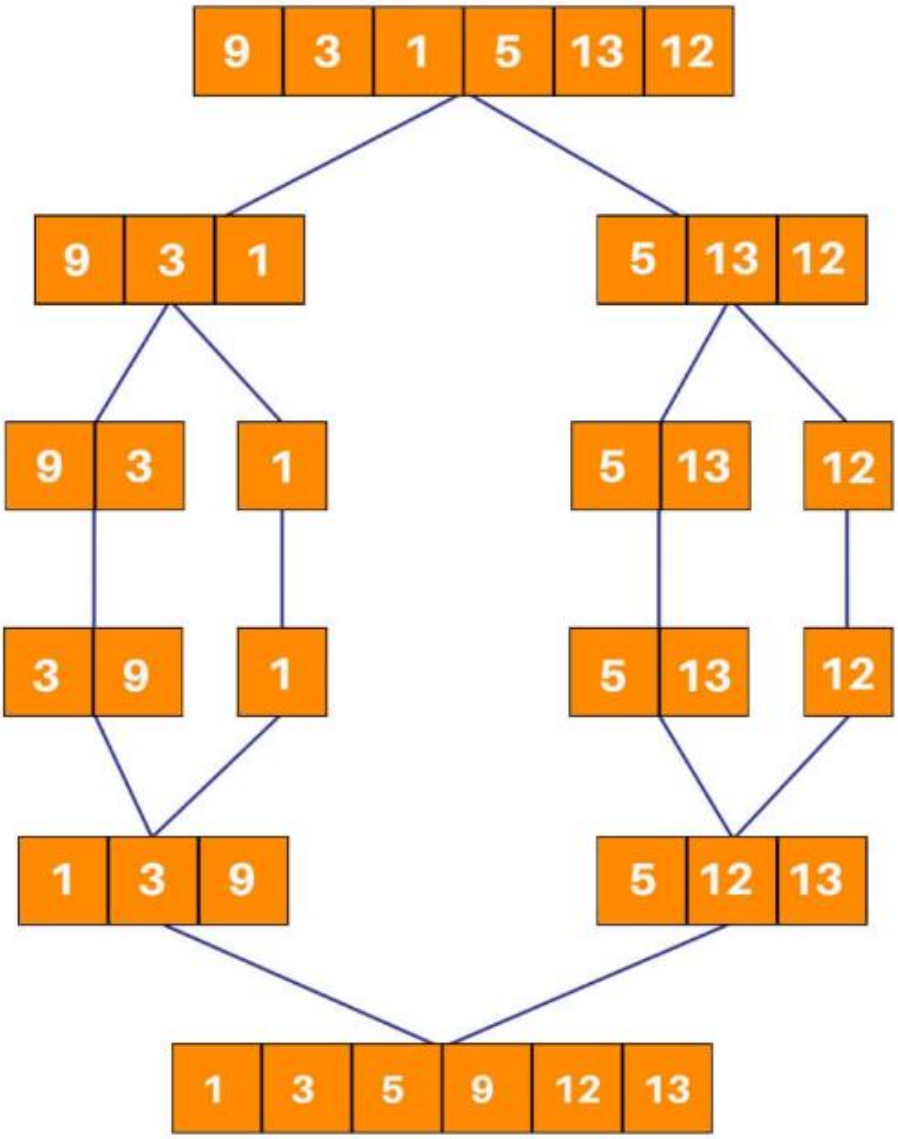
This algorithm has two main parts:

- mergeSort() – This function calculates the middle index for the subarray and then partitions the subarray into two halves. The first half runs from index left to middle, while the second half runs from index middle+1 to right. After the partitioning is done, this function automatically calls the merge() function for sorting the subarray being handled by the mergeSort() call.
- merge() – This function does the actual heavy lifting for the sorting process. It requires the input of four parameters – the array, the starting index (left), the middle index (middle), and the ending index (right). Once received, merge() will split the subarray into two subarrays – one left subarray and one right subarray. The left subarray runs from index left to middle, while the right subarray runs from index middle+1 to right. This function then merges the two subarrays to get the sorted subarray.

Merge Sort Java Code:

```
class Sort
{
    void merge(int arr[], int left, int middle, int right)
    {
        int low = middle - left + 1;          //size of the left subarray
        int high = right - middle;           //size of the right subarray

        int L[] = new int[low];              //create the left and right subarray
        int R[] = new int[high];

        int i = 0, j = 0;

        for (i = 0; i < low; i++)            //copy elements into left subarray
        {
            L[i] = arr[left + i];
        }
        for (j = 0; j < high; j++)         //copy elements into right subarray
        {
            R[j] = arr[middle + 1 + j];
        }


        int k = left;                         //get starting index for sort
        i = 0;                     //reset loop variables before performing merge
        j = 0;

        while (i < low && j < high)        //merge the left and right subarrays
        {
            if (L[i] <= R[j])
            {
                arr[k] = L[i];
                i++;
            }
            else
            {
                arr[k] = R[j];
                j++;
            }
            k++;
        }

        while (i < low)     //merge the remaining elements from the left subarray
        {
            arr[k] = L[i];
            i++;
            k++;
```

```
        }

        while (j < high)     //merge the remaining elements from right subarray
        {
            arr[k] = R[j];
            j++;
            k++;
        }
    }


    void mergeSort(int arr[], int left, int right)       //helper function that
creates the sub cases for sorting
    {
        int middle;
        if (left < right) {      //sort only if the left index is lesser than the
right index (meaning that sorting is done)
            middle = (left + right) / 2;

            mergeSort(arr, left, middle);                    //left subarray
            mergeSort(arr, middle + 1, right);               //right subarray

            merge(arr, left, middle, right);          //merge the two subarrays
        }
    }

    void display(int arr[])                 //display the array
    {
        for (int i=0; i<arr.length; ++i)
        {
            System.out.print(arr[i]+" ");
        }
    }

    public static void main(String args[])
    {
        int arr[] = { 9, 3, 1, 5, 13, 12 };
        Sort ob = new Sort();
        ob.mergeSort(arr, 0, arr.length - 1);
        ob.display(arr);
    }
}
```


9 3 1 5 13 12
9 3 1
5 13 12
9 3
1
5 13
12
3 9
1
5 13
12
1 3 9
5 12 13
1 3 5 9 12 13

2) Heap Sort

Heap sort is one of the most important sorting methods in java that one needs to learn to get into sorting. It combines the concepts of a tree as well as sorting, properly reinforcing the use of concepts from both. A heap is a complete binary search tree where items are stored in a special order depending on the requirement. A min-heap contains the minimum element at the root, and every child of the root must be greater than the root itself. The children at the level after that must be greater than these children, and so on. Similarly, a max-heap contains the maximum element at the root. For the sorting process, the heap is stored as an array where for every parent node at the index i, the left child is at index 2 * i + 1, and the right child is at index 2 * i + 2.

A max heap is built with the elements of the unsorted array, and then the maximum element is extracted from the root of the array and then exchanged with the last element of the array. Once done, the max heap is rebuilt for getting the next maximum element. This process continues till there is only one node present in the heap.

This algorithm has two main parts:-

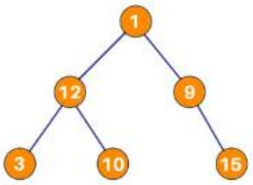
- heapSort() – This function helps construct the max heap initially for use. Once done, every root element is extracted and sent to the end of the array. Once done, the max heap is reconstructed from the root. The root is again extracted and sent to the end of the array, and hence the process continues.
- heapify() – This function is the building block of the heap sort algorithm. This function determines the maximum from the element being examined as the root and its two children. If the maximum is among the children of the root, the root and its child are swapped. This process is then repeated for the new root. When the maximum element in the array is found (such that its children are smaller than it) the function stops. For the node at index i, the left child is at index 2 * i + 1, and the right child is at index 2 * i + 1. (indexing in an array starts from 0, so the root is at 0).

Heap Sort Java Code:

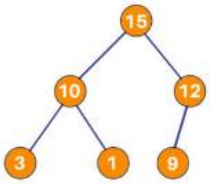
```
class Sort {
    public void heapSort(int arr[])
    {
        int temp;

        for (int i = arr.length / 2 - 1; i >= 0; i--)                //build the
heap
        {
            heapify(arr, arr.length, i);
        }

        for (int i = arr.length - 1; i > 0; i--)
//extract elements from the heap
        {
            temp = arr[0];
//move current root to end (since it is the largest)
            arr[0] = arr[i];
            arr[i] = temp;
            heapify(arr, i, 0);
//recall heapify to rebuild heap for the remaining elements
        }
    }

    void heapify(int arr[], int n, int i)
    {
        int MAX = i; // Initialize largest as root
        int left = 2 * i + 1; //index of the left child of ith node = 2*i + 1
        int right = 2 * i + 2; //index of the right child of ith node  = 2*i + 2
        int temp;

        if (left < n && arr[left] > arr[MAX])            //check if the left
child of the root is larger than the root
        {
            MAX = left;
        }

        if (right < n && arr[right] > arr[MAX])            //check if the right
child of the root is larger than the root
        {
            MAX = right;
        }

        if (MAX != i)
        {                                                 //repeat the procedure
for finding the largest element in the heap
            temp = arr[i];
```

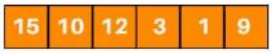
```
            arr[i] = arr[MAX];
            arr[MAX] = temp;
            heapify(arr, n, MAX);
        }
    }

    void display(int arr[])                 //display the array
    {
        for (int i=0; i<arr.length; ++i)
        {
            System.out.print(arr[i]+" ");
        }
    }

    public static void main(String args[])
    {
        int arr[] = { 1, 12, 9 , 3, 10, 15 };

        Sort ob = new Sort();
        ob.heapSort(arr);
        ob.display(arr);
    }
}
```

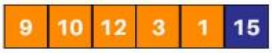
Explanation of how it works:



After construction of max heap:





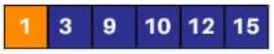


Again, after construction of max heap:

Again, after construction of max heap:

Again, after construction of max heap:

Again, after construction of max heap:



3) Insertion Sort

If you're quite done with more complex sorting algorithms and want to move on to something simpler: insertion sort is the way to go. While it isn't a much-optimized algorithm for sorting an array, it is one of the more easily understood ones. Implementation is pretty easy too. In insertion sort, one picks up an element and considers it to be the key. If the key is smaller than its predecessor, it is shifted to its correct location in the array.

Algorithm:

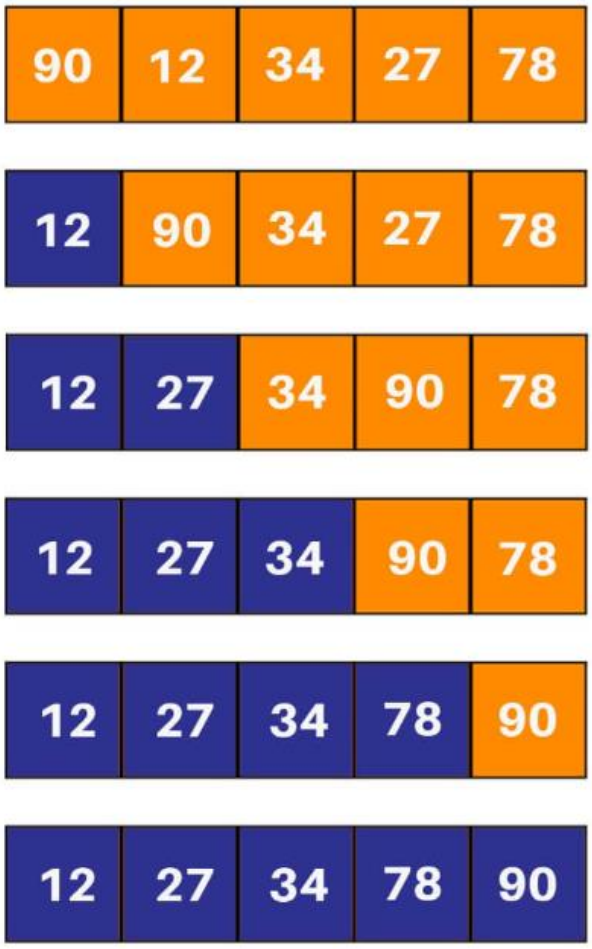
1. START
2. Repeat steps 2 to 4 till the array end is reached.
3. Compare the element at current index i with its predecessor. If it is smaller, repeat step 3.
4. Keep shifting elements from the "sorted" section of the array till the correct location of the key is found.
5. Increment loop variable.
6. END

Insertion Sort Java Code:

```
class Sort
{
    static void insertionSort(int arr[], int n)
    {
        if (n <= 1)                             //passes are done
        {
            return;
        }

        insertionSort( arr, n-1 );        //one element sorted, sort the remaining array

        int last = arr[n-1];                        //last element of the array
        int j = n-2;                                //correct index of last element of
            the array

        while (j >= 0 && arr[j] > last)                 //find the correct index of the
            last element
        {
            arr[j+1] = arr[j];                          //shift section of sorted
                elements upwards by one element if correct index isn't found
            j--;
        }
        arr[j+1] = last;                            //set the last element at its
            correct index
    }
```

```
     void display(int arr[])                 //display the array
     {
         for (int i=0; i<arr.length; ++i)
         {
             System.out.print(arr[i]+" ");
         }
     }


     public static void main(String[] args)
     {
         int arr[] = {22, 21, 11, 15, 16};

         insertionSort(arr, arr.length);
         Sort ob = new Sort();
         ob.display(arr);
     }
 }
```

Explanation of how it works:



4) Selection Sort

Quadratic sorting algorithms are some of the more popular sorting algorithms that are easy to understand and implement. These don't offer a unique or optimized approach for sorting the array - rather they should offer building blocks for the concept of sorting itself for someone new to it. In selection sort, two loops are used. The inner loop one picks the minimum element from the array and shifts it to its correct index indicated by the outer loop. In every run of the outer loop, one element is shifted to its correct location in the array. It is a very popular sorting algorithm in python as well.

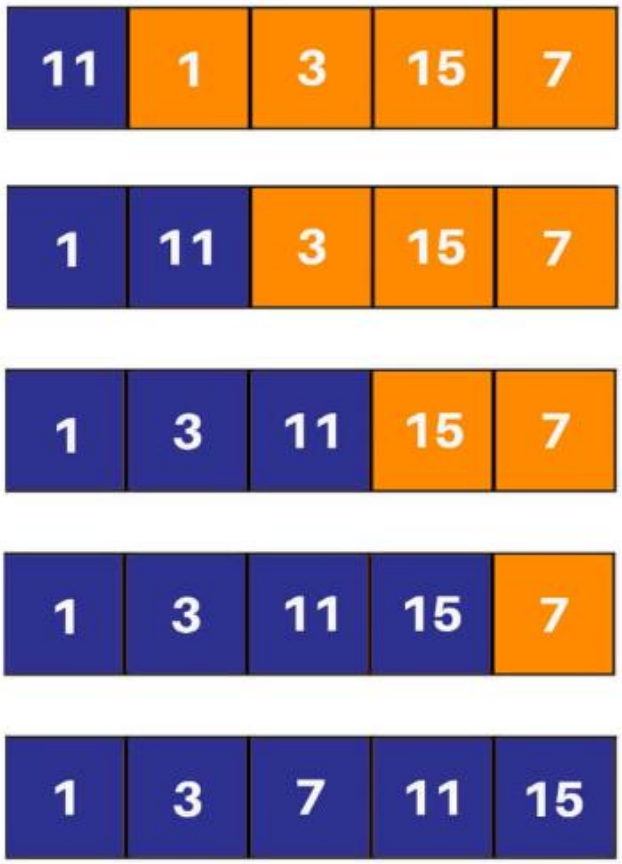
Algorithm:

1. START
2. Run two loops: an inner loop and an outer loop.
3. Repeat steps till the minimum element are found.
4. Mark the element marked by the outer loop variable as a minimum.
5. If the current element in the inner loop is smaller than the marked minimum element, change the value of the minimum element to the current element.
6. Swap the value of the minimum element with the element marked by the outer loop variable.
7. END

Selection Sort Java Code:

```java
class Sort
{
    void selectionSort(int arr[])
    {
        int pos;
        int temp;
        for (int i = 0; i < arr.length; i++)
        {
            pos = i;
            for (int j = i+1; j < arr.length; j++)
           {
                if (arr[j] < arr[pos])                  //find the index of the minimum element
                {
                    pos = j;
                }
            }

            temp = arr[pos];            //swap the current element with the minimum element
            arr[pos] = arr[i];
            arr[i] = temp;
        }
    }

    void display(int arr[])                     //display the array
    {
        for (int i=0; i<arr.length; i++)
        {
            System.out.print(arr[i]+" ");
        }
    }

    public static void main(String args[])
    {
        Sort ob = new Sort();
        int arr[] = {64,25,12,22,11};
        ob.selectionSort(arr);
        ob.display(arr);
    }
}
```

Explanation of how it works:



5) Bubble Sort

The two algorithms that most beginners start their sorting career with would be bubble sort and selection sort. These sorting algorithms are not very efficient, but they provide a key insight into what sorting is and how a sorting algorithm works behind the scenes. Bubble sort relies on multiple swaps instead of a single like selection sort. The algorithm continues to go through the array repeatedly, swapping elements that are not in their correct location.

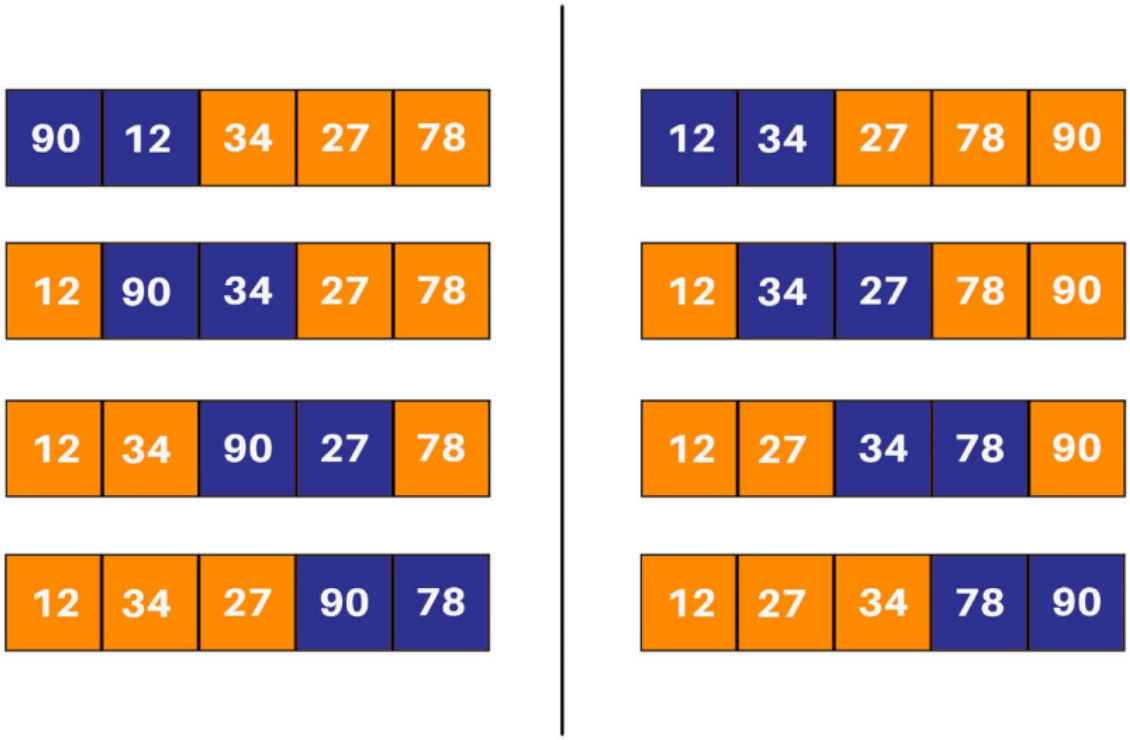
Algorithm:

1. START
2. Run two loops – an inner loop and an outer loop.
3. Repeat steps till the outer loop are exhausted.
4. If the current element in the inner loop is smaller than its next element, swap the values of the two elements.
5. END

Bubble Sort Java Code:

```
class Sort
{
    static void bubbleSort(int arr[], int n)
    {
        if (n == 1)                     //passes are done
        {
            return;
        }

        for (int i=0; i<n-1; i++)       //iteration through unsorted elements
        {
            if (arr[i] > arr[i+1])      //check if the elements are in order
            {                           //if not, swap them
                int temp = arr[i];
                arr[i] = arr[i+1];
                arr[i+1] = temp;
            }
        }

        bubbleSort(arr, n-1);           //one pass done, proceed to the next
    }

    void display(int arr[])                 //display the array
    {
        for (int i=0; i<arr.length; ++i)
        {
            System.out.print(arr[i]+" ");
        }
    }

    public static void main(String[] args)
    {
        Sort ob = new Sort();
        int arr[] = {6, 4, 5, 12, 2, 11, 9};
        bubbleSort(arr, arr.length);
        ob.display(arr);
    }
}
```

Explanation of how it works:



Time Complexity

Now, learn about the time complexity of each sorting algorithm in java. Merge sort is a divide and conquer algorithm - hence it offers a more optimized approach for sorting than the others. The time complexity of mergeSort() function is O(nlogn) while the time complexity of merge() function is O(n) - making the average complexity of the algorithm as O(nlogn). Heap sort, like merge sort, is an optimized sorting algorithm (even though it is not a part of the divide and conquer paradigm). The time complexity of heapify() is O(nlogn) while the time complexity of the heapSort() function is O(n) – making the average complexity of the algorithm as O(nlogn). Selection sort, bubble sort, and insertion sort all have the best case time complexity is O(n) and the worst-case time complexity is $O(n^2)$.

Algorithm	Approach	Best Time Complexity
Merge Sort	Split the array into smaller subarrays till pairs of elements are achieved, and then combine them in such a way that they are in order.	O(n log (n))
Heap Sort	Build a max (or min) heap and extract the first element of the heap (or root), and then send it to the end of the heap. Decrement the size of the heap and repeat till the heap has only one node.	O(n log (n))
Insertion Sort	In every run, compare it with the predecessor. If the current element is not in the correct location, keep shifting the predecessor subarray till the correct index for the element is found.	O (n)
Selection Sort	Find the minimum element in each run of the array and swap it with the element at the current index is compared.	O(n^2)
Bubble Sort	Keep swapping elements that are not in their right location till the array is sorted.	O (n)