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Lecture 25: An Introduction to Sorting - 1

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Sorting

- Arranging things into either ascending or descending order is called sorting.
- We seek algorithms to arrange items, a_i, such that

  $a_1 \leq a_2 \leq . . . \leq a_n$
- Sorting an array is usually easier than sorting a chain of linked nodes.
- Efficiency of a sorting algorithm is significant.

Sorting Algorithms

- Selection Sort
- Insertion Sort
- Shell Sort
- Merge Sort
- Quick Sort
- Radix Sort
- Bubble sort
- Heapsort
- Introsort
- Timsort
- Cubesort
- …

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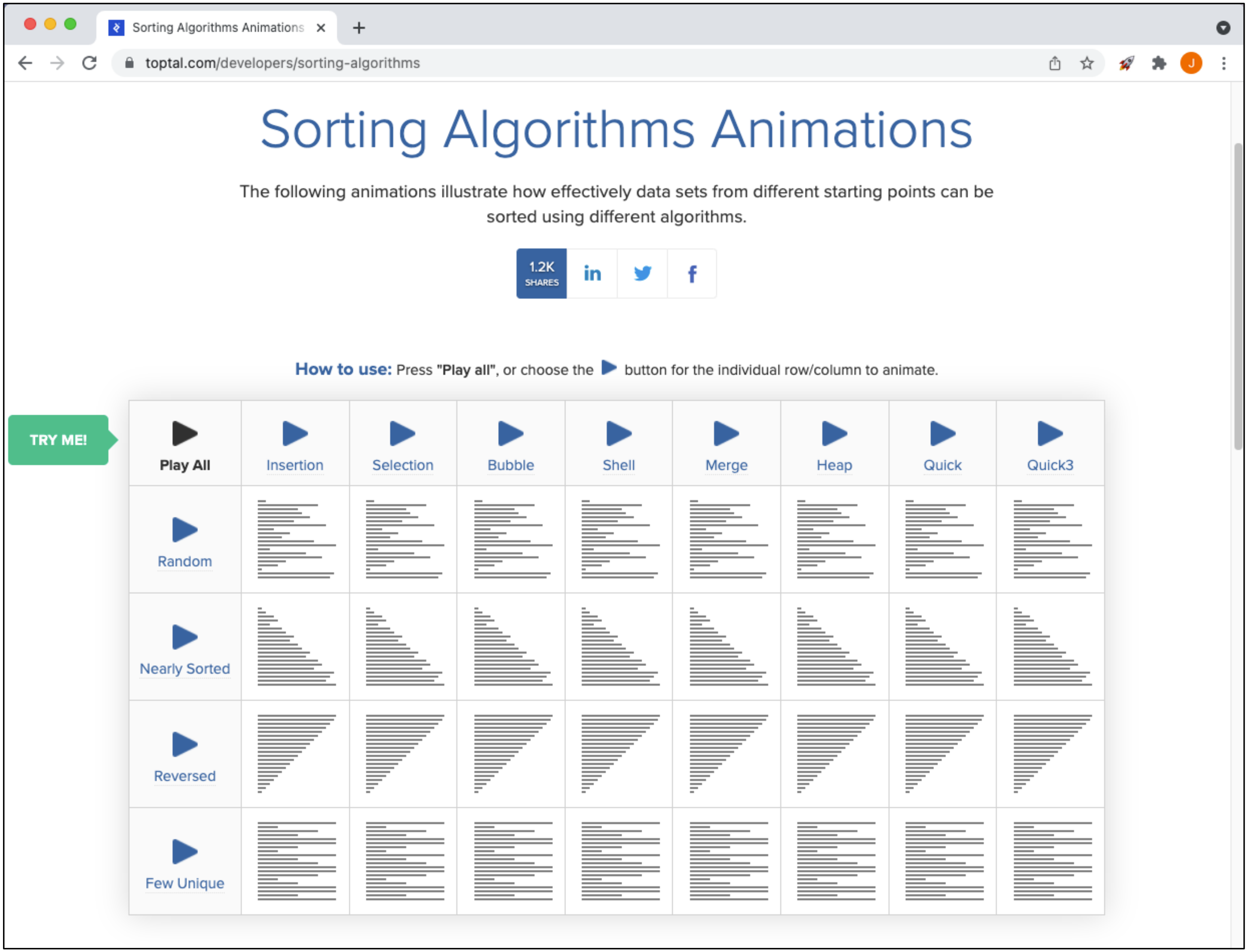
Sorting Algorithms Animations
toptal.com/developers/sorting-algorithms
1.2K SHARES
TRY ME!

Sorting Algorithms Animations

The following animations illustrate how effectively data sets from different starting points can be sorted using different algorithms.

How to use: Press **"Play all"**, or choose the ▶ button for the individual row/column to animate.

▶ Play All	▶ Insertion	▶ Selection	▶ Bubble	▶ Shell	▶ Merge	▶ Heap	▶ Quick	▶ Quick3
▶ Random								
▶ Nearly Sorted								
▶ Reversed								
▶ Few Unique								

Sorting Algorithm Animation: http://www.sorting-algorithms.com/

Selection Sort

Selection Sort

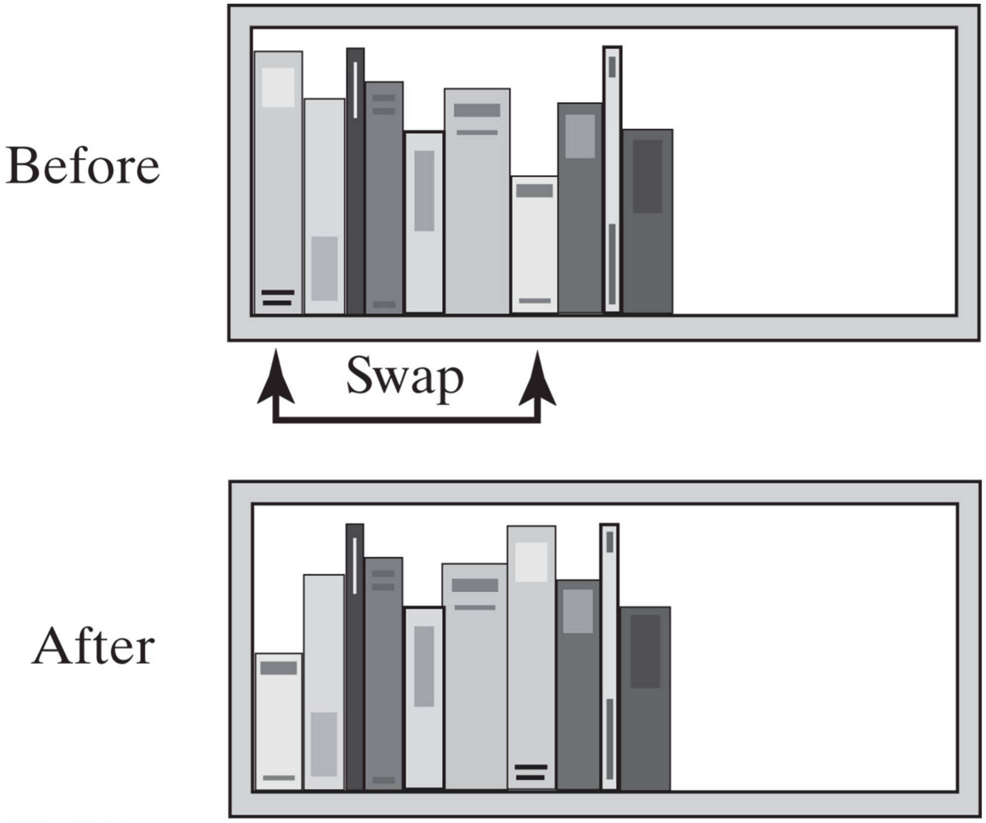

Figure 15-1: Before and after exchanging the shortest book and the first book

Selection Sort

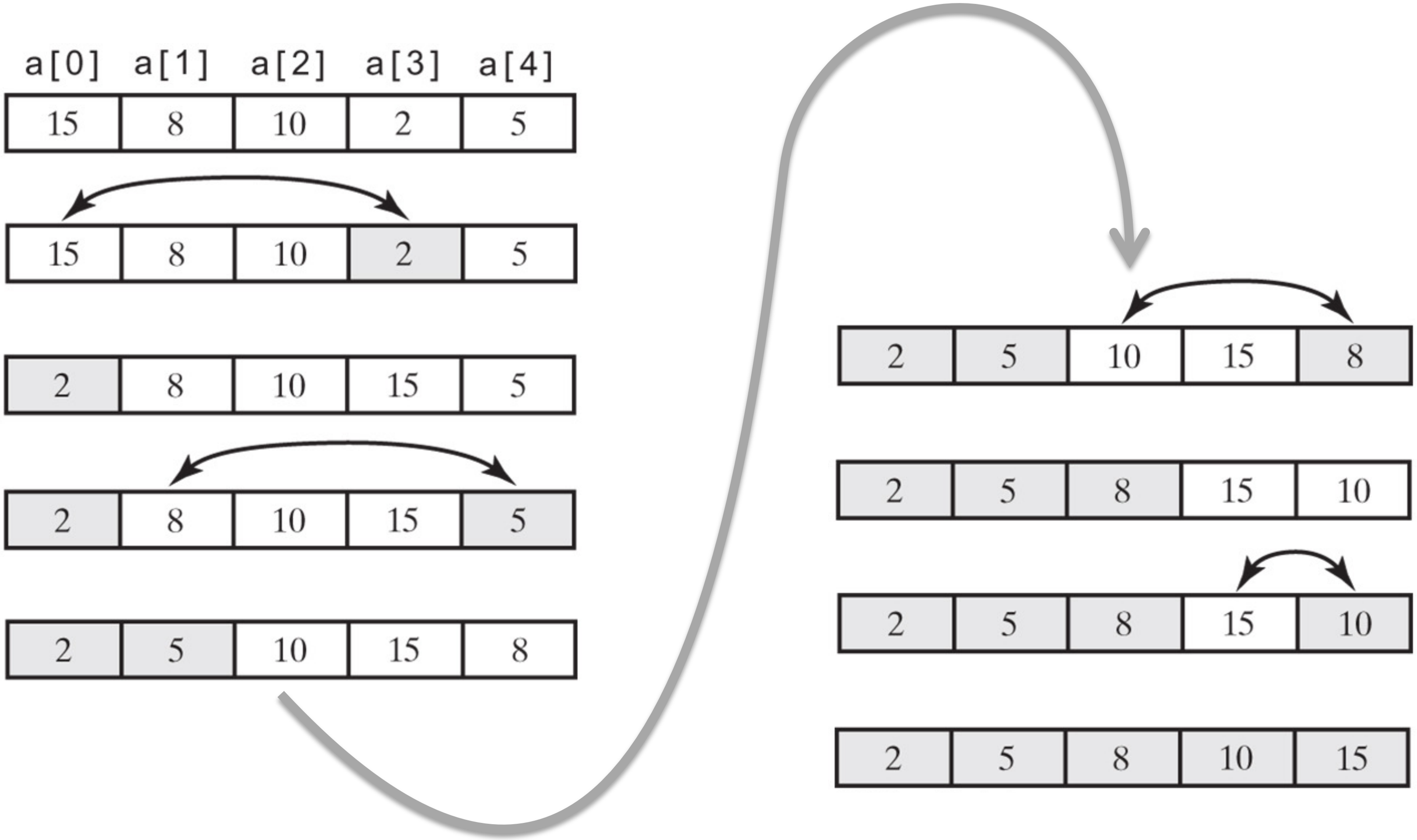

Figure 15-2: A selection sort of an array of integers into ascending order

Iterative Selection Sort

```
Algorithm selectionSort(a, n)

// Sorts the first n entries of an array a.
for (index = 0; index < n – 1; index++)
{

  indexOfNextSmallest = the index of the smallest value among
                                  a[index], a[index + 1], . . . , a[n – 1]
  Interchange the values of a[index] and a[indexOfNextSmallest]

  // Assertion: a[0] ≤ a[1] ≤ . . . ≤ a[index], and these are the smallest
  // of the original array entries. The remaining array entries begin at a[index + 1].

}
```

This pseudocode describes an iterative algorithm for the selection sort

Iterative Selection Sort - Part 1

```
/**  A class of static, iterative methods for sorting an array of
   Comparable objects from smallest to largest. */
public class SortArray
{
   /** Sorts the first n objects in an array into ascending order.
       @param a  An array of Comparable objects.
       @param n  An integer > 0. */
   public static <T extends Comparable<? super T>>
          void selectionSort(T[] a, int n)
   {
      for (int index = 0; index < n – 1; index++)
      {
         int indexOfNextSmallest = getIndexOfSmallest(a, index, n – 1);
         swap(a, index, indexOfNextSmallest);
      // Assertion: a[0] <= a[1] <= . . . <= a[index] <= all other a[i]
      } // end for
   } // end selectionSort
```

Listing 15-1: A class for sorting an array using selection sort

Iterative Selection Sort - Part 2

```java
// Finds the index of the smallest value in a portion of an array a.
// Precondition: a.length > last >= first >= 0.
// Returns the index of the smallest value among
// a[first], a[first + 1], . . . , a[last].
private static <T extends Comparable<? super T>>
        int getIndexOfSmallest(T[] a, int first, int last)
{
   T min = a[first];
   int indexOfMin = first;
   for (int index = first + 1; index <= last; index++)
   {
      if (a[index].compareTo(min) < 0)
      {
         min = a[index];
         indexOfMin = index;
      } // end if
      // Assertion: min is the smallest of a[first] through a[index].
   } // end for

   return indexOfMin;
} // end getIndexOfSmallest
```

Listing 15-1: A class for sorting an array using selection sort

Iterative Selection Sort - Part 3

```
  // Swaps the array entries a[i] and a[j].
   private static void swap(Object[] a, int i, int j)
   {
      Object temp = a[i];
      a[i] = a[j];
      a[j] = temp;
   } // end swap
} // end SortArray
```

Listing 15-1: A class for sorting an array using selection sort

Recursive Selection Sort

```
Algorithm selectionSort(a, first, last)

// Sorts the array entries a[first] through a[last] recursively.
if (first < last)
{
  indexOfNextSmallest = the index of the smallest value among
                                  a[first], a[first + 1], . . . , a[last]
  Interchange the values of a[first] and a[indexOfNextSmallest]

  // Assertion: a[0] ≤ a[1] ≤ . . . ≤ a[first] and these are the smallest
  // of the original array entries. The remaining array entries begin at a[first + 1].

  selectionSort(a, first + 1, last)
}
```

Recursive selection sort algorithm

Exercise

- Show the contents of the array of integers 5 7 4 9 8 5 6 3 each time a selection sort changes it while sorting the array into ascending order.

Answer

Initial array:

5 7 4 9 8 5 6 3

Array after each selection and swap:

5 7 4 9 8 5 6 3

3 7 4 9 8 5 6 5

3 4 7 9 8 5 6 5

3 4 5 9 8 7 6 5

3 4 5 5 8 7 6 9

3 4 5 5 6 7 8 9

Two more passes are performed, but they just swap the 7 with itself and the 8 with itself.

Efficiency of Selection Sort

- Selection sort is $O(n^2)$ regardless of the initial order of the entries.
  - Requires $O(n^2)$ comparisons
  - Does only $O(n)$ swaps

Exercise

- Write pseudocode for a selection sort algorithm that selects the largest, instead of the smallest, entry in the array and sorts the array into descending order.

Answer

```
Algorithm selectionSort(a, n)

// Sorts the first n entries of an array a into descending order.

for (index = 0; index < n − 1; index++)
{
   indexOfNextLargest = the index of the largest value among a[index],
                                 a[index + 1], . . . , a[n − 1]

   Interchange the values of a[index] and a[indexOfNextLargest]

   // Assertion: a[0] ≥ a[1] ≥ . . . ≥ a[index], and these are the largest of
   // the original array entries.

   // The remaining array entries begin at a[index + 1].
}
```