Which of the following is the efficient way to search for an element in an unsorted list?

A. Perform linear search
B. Perform binary search
C. Sort the list, then perform linear search
D. Sort the list, then perform binary search
E. Whatever
**Search Time Complexity**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Best</th>
<th>Worst</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>$O(1)$</td>
<td>$O(n)$</td>
<td>$O(n)$</td>
</tr>
<tr>
<td>Binary</td>
<td>$O(1)$</td>
<td>$O(\log n)$</td>
<td>$O(\log n)$</td>
</tr>
</tbody>
</table>

- Caveat: Binary search only works on sorted data.
- Some classes are sortable: Integer, String, …
- But how do we define new sortable classes?
Today’s Outline

• Defining Sortable Classes
  • Comparable
  • Comparator
• Sort
  • Bubble Sort
  • Selection Sort
2 Types of Sortable Classes

• One “obvious” way to compare/sort
  • Examples: Integer
  • Make the given class Comparable (=implement Comparable)

• Multiple ways to compare/sort
  • Examples: PatientRecord
  • Make Comparator classes
    • E.g. nameComparator, idComparator
Today’s Outline

- Defining Sortable Classes
  - Comparable
  - Comparator
- Sort
  - Bubble Sort
  - Selection Sort
public interface Comparable<T> {
    public int compareTo(T o);
}

Comparable\textless{}E\textgreater{} Interface

- “Class X implement Comparable\textless{}X\textgreater{}”
  - “X contains \texttt{compareTo(X obj)} method”
  - “X can compare objects of class X”
- To compare object A to object B (both of type X), call \texttt{A.compareTo(B)}, which returns an int:
  - Negative when A is “<” in rank
  - Zero A and B are “=” in rank
  - Positive when A is “>” in rank
Example: `Integer`

```java
public class Integer ... implements Comparable<Integer> {
    ...
    // From Java6 Integer implementation (renamed variables)
    public int compareTo(Integer anotherInteger) {
        int x = this.value;
        int y = anotherInteger.value;
        return (x < y ? -1 : (x == y ? 0 : 1));
    }
}
```
Given the lines above, which of the following is true?

A. val < 0  
B. val = 0  
C. val > 0  
D. Not sure
Today’s Outline

• Defining Sortable Classes
  • Comparable
  • Comparator
• Sort
  • Bubble Sort
  • Selection Sort
public interface Comparator<T> {
    ...
    int compare(T o1, T o2);
    ...
}
Comparator\(<E>\) Interface

• “Class X implements Comparator\(<Y>\)”
  → “X contains \textbf{compare}(Y \texttt{obj1}, Y \texttt{obj2}) method.”
  → “X can compare objects of class Y”

• To compare object A to object B (both of type Y), create an object C (of type X) and call
  \texttt{C.compare(A, B)}, which returns an int:
  • Negative when A is “<” in rank
  • Zero A and B are “=” in rank
  • Positive when A is “>” in rank
Example: Comparator

class Patient {
    protected int age;
    protected String name;
    public Patient (String s, int a) {name = s; age = a;}
    public String getName() { return name; }
    public int getAge() {return age;}
}

class AgeComparator implements Comparator<Patient>{
    public int compare(Patient a, Patient b) {
        return a.getAge() - b.getAge();
    }
}

class NameComparator implements Comparator<Patient>{
    public int compare(Patient a, Patient b) {
        return a.getName().compareTo(b.getName());
    }
}
Exercise: *Patient* class

Patient A = new Patient(“Deepak”, 27);
Patient B = new Patient(“Jenny”, 52);

Given the lines above, how would you figure out the order between A and B?

```java
NameComparator c = new NameComparator();
c.compare(A, B);
```
### 2 Types of Sortable Classes

- Classes with 1 “obvious” way to compare/sort (a) vs Classes with multiple ways to compare/sort (b)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implements Comparable&lt;E&gt; (i.e. contains compareTo(E otherObj))</td>
<td>☒</td>
<td>✗</td>
</tr>
<tr>
<td>Need comparator classes containing compare(E obj1, E obj2)</td>
<td>✗</td>
<td>☒</td>
</tr>
<tr>
<td>The class itself supports comparison</td>
<td>☒</td>
<td>✗</td>
</tr>
<tr>
<td>Can be compared/sorted in multiple ways</td>
<td>✗</td>
<td>☒</td>
</tr>
</tbody>
</table>
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• Defining Sortable Classes
  • Comparable
  • Comparator
• Sort
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  • Selection Sort
Sorting a Deck of Cards

• Come up with your own algorithm! (and let me know when one of the algorithms presented today is exactly like yours. ;) )

• Hint: If you’re stuck, think of it this way:
  • After 1st iteration, at least 1 item is sorted.
  • After ith iteration, at least i items are sorted.
  • After nth iteration, all items are sorted. Done!
  • What needs to happen during each iteration?
Sorting a Deck of Cards

Time Complexity:
A. $O(n)$ ← best
B. $O(n \log n)$
C. $O(n^2)$ ← Ave, worst
D. $O(n^3)$
E. Not sure
Bubble Sort

First Pass:
- [5 1 3 2 9]
- [1 5 3 2 9]
- [1 3 5 2 9]
- [1 3 2 5 9]

Second Pass:
- [1 3 2 5 9]
- [1 3 2 5 9]
- [1 2 3 5 9]
- [1 2 3 5 9]

Third Pass:
- [1 2 3 5 9]
- [1 2 3 5 9]
- [1 2 3 5 9]
- [1 2 3 5 9]
Bubble Sort

public static void bubbleSort(int[] data) {
    for (int curN = data.length - 1; curN > 0; curN--)
        boolean swapped = false;
    for (int i = 1; i <= curN; i++)
        if (data[i-1] > data[i])
            swap(data, i, i-1);
        swapped = true;
    if (!swapped)
        break;
}

O \left( n \right)

O \left( n^2 \right)

Best
Bubble Sort Summary

• Overview
  • After $ith$ iteration, at least $i$ items are sorted.
  • During $ith$ iteration, sweep through the unsorted portion of the list, swapping 2 adjacent elements if the right one is smaller. (End after iteration $i$ if no swapping happens!)

• Time complexity:
  • Best case: $O(n)$
  • Worst case: $O(n^2)$
  • Average case: $O(n^2)$
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Time Complexity:
A. $O(n)$
B. $O(n \log n)$
C. $O(n^2)$ ← worst, ave, best
D. $O(n^3)$
E. Not sure
Selection Sort

- [11 3 27 5 16]
- [11 3 16 5 27]
- [11 3 5 16 27]
- [5 3 11 16 27]
- [3 5 11 16 27]
public static void selectionSort(int[] data) {
    for (int curN = data.length - 1; curN > 0; curN--) {
        int maxIdx = 0;
        for (int i = 1; i <= curN; i++) {
            if (data[i] > data[maxIdx])
                maxIdx = i;
        }
        swap(data, maxIdx, curN);
    }
}
Selection Sort Summary

• Overview
  • After $ith$ iteration, at least $i$ items are sorted.
    $\Rightarrow$ the list is sorted at least after $n$ iterations.
  • During $ith$ iteration, select the max item in the unsorted portion of the list and move it to right-most location of the unsorted portion.

• Time complexity:
  • Best case: $O(n^2)$
  • Worst case: $O(n^2)$
  • Average case: $O(n^2)$