The Comparable Interface

reading: 10.2

Binary search and objects

- Can we `binarySearch` an array of Strings?
  - Operators like `<` and `>` do not work with `String` objects.
  - But we do think of strings as having an alphabetical ordering.

- **natural ordering**: Rules governing the relative placement of all values of a given type.

- **comparison function**: Code that, when given two values *A* and *B* of a given type, decides their relative ordering:
  - A < B, A == B, A > B

`Collections` class

Method name	Description
`binarySearch(`**list**`,` **value**`)`	returns the index of the given value in a sorted list (< 0 if not found)
`copy(`**listTo**`,` **listFrom**`)`	copies **listFrom**'s elements to **listTo**
`emptyList(), emptyMap(), emptySet()`	returns a read-only collection of the given type that has no elements
`fill(`**list**`,` **value**`)`	sets every element in the list to have the given value
`max(`**collection**`), min(`**collection**`)`	returns largest/smallest element
`replaceAll(`**list**`,` **old**`,` **new**`)`	replaces an element value with another
`reverse(`**list**`)`	reverses the order of a list's elements
`shuffle(`**list**`)`	arranges elements into a random order
`sort(`**list**`)`	arranges elements into ascending order

The `compareTo` method (10.2)

- The standard way for a Java class to define a comparison function for its objects is to define a `compareTo` method.
  - Example: in the `String` class, there is a method:

```
public int compareTo(String other)
```

- A call of **A**`.compareTo(`**B**`)` will return:

a value < 0	if **A** comes "before" **B** in the ordering,
a value > 0	if **A** comes "after" **B** in the ordering,
0	if **A** and **B** are considered "equal" in the ordering.

Using `compareTo`

- `compareTo` can be used as a test in an `if` statement.

```
String a = "alice";
String b = "bob";
if (a.compareTo(b) < 0) {  // true
    ...
}
```

Primitives	Objects
`if (a < b) { ...`	`if (a.compareTo(b) < 0) { ...`
`if (a <= b) { ...`	`if (a.compareTo(b) <= 0) { ...`
`if (a == b) { ...`	`if (a.compareTo(b) == 0) { ...`
`if (a != b) { ...`	`if (a.compareTo(b) != 0) { ...`
`if (a >= b) { ...`	`if (a.compareTo(b) >= 0) { ...`
`if (a > b) { ...`	`if (a.compareTo(b) > 0) { ...`

Binary search w/ strings

```
// Returns the index of an occurrence of target in a,
// or a negative number if the target is not found.
// Precondition: elements of a are in sorted order
public static int binarySearch(String[] a, int target) {
    int min = 0;
    int max = a.length - 1;

    while (min <= max) {
        int mid = (min + max) / 2;
        if (a[mid].compareTo(target) < 0) {
            min = mid + 1;
        } else if (a[mid].compareTo(target) > 0) {
            max = mid - 1;
        } else {
            return mid;    // target found
        }
    }

    return -(min + 1);     // target not found
}
```

`compareTo` and collections

- You can use an array or list of strings with Java's included binary search method because it calls `compareTo` internally.

```
String[] a = {"al", "bob", "cari", "dan", "mike"};
int index = Arrays.binarySearch(a, "dan");  // 3
```

- Java's `TreeSet/Map` use `compareTo` internally for ordering.

```
Set<String> set = new TreeSet<String>();
for (String s : a) {
    set.add(s);
}
System.out.println(s);
// [al, bob, cari, dan, mike]
```

Ordering our own types

- We cannot binary search or make a `TreeSet`/`Map` of arbitrary types, because Java doesn't know how to order the elements.
  - The program compiles but crashes when we run it.

```
Set<HtmlTag> tags = new TreeSet<HtmlTag>();
tags.add(new HtmlTag("body", true));
tags.add(new HtmlTag("b", false));
...

Exception in thread "main"
  java.lang.ClassCastException
        at java.util.TreeSet.add(TreeSet.java:238)
```

Interfaces (9.5)

- **interface**: A list of methods that a class can promise to implement.
  - Inheritance gives you an is-a relationship *and* code sharing.
    - A `Lawyer` can be treated as an `Employee` and inherits its code.
  - Interfaces give you an is-a relationship *without* code sharing.
    - A `Rectangle` object can be treated as a `Shape` but inherits no code.
  - Analogous to non-programming idea of roles or certifications:
    - "I'm certified as a CPA accountant.
      This assures you I know how to do taxes, audits, and consulting."
    - "I'm 'certified' as a Shape, because I implement the Shape interface.
      This assures you I know how to compute my area and perimeter."

Comparable (10.2)

```
public interface Comparable<E> {
    public int compareTo(E other);
}
```

- A class can implement the `Comparable` interface to define a natural ordering function for its objects.

- A call to your `compareTo` method should return:

a value < 0	if the `this` object comes "before" `other` one,
a value > 0	if the `this` object comes "after" `other` one,
0	if the `this` object is considered "equal" to `other`.

Poll Everywhere

pollev.com/cse143

```
Cat cat1 = new Cat("Clawdia", 6, 3.6);
Cat cat2 = new Cat("Shakespurr", 2, 1.4);
Cat cat3 = new Cat("Grumpy", 6, 3.8);

List<Cat> cats = Arrays.asList(cat1, cat2, cat3);
Collections.sort(cats);
```

- What is the order of the list after we sort?

[cat1, cat2, cat3]
[cat1, cat3, cat2]
[cat2, cat1, cat3] ☆
[cat2, cat3, cat1] ← seems right, but code has a bug because of casting
[cat3, cat1, cat2]
[cat3, cat2, cat1]

```
// first sort on lives in ascending order
// then sort on cuteness in descending order
public int compareTo(Cat other) {
  if (other.lives != this.lives) {
    return this.lives - other.lives;
  } else {
    return (int) (other.cuteness - this.cuteness);
  }
}
```

Comparable template

```
public class name implements Comparable<name> {

    ...

    public int compareTo(name other) {
        ...
    }
}
```

Comparable example

```
public class Point implements Comparable<Point> {
    private int x;
    private int y;
    ...

    // sort by x and break ties by y
    public int compareTo(Point other) {
        if (x < other.x) {
            return -1;
        } else if (x > other.x) {
            return 1;
        } else if (y < other.y) {
            return -1;    // same x, smaller y
        } else if (y > other.y) {
            return 1;     // same x, larger y
        } else {
            return 0;     // same x and same y
        }
    }
}
```

`compareTo` tricks

- *subtraction trick* - Subtracting related numeric values produces the right result for what you want `compareTo` to return:

```
// sort by x and break ties by y
public int compareTo(Point other) {
    if (x != other.x) {
        return x - other.x;   // different x
    } else {
        return y - other.y;   // same x; compare y
    }
}
```

  - The idea:
    - if `x > other.x`, then `x - other.x > 0`
    - if `x < other.x`, then `x - other.x < 0`
    - if `x == other.x`, then `x - other.x == 0`
      - NOTE: This trick doesn't work for `doubles` (but see `Math.signum`)

`compareTo` tricks 2

- *delegation trick* - If your object's fields are comparable (such as strings), use their `compareTo` results to help you:

```
// sort by employee name, e.g. "Jim" < "Susan"
public int compareTo(Employee other) {
    return name.compareTo(other.getName());
}
```

- *`toString` trick* - If your object's `toString` representation is related to the ordering, use that to help you:

```
// sort by date, e.g. "09/19" > "04/01"
public int compareTo(Date other) {
    return toString().compareTo(other.toString());
}
```

Exercises

- Make the `HtmlTag` class from HTML Validator comparable.
  - Compare tags by their elements, alphabetically by name.
  - For the same element, opening tags come before closing tags.

```
// <body><b></b><i><b></b><br/></i></body>
Set<HtmlTag> tags = new TreeSet<HtmlTag>();
tags.add(new HtmlTag("body", true));    // <body>
tags.add(new HtmlTag("b", true));       // <b>
tags.add(new HtmlTag("b", false));      // </b>
tags.add(new HtmlTag("i", true));       // <i>
tags.add(new HtmlTag("b", true));       // <b>
tags.add(new HtmlTag("b", false));      // </b>
tags.add(new HtmlTag("br"));            // <br />
tags.add(new HtmlTag("i", false));      // </i>
tags.add(new HtmlTag("body", false));   // </body>
System.out.println(tags);
// [<b>, </b>, <body>, </body>, <br />, <i>, </i>]
```

Exercise solution

```
public class HtmlTag implements Comparable<HtmlTag> {
    ...
    // Compares tags by their element ("body" before "head"),
    // breaking ties with opening tags before closing tags.
    // Returns < 0 for less, 0 for equal, > 0 for greater.
    public int compareTo(HtmlTag other) {
        int compare = element.compareTo(other.getElement());
        if (compare != 0) {
            // different tags; use String's compareTo result
            return compare;
        } else {
            // same tag
            if ((isOpenTag == other.isOpenTag()) {
                return 0;   // exactly the same kind of tag
            } else if (other.isOpenTag()) {
                return 1;   // he=open, I=close; I am after
            } else {
                return -1;  // I=open, he=close; I am before
            }
        }
    }
}
```