11.3 Comparables

One Sizable Application of Subtype Polymorphism

Max Function

Say we want to write a `max` function which takes in any array - regardless of type - and returns the maximum item in the array.

Exercise 4.3.1. Your task is to determine how many compilation errors there are in the code below.

```
public static Object max(Object[] items) {
    int maxDex = 0;
    for (int i = 0; i < items.length; i += 1) {
        if (items[i] > items[maxDex]) {
            maxDex = i;
        }
    }
    return items[maxDex];
}

public static void main(String[] args) {
    Dog[] dogs = {new Dog("Elyse", 3), new Dog("Sture", 9), new Dog("Benjamin",
    Dog maxDog = (Dog) max(dogs);
    maxDog.bark();
}
```

In the code above, there was only 1 error, found at this line:

```
if (items[i] > items[maxDex]) {
```

The reason why this results in a compilation error is because this line assumes that the `>` operator works with arbitrary Object types, when in fact it does not.

Instead, one thing we could is define a `maxDog` function in the Dog class, and give up on writing a "one true max function" that could take in an array of any arbitrary type. We might define something like this:

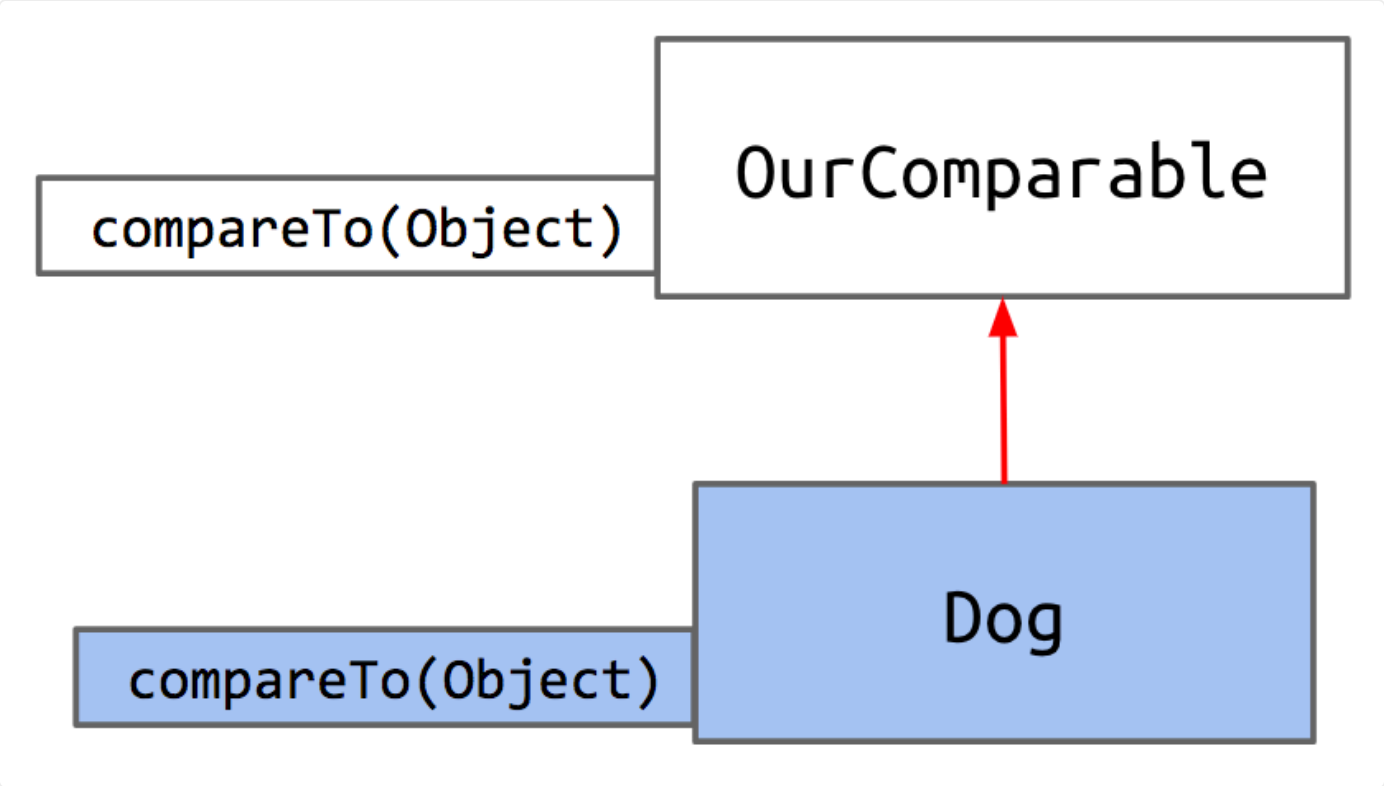
```
public static Dog maxDog(Dog[] dogs) {
    if (dogs == null || dogs.length == 0) {
        return null;
    }
    Dog maxDog = dogs[0];
    for (Dog d : dogs) {
        if (d.size > maxDog.size) {
            maxDog = d;
        }
    }
    return maxDog;
}
```

While this would work for now, if we give up on our dream of making a generalized `max` function and let the Dog class define its own `max` function, then we'd have to do the same for any class we define later. We'd need to write a `maxCat` function, a `maxPenguin` function, a `maxWhale` function, etc., resulting in unnecessary repeated work and a lot of redundant code.

The fundamental issue that gives rise to this is that Objects cannot be compared with `>`. This makes sense, as how could Java know whether it should use the String representation of the object, or the size, or another metric, to make the comparison? In Python or C++, the way that the `>` operator works could be redefined to work in different ways when applied to different types. Unfortunately, Java does not have this capability. Instead, we turn to interface inheritance to help us out.

Solution: Comparables

We can create an interface that guarantees that any implementing class, like Dog, contains a comparison method, which we'll call `compareTo`.



Let's write our interface. We'll specify one method `compareTo`.

```
public interface OurComparable {
    public int compareTo(Object o);
}
```

We will define its behavior like so:

- Return -1 if `this` < o.
- Return 0 if `this` equals o.
- Return 1 if `this` > o.

Now that we've created the `OurComparable` interface, we can require that our Dog class implements the `compareTo` method. First, we change Dog's class header to include `implements OurComparable`, and then we write the `compareTo` method according to its defined behavior above.

Exercise 4.3.2. Implement the `compareTo` method for the Dog class.

The `OurComparable` interface that we just built works, but it's not perfect. Here are some issues with it:

- Awkward casting to/from Objects
- We made it up.
  - No existing classes implement OurComparable (e.g. String, etc.)
  - No existing classes use OurComparable (e.g. no built-in max function that uses OurComparable)

The solution? We'll take advantage of an interface that already exists called `Comparable`. `Comparable` is already defined by Java and is used by countless libraries.

`Comparable` looks very similar to the OurComparable interface we made, but with one main difference. Can you spot it?

```
public interface Comparable<T> {
    public int compareTo(T obj);
}
```

```
public interface OurComparable {
    public int compareTo(Object obj);
}
```

Notice that `Comparable<T>` means that it takes a generic type. This will help us avoid having to cast an object to a specific type! Now, we will rewrite the Dog class to implement

the Comparable interface, being sure to update the generic type `T` to Dog:

```
public class Dog implements Comparable<Dog> {
    ...
    public int compareTo(Dog uddaDog) {
        return this.size - uddaDog.size;
    }
}
```

Now all that's left is to change each instance of OurComparable in the Maximizer class to Comparable. Watch as the largest Dog says bark:

We use the instance variable `size` to make our comparison.

```
public class Dog implements OurComparable {
    private String name;
    private int size;

    public Dog(String n, int s) {
        name = n;
        size = s;
    }

    public void bark() {
        System.out.println(name + " says: bark");
    }

    public int compareTo(Object o) {
        Dog uddaDog = (Dog) o;
        if (this.size < uddaDog.size) {
            return -1;
        } else if (this.size == uddaDog.size) {
            return 0;
        }
        return 1;
    }
}
```

Notice that since `compareTo` takes in any arbitrary Object o, we have to *cast* the input to a Dog to make our comparison using the `size` instance variable.

Now we can generalize the `max` function we defined in exercise 4.3.1 to, instead of taking in any arbitrary array of objects, takes in `OurComparable` objects - which we know for certain all have the `compareTo` method implemented.

```
public static OurComparable max(OurComparable[] items) {
    int maxDex = 0;
    for (int i = 0; i < items.length; i += 1) {
        int cmp = items[i].compareTo(items[maxDex]);
        if (cmp > 0) {
            maxDex = i;
        }
    }
    return items[maxDex];
}
```

Great! Now our `max` function can take in an array of any `OurComparable` type objects and return the maximum object in the array. Now, this code is admittedly quite long, so we can

make it much more succinct by modifying our `compareTo` method's behavior:

- Return negative number if `this` < o.
- Return 0 if `this` equals o.
- Return positive number if `this` > o.

Now, we can just return the difference between the sizes. If my size is 2, and uddaDog's size is 5, `compareTo` would return -3, a negative number indicating that I am smaller.

```
public int compareTo(Object o) {
    Dog uddaDog = (Dog) o;
    return this.size - uddaDog.size;
}
```

Using inheritance, we were able to generalize our maximization function. What are the benefits to this approach?

- No need for maximization code in every class(i.e. no `Dog.maxDog(Dog[])` function required
- We have code that operates on multiple types (mostly) gracefully

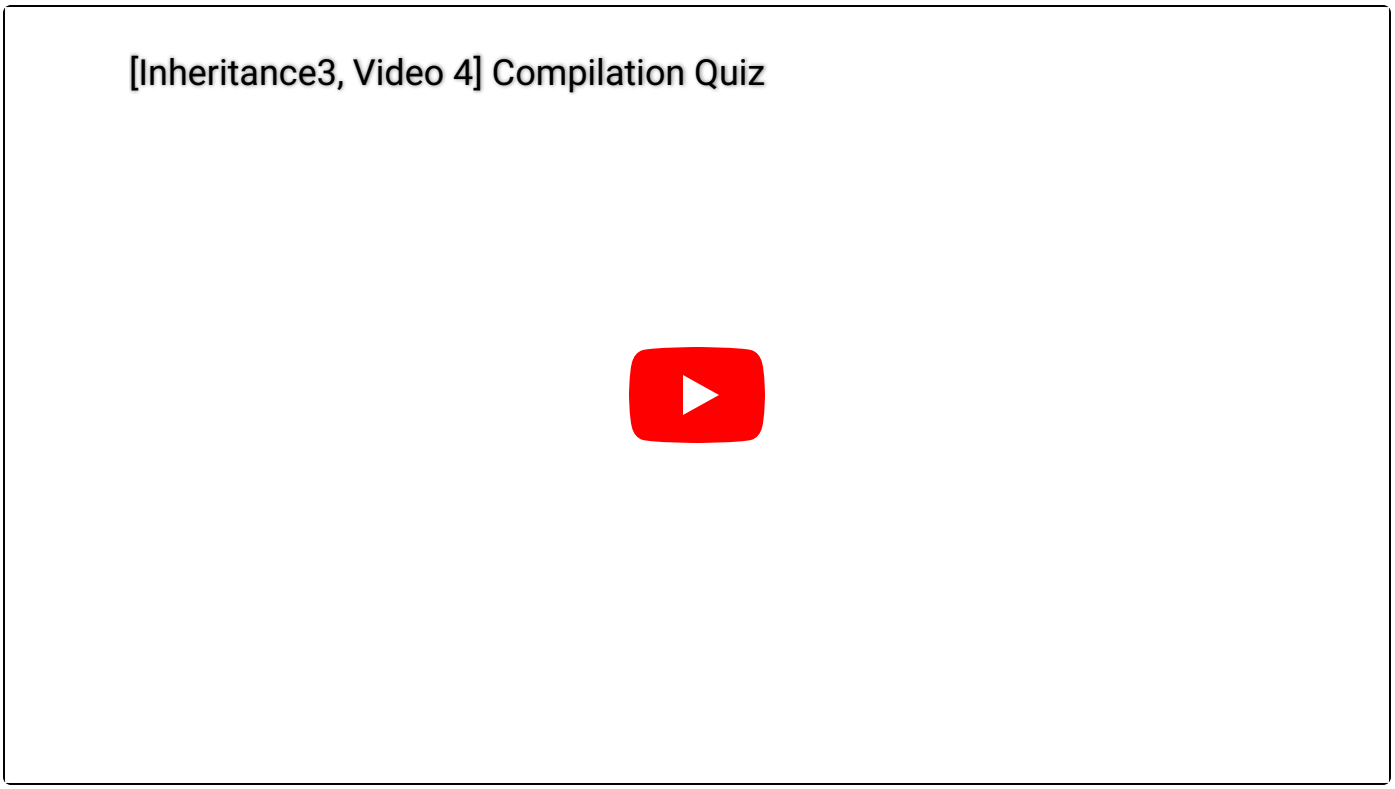
Interfaces Quiz

Exercise 4.3.3. Given the `Dog` class, `DogLauncher` class, `OurComparable` interface, and the `Maximizer` class, if we omit the compareTo() method from the Dog class, which file will fail to compile?

```
public class DogLauncher {
    public static void main(String[] args) {
        ...
        Dog[] dogs = new Dog[]{d1, d2, d3};
        System.out.println(Maximizer.max(dogs));
    }
}

public class Dog implements OurComparable {
    ...
    public int compareTo(Object o) {
        Dog uddaDog = (Dog) o;
        if (this.size < uddaDog.size) {
            return -1;
        } else if (this.size == uddaDog.size) {
            return 0;
        }
        return 1;
    }
    ...
}

public class Maximizer {
    public static OurComparable max(OurComparable[] items) {
        ...
        int cmp = items[i].compareTo(items[maxDex]);
        ...
    }
}
```



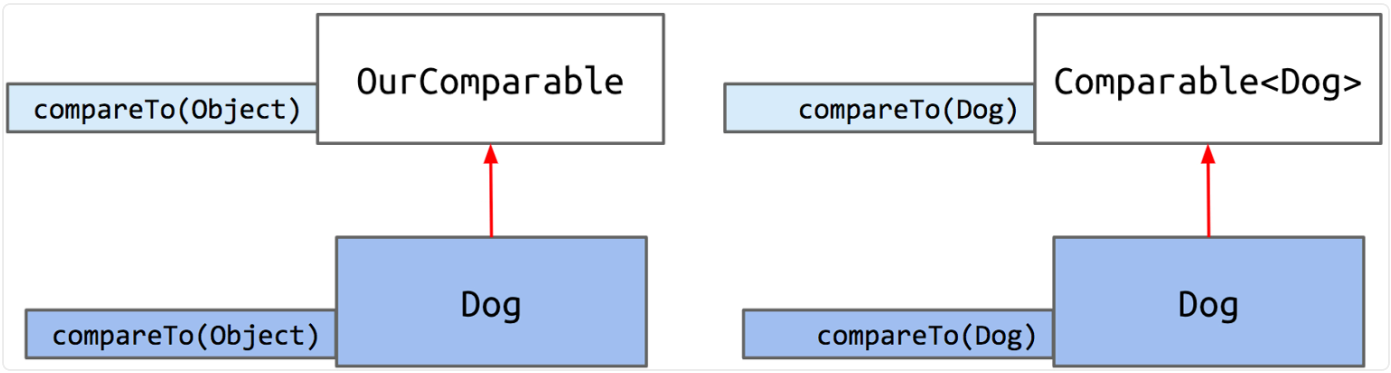
In this case, the `Dog` class fails to compile. By declaring that it `implements OurComparable`, the Dog class makes a claim that it "is-an" OurComparable. As a result, the compiler checks that this claim is actually true, but sees that Dog doesn't implement `compareTo`.

What if we were to omit `implements OurComparable` from the Dog class header? This would cause a compile error in DogLauncher due to this line:

```
System.out.println(Maximizer.max(dogs));
```

If Dog does not implement the OurComparable interface, then trying to pass in an array of Dogs to Maximizer's `max` function wouldn't be approved by the compiler. `max` only accepts an array of OurComparable objects.

Instead of using our personally created interface `OurComparable`, we now use the real, built-in interface, `Comparable`. As a result, we can take advantage of all the libraries that already exist and use `Comparable`.



Previous
11.2 Subtype Polymorphism vs Explicit Higher Order Functions

Next
11.4 Comparators

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