Lecture 4: Inheritance and Abstract Classes

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Objectives

By the end of this lecture, you will know:

- How to share common code across classes
- What inheritance is in object-oriented programming
- What super classes and abstract classes are in Java

By the end of this lecture, you will be able to:

- Share common code across classes
- Create class hierarchies

1 Abstracting over Common Methods in Different Classes

Recall our isNormalSize methods on animals:

// in the Boa class
public boolean isNormalSize () {
    return 5 <= this.length && this.length <= 10;
}
The method bodies on Boa and Dillo differ only in the numbers for the low and high bounds. We know that we should create helper functions to share common code in cases such as this. How do we do this in Java?

The first question is what helper function we should create. There are two main options:

```java
public boolean isNormalSize(int low, int high) { ... }
public boolean isLenWithin(int low, int high) { ... }
```

While these functions have the same signature, they signal different expectations about the code. The first suggests that the isNormalSize computation will be pretty much the same across all animals, while the second suggests that the common computation is about the length being within bounds, and that there could be other conditions to consider in determining whether an animal is normal size (such as its height, wing span, etc).

Since there could be many other kinds of animals, we’ll go with option 2.

## 2 Inheritance

Fortunately, Java (and all other object-oriented languages) follows a model of class hierarchies in which one class can build upon (or extend) the definitions in another. We can define a class for the shared information between Boa and Dillo and make isLenWithin a method in that class. Since our new class exists to abstract over animals, we name the class AbsAnimal.

We initially populate AbsAnimal with the code that is common to Boa and Dillo. We have already noted that the isNormalSize method is (largely) common, and that we want to have a common helper called isLenWithin. Looking at the two classes, however, we see that the length field is also common. This suggests that AbsAnimal needs the following contents:

```java
public class AbsAnimal {
    int length;

    // the constructor
    public AbsAnimal (int length) {
        this.length = length;
    }

    /**
     * Helper to determine whether length is within bounds
     */
    public boolean isLenWithin(int low, int high) {
        return low <= this.length && this.length <= high;
    }
}
```
Next, we need a way to say that Boa and Dillo should extend on what is already defined in AbsAnimal. In standard OO (object-oriented) terminology, Boa and Dillo should *inherit* from AbsAnimal. We indicate inheritance using a new keyword called `extends` in the class definition:

```java
class Dillo extends AbsAnimal implements IAnimal {
    ...
}
```

```java
class Boa extends AbsAnimal implements IAnimal {
    ...
}
```

In OO terminology, AbsAnimal is the *supertype* of each of Boa and Dillo. Each of Boa and Dillo is a *subsupertype* of AbsAnimal.

### 2.1 Simplifying the Boa/Dillo Classes

As a result of using `extends`, every field and method in AbsAnimal is now part of Boa and Dillo. This means that we can remove some code from each of these classes. We’ll work just with Boa in these notes (the changes to Dillo are similar).

#### 2.1.1 Fields and Constructor

The first thing to note is that we can remove the `length` field from Boa. Furthermore, the AbsAnimal constructor, not the Boa constructor, should set the value of the `length` field. The Boa constructor passes the value for `length` to the AbsAnimal constructor by calling `super(length)`. In general, `super` refers to the supertype; here, it is the name of the constructor in the supertype. This gives the following code:

```java
public class Boa extends AbsAnimal implements IAnimal {
    String name;
    String eats;

    public Boa (String name, int length, String eats) {
        super(length);
        this.name = name;
        this.eats = eats;
    }
    ...
}
```

In Java, each class may extend at most one other class, so the meaning of `super` is unambiguous. Note that the call to `super` must be the first line in the Boa constructor (this is again one of the rules of Java).

#### 2.1.2 The `isLenWithin` Helper

Finally, we need to clean up Boa to use the `isLenWithin` method that is in AbsAnimal.
public class Boa extends AbsAnimal implements IAnimal {
    String name;
    String eats;

    public Boa (String name, int length, String eats) {
        super(length);
        this.name = name;
        this.eats = eats;
    }

    /**
     * check whether boa's length is considered normal
     */
    public boolean isNormalSize() {
        return super.isLenWithin(30, 60);
    }
}

We now have code that reflects the code sharing that you learned to do in CS17. We’ve also left ourselves the ability to tailor isNormalSize differently for different animals, while still sharing the common length computation.

3 Abstract Classes

One last detail: our current code allows someone to write new AbsAnimal(6). This would mean "some animal of length 6". If our goal were only to create instances of specific animals (which seems reasonable), this object wouldn’t make much sense. We therefore want to prevent someone from creating AbsAnimal objects (allowing only Boa and Dillo objects).

An abstract class is a class that can be extended but not instantiated as a standalone object. We specify this through the keyword abstract when defining a class:

public abstract class AbsAnimal {
    int length;
    ...
}

Now, new AbsAnimal(6) yields an error.

4 Abstract/Super Classes versus Interfaces

We now have two mechanisms, abstract/super classes and interfaces, through which classes can share information. What is each one best used for?

- Interfaces specify new types. If you need a type name, create an interface.
- Super classes capture common code. If you have common or shared code, create a super class.
- *Abstract classes* exist ONLY to share common code, but not to create data. If you have a class that should not be used to create new objects, mark it as abstract.

Those with prior Java experience may have learned to use abstract classes for both creating types and sharing code, but this is not good OO programming. Interfaces are fairly permissive: a class must provide methods that implement those outlined in the interface, but how that implementation works (including what data structures get used) is entirely up to the author of the class. Abstract classes provide actual code, which means that any class which uses an abstract class must do so in a way that is consistent with the existing code or data structures. The restriction that a class may only ever extend one other class reflects this consistency problem. In contrast, a class can implement any number of interfaces, because interfaces do not constrain the implementation of behavior.

Interfaces also recognize that the world is not neatly hierarchical. Different kinds of real world objects have all sorts of different properties that affect how we use them. For example, within Brown’s information system, I am each of a faculty member, first-year advisor, and a director of undergraduate studies. Different tasks within the university view me as having these different roles. Interfaces let a program say “I need an object that has the methods associated with this particular role”. Class hierarchies can’t do this (because of the single-extension restriction).

Put differently, there is an important distinction between stating which operations are required and stating how those operations are implemented (we’ll see a lot of this in the coming days). The former is called specification; the latter implementation. Interfaces are for specification; abstract classes for implementation.

### 5 Class Extension without Abstraction

Abstract classes support field and method abstraction, but class extensions are also used to express hierarchy among data. For example, let’s add two kinds of animals to our class hierarchy: Fish, which have a length and an optimal saline level for water in their tanks; and Sharks, which are fish for which we record the number of times they attacked people. The new classes appear as follows:

```java
public class Fish extends AbsAnimal {
    double salinity;

    public Fish (int length, double salinity) {
        super(length);
        this.salinity = salinity;
    }

    /**
     * check whether fish's length is considered normal
     */
    public boolean isNormalSize () {
        return isLenWithin(3, 15);
    }
}

public class Shark extends Fish {
    int attacks;
}
```
public Shark (int length, int attacks) {
    super(length, 3.75);
    this.attacks = attacks;
}

A few things to note here:

- The salinity data has type double; this is a common type to use for real numbers.
- Shark extends Fish, but Fish is not an abstract class. It still makes sense to create Fish that are not also Sharks.
- Constructors do not need to take all of the initial field data as parameters. For example, if we assume that all sharks have the same saline level, then the Shark constructor asks for only the length and number of attacks; it provides the fixed saline level to the Fish constructor on the call to super.
- Shark does not need to define isLenWithin, since it inherits the definition from Fish. If you wanted Shark to have its own definition (since it might have a different normal size), you could provide one in the Shark class. Java calls the most specific method for each object.

6 Summary

This lecture introduced the following concepts:

- Classes can be organized into hierarchies. Subclasses inherit data and methods from their superclasses.
- Parameters to otherwise common methods are passed as constructor arguments to superclasses.
- Abstract classes enable sharing but not instantiation (i.e., you can’t use the new keyword to make an object of an abstract class).
- A class can have at most one superclass. The constructor for a subclass should call super to initialize the superclass.
- Class hierarchies are only used for capturing shared code (implementation). Shared requirements belong in interfaces. Unless your code relies on a common implementation across classes, use an interface.

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