Lecture 3: Interfaces and Types

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Objectives

By the end of this lecture, you will know:

• how to capture data with variants in Java

• what Java interfaces are

• how Java interprets each of classes and interfaces as types

what we can use as types in Java programs

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

• define and use interfaces

1 Migrating Data with Variants: Animals

So far, we’ve defined a class for Dillos. What if we were managing an entire zoo with other kinds of animals as well? We would need to define classes for those other kinds of animals. We would probably have methods or fields in other classes that could hold any kind of animal (for example, a class storing information about shows at the zoo might need fields for the featured animal and the duration of the show: the featured animal could be from one of several classes).

In this section, we will add a second kind of animal, create a type for animals, and write a method isNormalSize that determines whether an animal’s length is in the usual range for its kind.

1.1 Defining Data with Variants

Data has variants if it has encompasses other kinds of data with different components. Animals have variants (not all animals have the same attributes), as do shapes (different attributes define
circles and rectangles, for example). You saw data with variants (or cases) in CS17. For example, here's a type definition for animals, containing armadillos and Boa constrictors (where boas have a name, length, and favorite food):

```ocaml
(* animals in OCaml *)
type animal =
  | Dillo of (int * bool)
  | Boa of (string * int * string)
```

Let's define the boa class in Java:

```java
public class Boa {
  String name;
  int length;
  String eats;

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

We mentioned wanting to write methods on animals. As we have already seen, Java requires us to label all fields, parameters and methods outputs with types. So if want to have a field that allows "either dillos or boas", we need a type for "any animal" (like you had in OCaml). For example, we might want to create a class for a (small) Zoo, where a zoo contains two animals:

```java
public class Zoo {
  ______ animal1;
  ______ animal2;
}
```

Our goal is to fill in the blank with a type that can accept either Boas or Dillos.

To introduce a new type that is simply one of several classes, we use a construct called an interface. We first create an interface, then we connect it to the classes that belong to it. First, here's the code to create the interface.

```java
interface IAnimal {}
```

Right now, all this interface does is declare a new type name called IAnimal (by convention, interfaces in Java start with a capital letter I). We will do more with it shortly.

The interface declaration introduces IAnimal as a type name, but we have not yet made Boas and Dillos valid variants of animals. To do that, we add IAnimal to the first line of each of the Boa and Dillo class definitions through an implements clause, as follows:

```java
interface IAnimal {}

class Dillo implements IAnimal {
```
In Java, `implements` achieves two things: it declares that a given class is a valid value of the type with the name of the interface, and it requires the class to satisfy all constraints of the interface. `IAnimal` doesn't yet impose constraints on its implementing classes, but we’ll get to that shortly.

*If you are coming from previous Java experience and would not have used an interface here, hold that thought. We will address your question in a couple of days when everyone has seen enough Java to understand the answer.*

What about examples of data? How do we create `IAnimals`? We can only create objects from classes, not from interfaces. Every Dillo and every Boa is an example of `IAnimal`, so there’s no need for you to create additional examples of data just because you added an interface.

### 1.2 Methods over Data with Variants

Let’s write a method on `IAnimal` that determines whether the animal is normal size for its type. We’ll say that a boa is normal size if its length is between 30 and 60 and an armadillo is normal size if its length is between 12 and 24.

First, we extend our `AnimalTest` class with examples of boas and some test cases for our new method. The code is in Figure 1.

We remarked earlier that in OOP, all methods live with their corresponding data. Since the data on animals lie in the `Boa` and `Dillo` classes, the `isNormalSize` method should live there too. We therefore put an `isNormalSize` method in each of the `Boa` and `Dillo` classes (for brevity, we omit the `Dillo`’s `canShelter` method). The code is in Figure 2.

Wait – we now appear to have two methods, each called `isNormalSize`. *How does Java know which one to use?*

Remember that we call methods through objects, and each object carries a copy of its methods. So if you call

```java
babyDillo.isNormalSize()
```

Java will use the version of the method from the `Dillo` class. This feature of choosing which version of a method to use based on the class for an object is called *dispatch*. This is another fundamental element of OOP. For now, all you need to understand is that you get to methods through objects, so you can have different "versions" of the same method in different classes, and Java will find the right one automatically (by going through the object).
public class AnimalTest {
    public AnimalTest () {} ;

    Dillo babyDillo = new Dillo (8, false);
    Dillo adultDillo = new Dillo (24, false);
    Dillo hugeDeadDillo = new Dillo (65, true);

    Boa meanBoa = new Boa("Slinky", 36, "nails") ;
    Boa thinBoa = new Boa("Slim", 24, "lettuce") ;

    // check that small live dillos can't shelter
    public void testBabyShelter(Tester t) {
        t.checkExpect(!babyDillo.canShelter());
    }

    // check that large dead dillos can shelter
    public void testHugeDeadShelter(Tester t) {
        t.checkExpect(hugeDeadDillo.canShelter());
    }

    // check that an undersize boa is not normal
    public void testSlimAbnormal(Tester t) {
        t.checkExpect(thinBoa.isNormalSize());
    }

    // check that an oversize dillo is not normal
    public void testHugeDeadAbnormal(Tester t) {
        t.checkExpect(!hugeDeadDillo.isNormalSize());
    }

    public static void main(String[] args) {
        Tester.run(new AnimalTest());
    }
}

Figure 1: AnimalTest with boas and normal-size tests
public class Dillo implements IAnimal {
    public int length;
    public boolean isDead;

    public Dillo (int len, boolean isD) {
        this.length = len;
        this.isDead = isD;
    }

    /**
     * check whether armadillo's length is considered normal
     */
    public boolean isNormalSize() {
        return 12 <= this.length && this.length <= 24;
    }
}

public class Boa implements IAnimal {
    public String name;
    public int length;
    public String eats;

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

    /**
     * check whether boa's length is considered normal
     */
    public boolean isNormalSize() {
        return 30 <= this.length && this.length <= 60;
    }
}

Figure 2: Dillos and Boas with the isNormalSize method
1.3 Requiring a Method in all Classes in an Interface

Now that we have the `isNormalSize` method on both Boas and Dillos, we can write a method in the `Zoo` class to check whether both animals are of normal size (this also lets us show you how to write if-expressions in Java). For brevity, the code below omits the constructor (since it follows the standard constructor pattern):

```java
public class Zoo {
    IAnimal animal1;
    IAnimal animal2;

    // constructor omitted

    /**
     * check whether all animals are of normal size
     */
    public String healthCheck() {
        if (animal1.isNormalSize() && animal2.isNormalSize()) {
            return "Passed";
        } else {
            return "Failed";
        }
    }
}
```

Hmm, Eclipse is flagging an error on the calls to `isNormalSize`. Why?

Java takes two passes over your program when you attempt to run it. In the first pass, it makes sure that the types of objects are consistent with the method calls that you make using those objects. Here, we are trying to call `animal1.isNormalSize()`.

Eclipse is reporting that `isNormalSize()` is undefined for type `IAnimal`. While every `IAnimal` class that we’ve written so far has a method called `isNormalSize`, nothing *requires* those classes to have that method. We could add another `IAnimal` that didn’t have that method. Hence Java reports an error.

We address this by expanding the `IAnimal` interface to require `isNormalSize`:

```java
interface IAnimal {
    boolean isNormalSize () ;
}
```

Now, if a class implements `IAnimal` but does not include an `isNormalSize` method, Java will flag an error. This is your first example of a constraint that an interface imposes on its implementing classes.

2 Review/Summary on Types

At this point, we’ve seen three kinds of types in Java:
• built in types for “atomic” data, like int, boolean, string
• Classes, like Dillo
• Interfaces, like IAnimal

The first is clearly distinct from the other two, but how do the other two compare?

Concretely, imagine that we used Dillo for the type of one armadillo and IAnimal for another in the AnimaTest class. What difference would that make?

```java
public class AnimalTest {
    Dillo adultDillo = new Dillo (24, false);
    IAnimal hugeDeadDillo = new Dillo (65, true);
}
```

We mentioned earlier that Java takes two passes when running your program: one (called compilation) to make sure that all the types (and some other constraints) make sense, and one to actually execute the code. Compilation performs its checks using information that can be found directly in class and interface definitions. What does the compiler know about Dillos, just from looking at the class definition?

• They have fields length and isDead
• They have methods isNormalSize and canShelter

What does the compiler know about IAnimals, again looking only at the interface definition?

• They have an isNormalSize method

So if you try to write hugeDeadDillo.canShelter() when hugeDeadDillo has type IAnimal, the compiler will raise an error, because it has no guarantee that all IAnimals have that method. But the method is clearly there – you can see it, so why can’t Java? Because you are chaining together information: that hugeDeadDillo is actually a Dillo, and that Dillos have the canShelter method. Java doesn’t do this sort of multi-step reasoning (we’ll try to explain why later in the semester). It only looks at what is known from the class or interface itself.

**Exercise:** play around with the types and interface annotations within the animal code, and see when the compiler raises errors. What if you take the IAnimal annotation off the Dillo class? What if you take isNormalSize() out of the interface? What if you change the types on the specific animals when defining them in AnimalTest. Play with this until you think you have a sense of how the types work, and come to office hours or post on Piazza if you have questions.

### 3 Exercise: Family Trees

As an additional exercise, try defining family trees in Java, where each node in the tree has the name of a person and references to the person’s mother and father. In OCaml, you’d have written:
type family_tree =
  | Unknown
  | Person of string * family_tree * family_tree

Migrate this to Java, using classes and interfaces as needed.

**Warning**: if you have programmed in Java before, make sure you are following the pattern we used for defining animals. Do NOT use any constructs or concepts that we haven’t yet discussed in this course. There’s a deep point in this warning that we will return to in a few days.

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