More OO Fundamentals

CSCI 4448/5448: Object-Oriented Analysis & Design

Lecture 4 — 01/20/2011

Goals of the Lecture

- Continue a review of fundamental object-oriented concepts

Overview of OO Fundamentals

- Delegation
  - HAS-A
- More on Inheritance
  - IS-A
- More on Polymorphism
  - message passing
  - polymorphic arguments and return types
- Interfaces
  - Abstract Classes
- Object Identity

Delegation (I)

- When designing a class, there are four ways to handle an incoming message
  - Handle message by implementing code in a method
  - Let the class's superclass handle the request via inheritance
  - Pass the request to another object (delegation)
  - some combination of the previous three

Delegation (II)

- Delegation is employed when some other class already exists to handle a request that might be made on the class being designed
  - The host class simply creates a private instance of the helper class and sends messages to it when appropriate
  - As such, delegation is often referred to as a "HAS-A" relationship
    - A Car object HAS-A Engine object

```java
import java.util.List;
import java.util.LinkedList;

public class GroceryList {

   private List<String> items;

   public GroceryList() {
      items = new LinkedList<String>();
   }

   public void addItem(String item) {
      items.add(item);
   }

   public void removeItem(String item) {
      items.remove(item);
   }

   public String toString() {
      String result = "Grocery List\n------------\n\n";
      int index = 1;
      for (String item: items) {
          result += String.format("%3d. %s", index++, item) + "\n";
      }
      return result;
   }

}
```

GroceryList delegates all of its work to Java's LinkedList class (which it accesses via the List interface).

```java
public class Test {

    public static void main(String[] args) {
        GroceryList g = new GroceryList();
        g.addItem("Granola");
        g.addItem("Milk");
        g.addItem("Eggs");
        System.out.println("" + g);
        g.removeItem("Milk");
        System.out.println("" + g);
    }

}

```

With the delegation, I get a nice abstraction in my client code. I can create grocery lists, add and remove items and get a printout of the current state of the list.

```java
import java.util.List;
import java.util.LinkedList;

public class TestWithout {

    public static void printList(List<String> items) {
       System.out.println("Grocery List");
       System.out.println("------------\n");
       int index = 1;
       for (String item : items) {
           System.out.println(String.format("%3d. %s", index++, item));
       }
       System.out.println();
    }

    public static void main(String[] args) {
        List<String> g = new LinkedList<String>();
        g.add("Granola");
        g.add("Milk");
        g.add("Eggs");
        printList(g);
        g.remove("Milk");
        printList(g);
    }

}

```

Without delegation, I get less abstraction. I'm using the List interface directly with its method names and I have to create a static method to handle the printing of the list rather than using toString().

Delegation (III)

- Now, the two programs (with delegation and without delegation) produce exactly the same output
  - So, do we care which method we use?

Delegation (IV)

- Benefits of Delegation
  - Better abstraction
  - Less code in classes we write ourselves
  - We can change delegation relationships at runtime!
    - Unlike inheritance relationships; Imagine if we had created GroceryList as a subclass of LinkedList (*shudder*)
      - Why? Because GroceryList IS-NOT-A LinkedList

Delegation (V)

- Changing delegation relationships at run-time
  - A class can use a set at run-time
    - `Set<String> items = new HashSet<String>();`
  - If the class suddenly needs to be sorted, it can do this
    - `items = new TreeSet<String>(items);`
  - We have changed the delegation to an entirely new object at run-time and now the items are sorted
    - In both cases, the type of items is Set<String> and we get the correct behavior via polymorphism

Delegation (VI)

- Summary
  - Don't re-invent the wheel… delegate!
  - Delegation is dynamic (not static)
    - delegation relationships can change at run-time
  - Not tied to inheritance
    - indeed, considered much more flexible; In languages that support only single inheritance this is important!

Inheritance (I)

- Inheritance is a mechanism for sharing (public/protected) features between classes
- A class defines a type.
  - A superclass is a more generic instance of that type.
  - A subclass is a more specific instance of that type.
    - A subclass restricts the legal values of its superclass
      - Component → Container → Control → Button → Checkbox

Inheritance (II)

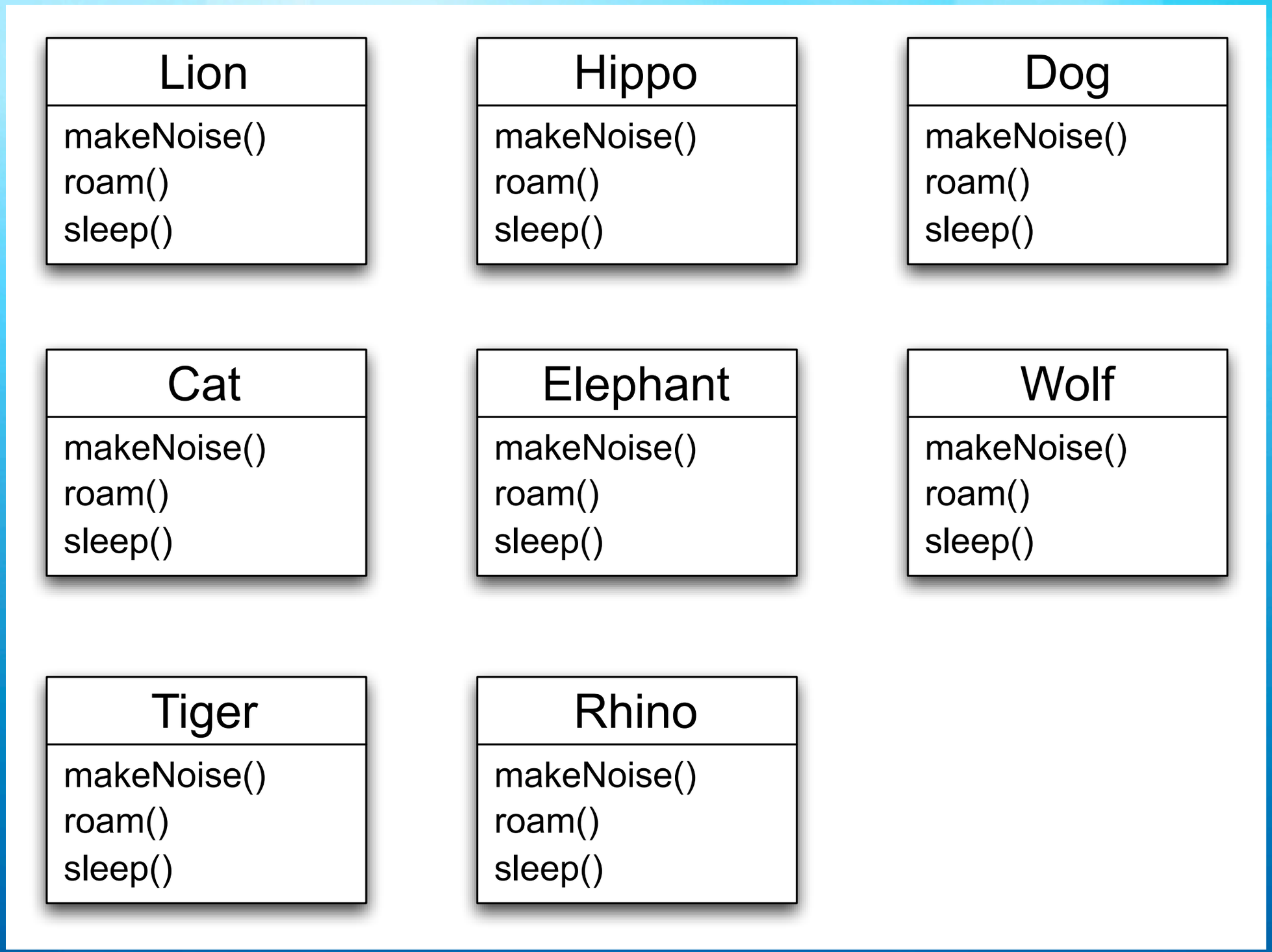
- Subclasses have an "IS-A" relationship with their superclass
  - A Hippo IS-A Animal makes sense while the reverse does not
  - IS-A relationships are transitive
    - If D is a subclass of C and C is a subclass of B, then D IS-A B is true

Inheritance (III)

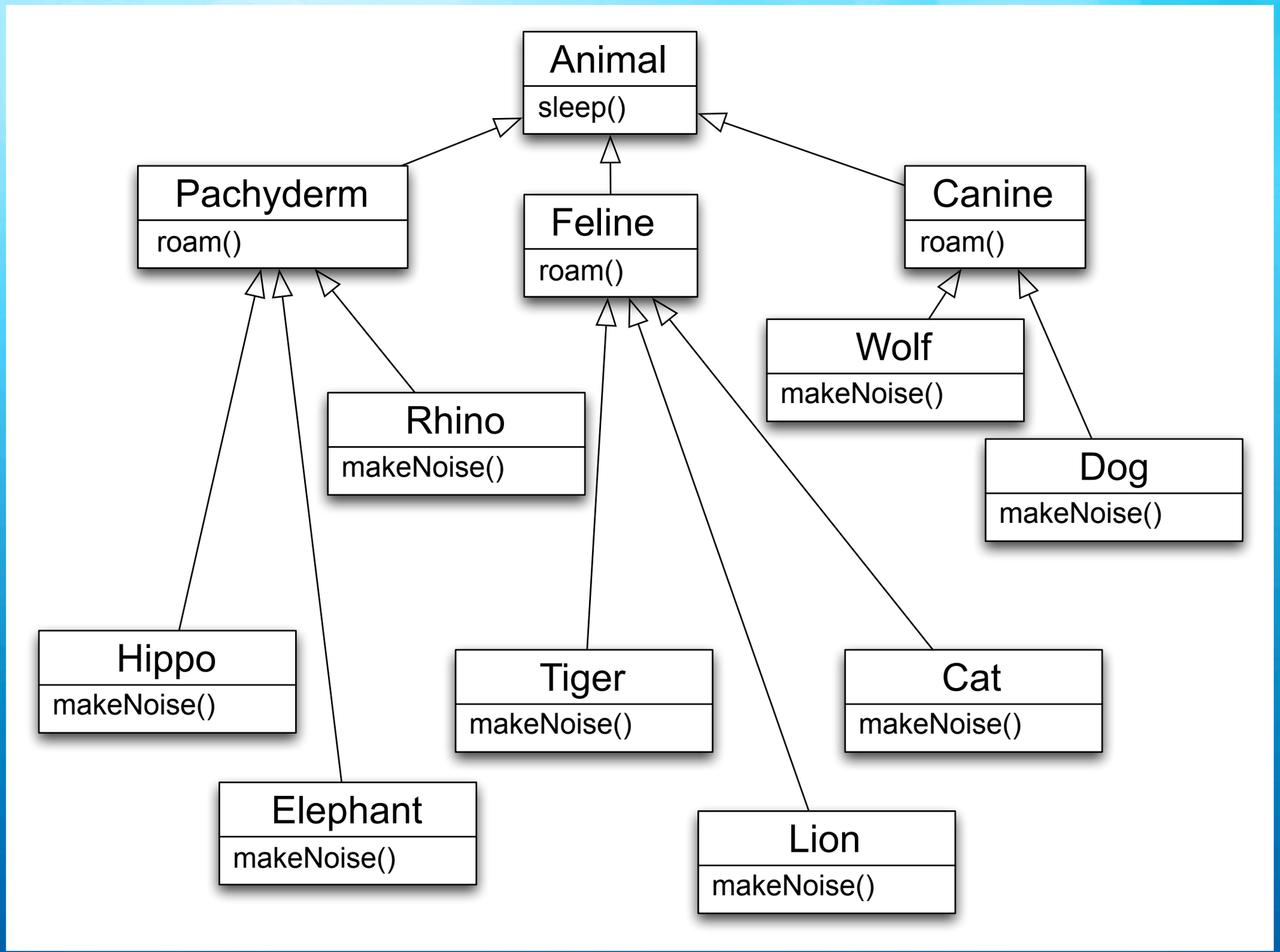
- Good OO design strives to make sure that all IS-A relationships in a software system "make sense"
  - Consider Dog IS-A Canine vs. Dog IS-A Window
    - The latter might actually be tried by an inexperienced designer who wants to display each Dog object in its own separate window
      - This is known as implementation inheritance; it is considered poor design and something to be avoided

Inheritance (IV)

- Inheritance enables significant code reuse since subclasses gain access to the code defined in their ancestors
- The next two slides show two ways of creating a set of classes modeling various types of Animals
  - The first uses no inheritance and likely contains a lot of duplicated code
  - The second uses inheritance and requires less code
    - even though it has more classes than the former



Animal Classes with no inheritance



Animal Classes with inheritance

Code Metrics

- Indeed, I coded these two examples and discovered
  - without inheritance: 9 files, 200 lines of code
  - with inheritance: 13 files, 167 lines of code
  - approximately a 15% savings, even for this simple example

Inheritance (V)

- An important aspect of inheritance is substitutability
  - Since a subclass can exhibit all of the behavior of its superclass, it can be used anywhere an instance of its superclass is used
    - The textbook describes this as polymorphism

Inheritance (VI)

- Furthermore, subclasses can add additional behaviors that make sense for it and override behaviors provided by the superclass, altering them to suit its needs
  - This is both powerful AND dangerous
    - Why? Stay tuned for the answer…

Polymorphism (I)

- OO programming languages support polymorphism ("many forms")
  - In practice, this allows code
    - to be written **with respect to the root of an inheritance hierarchy**
    - and **function correctly when applied to the root's subclasses**

Polymorphism (II)

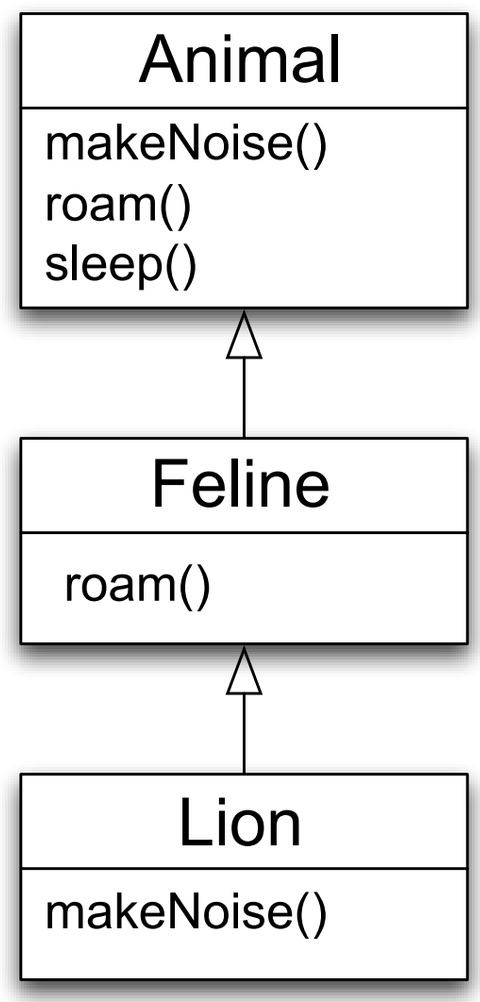
- Message Passing vs. Method Invocation
  - With polymorphism, a message ostensibly sent to a superclass, may be handled by a subclass
    - as discussed in lecture 3

Polymorphism (III)

- Compare this
  - `Animal a = new Animal();`
  - `a.sleep(); // sleep() in Animal called`
- with this
  - `Animal a = new Lion();`
  - `a.sleep(); // sleep() in Lion called`

Polymorphism Example

- Without polymorphism, the code on the right only calls methods in Animal
  - Think C++ non-virtual method invocations
- With polymorphism
  - a.roam() invokes Feline.roam()
  - a.makeNoise() invokes Lion.makeNoise()
- A message sent to Animal travels down the hierarchy looking for the "most specific" method body
  - In actuality, method lookup starts with Lion and goes up




```
Animal a = new Lion()
a.makeNoise();
a.roam();
a.sleep();
```

Why is this important?

- Polymorphism allows us to write very abstract code that is robust with respect to the creation of new subclasses
- For instance

```
public void goToSleep(Animal[] zoo) {
    for (int i = 0; i < zoo.length; i++) {
        zoo[i].sleep();
    }
}
```

Importance (II)

- In the previous code
  - we don't care what type of animals are contained in the array
  - we just call sleep() and get the correct behavior for each type of animal

Importance (III)

- Indeed, if a new subclass of animal is created
  - the above code still functions correctly AND
  - it doesn't need to be recompiled
  - with dynamic class loading, if the above code was running in a server, you wouldn't even need to "stop the server"; you could simply load a new subclass and "keep on trucking" ☺
- It only cares about Animal, not its subclasses
  - as long as Animal doesn't change, the addition/removal of Animal subclasses has no impact

Importance (IV)

- We can view a class's public methods as establishing a contract that it and its subclasses promise to keep
  - if we code to the (root) contract, as we did in the previous example, we can create very robust and easy to maintain software systems
  - This perspective is known as design by contract

Importance (IV)

- Earlier, we referred to method overloading as "powerful AND dangerous"
  - The danger comes from the possibility that a subclass may change the behavior of a method such that it no longer follows the contract established by a superclass
    - such a change will break previously abstract and robust code

Importance (V)

- Consider what would happen if an Animal subclass overrides the sleep() method to make its instances flee from a predator or eat a meal
  - Our goToSleep() method would no longer succeed in putting all of the Zoo's animals to sleep
- If we could not change the offending subclass, we would have to modify the goToSleep() method to contain special case code to handle it
  - this would break abstraction and seriously degrade the maintainability of that code
    - Why?

Polymorphism (IV)

- Finally, polymorphism is supported in arguments to methods and method return types
  - In our goToSleep() method, we passed in a polymorphic argument, namely an array of Animals
    - The code doesn't care if the array contains Animal instances or any of its subclasses

Polymorphism (IV)

- In addition, we can create methods that return polymorphic return values. For example

```
public Animal createRandomAnimal() {
    // code that randomly creates and
    // returns one of Animal's subclasses
}
```

- When using the createRandomAnimal() method, we don't know ahead of time which instance of an Animal subclass will be returned
  - That's okay as long as we are happy to interact with it via the API provided by the Animal superclass

Abstract Classes (I)

- There are times when you want to make the "design by contract" principle explicit
  - **Abstract classes and Interfaces let you do this**
- An abstract class is simply one which cannot be directly instantiated
  - It is designed from the start to be subclassed
  - It does this by declaring a number of method signatures without providing method implementations for them
    - this sets a contract that each subclass must meet

Abstract Classes (II)

- Abstract classes are useful since
  - they allow you to provide code for some methods (enabling code reuse)
  - while still defining an abstract interface that subclasses must implement

Abstract Classes (III)

- Zoo example
  - `Animal a = new Lion(); // manipulate Lion via Animal interface`
  - `Animal a = new Animal(); // what Animal is this?`
- Animal, Feline, Pachyderm, and Canine are good candidates for being abstract classes

Interfaces

- Interfaces go one step further and only allow the declaration of abstract methods
  - you cannot provide method implementations for any of the methods declared by an interface
- Interfaces are useful when you want to define a role in your software system that could be played by any number of classes

Interface Example (I)

- Consider modifying the Animal hierarchy to provide operations related to pets (e.g. play() or takeForWalk())
  - We have several options, all with pros and cons
    - add Pet-related methods to Animal
    - add abstract Pet methods to Animal
    - add Pet methods only in the classes they belong (no explicit contract)

Interface Example (II)

- Options continued…
  - make a separate Pet superclass and have pets inherit from both Pet and Animal
  - make a Pet interface and have only pets implement it
    - This often makes the most sense although it hinders code reuse
    - Variation: create Pet interface, but then create Pet helper class that is then composed internally and Pet's delegate if they want the default behavior

Object Identity

- In OO programming languages, all objects have a unique id
  - This id might be its memory location or a unique integer assigned to it when it was created
- This id is used to enable a comparison of two variables to see if they point at the same object
  - See example next slide

```
public class identity {

    public static void compare(String a, String b) {
        if (a == b) {
            System.out.println("(" + a + ", " + b + "): identical");
        } else if (a.equals(b)) {
            System.out.println("(" + a + ", " + b + "): equal");
        } else {
            System.out.println("(" + a + ", " + b + "): not equal");
        }
    }

    public static void main(String[] args) {
        String ken = "Ken Anderson";
        String max = "Max Anderson";
        compare(ken, max);  ———————  Not Equal
        ken = max;
        compare(ken, max);  ———————  Identical
        max = new String("Max Anderson");
        compare(ken, max);  ———————  Equal
    }

}
```

Identity in OO A&D (I)

- Identity is also important in analysis and design
  - We do not want to create a class for objects that do not have unique identity in our problem domain
    - Consider people in an elevator
      - Does the elevator care who pushes its buttons?

Identity in OO A&D (II)

- Examples, continued
  - Consider a cargo tracking application
    - Does the system need to monitor every carrot that exists inside a bag? How about each bag of carrots in a crate?
  - Consider a flight between Denver and Chicago
    - What uniquely identifies that flight? The plane? The flight number? The cities? What?

Identity in OO A&D (III)

- When doing analysis, you will confront similar issues
  - you will be searching for uniquely identifiable objects that help you solve your problem

Coming Up Next

- Homework 2 assigned tomorrow, due next Wednesday
- Lecture 5: Example problem domain and initial OO solution (from book)
  - Read Chapters 3 and 4 of the Textbook
- Lecture 6: Introduction to Design Patterns
  - Read Chapter 5 of the Textbook