Object Fundamentals
Part Three

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Lecture Goals

- Continue our tour of the basic concepts, terminology, and notations for object-oriented analysis, design, and programming
  - Some material for this lecture is drawn from **Head First Java** by Sierra & Bates, © O'Reilly, 2003

Overview

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

Delegation (I)

- When designing a class, there are three ways to handle an incoming message
  - Handle message by implementing code in a method
  - Let the class's superclass handle the request via inheritance
  - Delegate the request to another object (delegation)
    - Note: goes hand in hand with composition (not to be confused with aggregation/composition which is a design concept)
      - You compose one object out of others
      - The host object delegates requests to its internal objects

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

Delegation (III)

- Advantages
  - 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 subtype typically restricts the legal values of its superclass
      - Real Numbers → Integers → Positive Integers
      - 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
- 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 (III)

- 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 would likely require less code
    - even though it has more classes than the former

Animals (No Inheritance)

Lion
makeNoise()
roam()
sleep()

Hippo
makeNoise()
roam()
sleep()

Dog
makeNoise()
roam()
sleep()

Cat
makeNoise()
roam()
sleep()

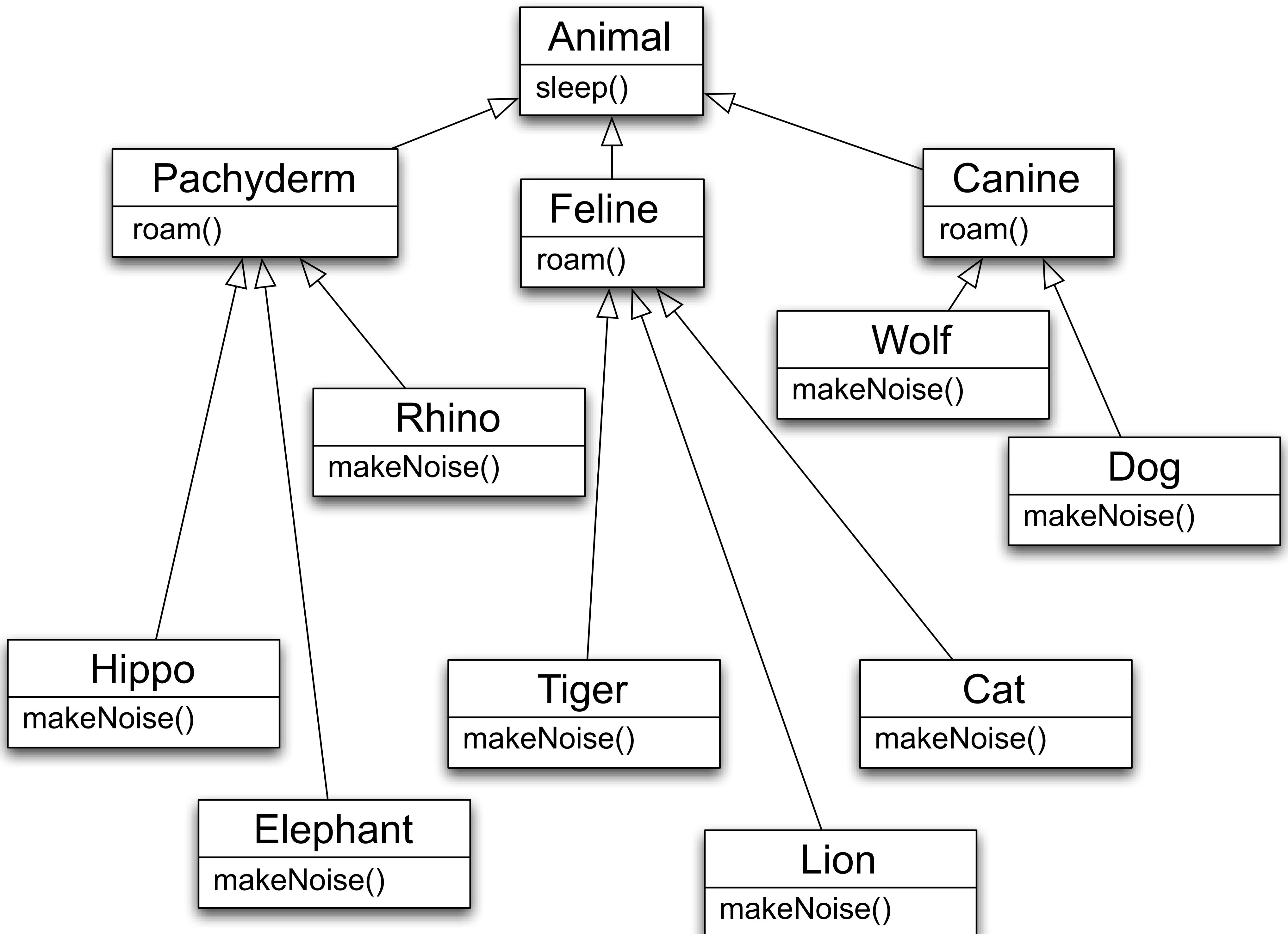
Elephant
makeNoise()
roam()
sleep()

Wolf
makeNoise()
roam()
sleep()

Tiger
makeNoise()
roam()
sleep()

Rhino
makeNoise()
roam()
sleep()

Animals (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 (IV)

- 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**
- 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
  - Compare this

```
Animal a = new Animal()

a.sleep() // sleep() in Animal called
```

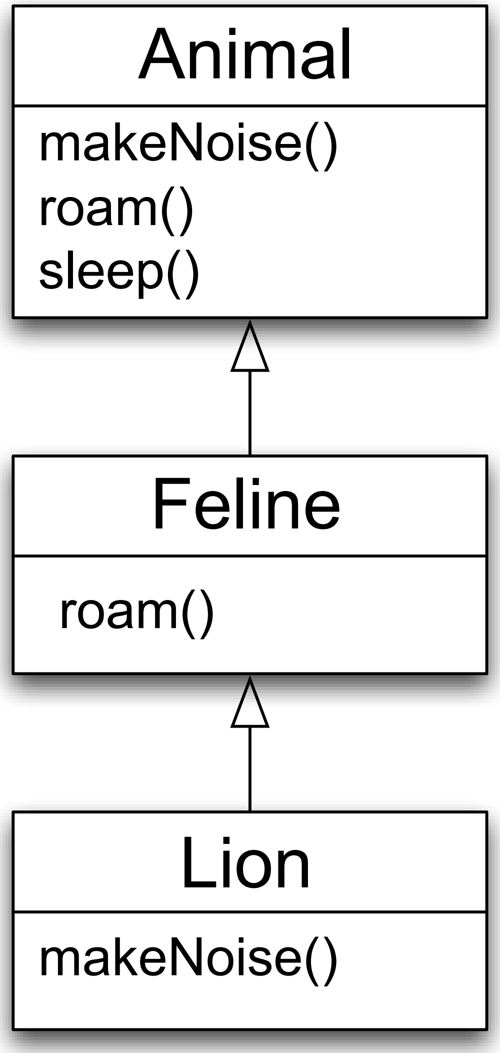
  - with this

```
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();
    }
}
```

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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
- 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 (III)

- 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 (III)

- 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 API provided by the Animal superclass

Abstract Classes/Interfaces

- 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, Continued

- 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
- Zoo example
  - Animal a = new Lion(); // manipulate Lion via Animal
  - 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

- 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)
    - 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

Object Identity

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

Identity Example

```
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?
    - 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 (II)

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

Ken’s Corner (I)

“Three Amigos”

- Big names in OO circles (this list is dreadfully incomplete)
  - **Alan Kay**: <http://en.wikipedia.org/wiki/Alan_Kay>
    - One of the “fathers” of OO programming
  - **Grady Booch**: <http://en.wikipedia.org/wiki/Grady_Booch>
    - Co-inventor of UML; long time advocate of OO A&D
  - **Ivar Jacobson**: <http://en.wikipedia.org/wiki/Ivar_Jacobson>
    - Co-inventor of UML; wrote OO software engineering
  - **James Rumbaugh**: <http://en.wikipedia.org/wiki/James_Rumbaugh>
    - Co-inventor of UML; developed Object Modeling Technique (OMT)
  - **Martin Fowler** <http://www.martinfowler.com/>
    - Prolific author on OO topics such as refactoring, patterns, UML, etc.

Ken's Corner (II)

- Big names in OO circles (this list is still dreadfully incomplete)
  - **Kent Beck**: <http://en.wikipedia.org/wiki/Kent_Beck>
    - Inventor of Extreme Programming; popularized test-driven design/JUnit
  - **Ward Cunningham**: <http://en.wikipedia.org/wiki/Ward_Cunningham>
    - Inventor of the wiki; long time advocate for design patterns
  - **Erich Gamma**: <http://en.wikipedia.org/wiki/Erich_Gamma>
    - Wrote Design Patterns with "The Gang of Four (GoF)" which also includes Richard Helm, Ralph Johnson, John Vlissides
  - Many, many more… for instance, the designers of OO languages: Alan Kay (Smalltalk), Bjarne Stroustrup (C++), Guido van Rossum (Python), Yukihiro Matsumoto "Matz" (Ruby), Anders Hejlsberg (C#), Brad Cox (Objective C), Brendan Eich (Javascript), Bertrand Meyer (Eiffel); See <http://en.wikipedia.org/wiki/Object-oriented_programming_language> for more!

Coming Up Next

- Lecture 5: Great Software
  - Read Chapter 1 of the OO A&D book
- Lecture 6: Give Them What They Want
  - Read Chapter 2 of the OO A&D book