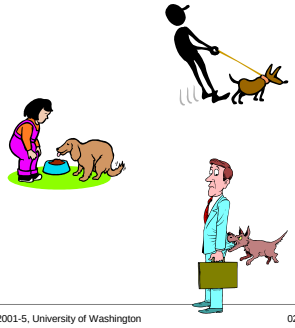
CSE 143

Object & Class Relationships – Inheritance

Reading: Ch. 9, 14

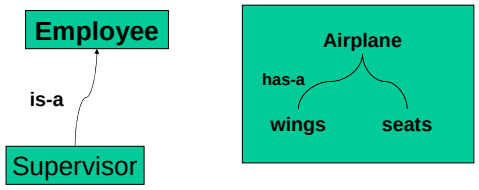
Relationships Between Real Things

- Man walks dog
- Dog strains at leash
- Dog wears collar
- Man wears hat
- Girl feeds dog
- Girl watches dog
- Dog eats food
- Man holds briefcase
- Dog bites man



Common Relationship Patterns

- A few types of relationships occur extremely often
  - IS-A: a supervisor is an employee (and a taxpayer and a sister and a skier and ....)
  - HAS-A: An airplane has seats (and lights and wings and engines and...)
- These are so important and common that programming languages have special features to model them
  - Some of these you know (maybe without knowing you know)
  - Some of them we'll cover carefully in this course, starting now, with inheritance



Composition: "has a"

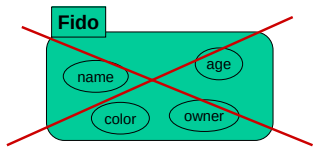
- Classes and objects can be related in several ways
- One way: *composition*, *aggregation*, or *reference*
- Dog has-a owner, dog has-a age, dog has-a name, etc.
- In java: one object refers to another object
  - via an instance variable

```
public class Dog {
    private String name;/          // this dog's name
    private int  age;              // this dog's age
    private Person owner;          // this dog's owner
    private Dog mother,  father;   // this dog's parents
    private Color coatColor;       // etc, etc.
}
```

- Composition: One can think of the dog as "composed" of various objects

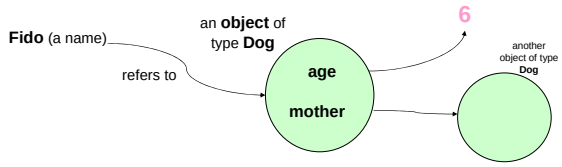
Picturing the Relationships

- Dog Fido; //might be 6 years old, brown, owned by Marge, etc.
- Dog Apollo; //might be 2 years old, no owner, etc.
- In Java, it is a mistake to think of the parts of an object as being "inside" the whole.



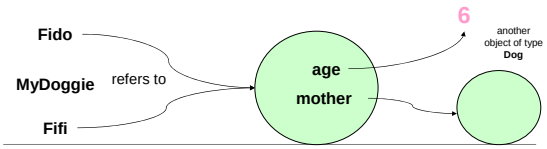
Drawing Names and Objects

- Names and objects
  - Very different things!
- In general, names refer to objects
  - Objects can *refer* to other objects using instance variable names



Drawing Names and Objects

- A name might not refer to any object
- One object might have more than one name
  - i.e., might be more than one reference to it
- An object might not have any name
  - "anonymous"



Specialization – "is a"

- Specialization relations can form *classification hierarchies*
  - cats and dogs are special kinds of mammals; mammals and birds are special kinds of animals; animals and plants are special kinds of living things
  - lines and triangles are special kinds of polygons; rectangles, ovals, and polygons are special kinds of shapes
- Keep in mind: Specialization is not the same as composition
  - A cat "is-a" animal vs. a cat "has-a" owner

"is-a" in Programming

- Classes (and interfaces) can be related via ***specialization***
  - one class/interface is *a special kind of* another class/interface
  - Rectangle class is a kind of Shape
- The general mechanism for representing "is-a" is *inheritance*

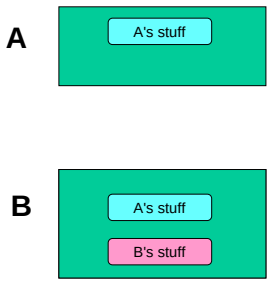
Inheritance

- Java provides direct support for "is-a" relations
  - likewise C++, C#, and other object-oriented languages
- Class *inheritance*
  - one class can *inherit from* another class, meaning that it's is a special kind of the other
- Terminology
  - Original class is called the *base class* or *superclass*
  - Specializing class is called the *derived class* or *subclass*

Inheritance: The Main Programming Facts

- Subclass *inherits* all instance variables and methods of the inherited class
  - All instance variables and methods of the superclass are *automatically* part of the subclass
  - Constructors are a special case (later)
- Subclass can *add* additional methods and instance variables
- Subclass can provide *different versions* of inherited methods

B extends A



A's stuff is *automatically* part of B

Design Example: Employee Database

- Suppose we want to generalize our Employee example to handle a more realistic situation
- Application domain – kinds of employees
  - Hourly
  - Exempt
  - Boss

Design Process – Step 1

- Think up a class to model each "kind" of thing

Design Process – Step 2

- Identify state/properties of each kind of thing

Design Process – Step 3

- Identify actions (behaviors) that each kind of thing can do

Key Observation

- Many kinds of employees share common properties and actions
- We can factor common properties into a base class and use inheritance to create variations for specific classes

Generic Employees

```
/** Representation of a generic employee. */
public class Employee {
  // instance variables
  private String name;       // employee name
  private int    id;         // employee id number
  /** Construct a new employee with the give name and id number… */
  public Employee(String name, int id) {
    this.name = name;
    this.id   = id;
  }
  /** Return the name of this employee */
  public String getName( ) { return name; }
  …
  /** Return the pay earned by this employee */
  public double getPay( ) { return 0.0; }    // ???
    …
  }
```


Specific Kinds of Employees

- Hourly Employee

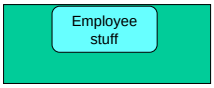
```
public class HourlyEmployee
             extends Employee {
  // additional instance variables
  private double hours;  // hours worked
  private double hourlyPay;  // pay rate

  /** Return pay earned  */
  public double getPay( ) {
    return hours * hourlyPay;
  }
  …
}
```

- Exempt Employee

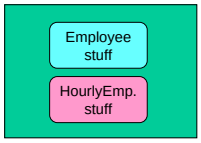
```
public class ExemptEmployee
             extends Employee {
  // additional instance variable
  private double salary;  // weekly pay

  /** Return pay earned  */
  public double getPay( ) {
    return salary;
  }
  …
}
```


In Pictures

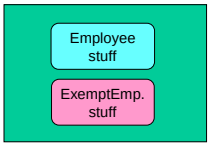
Employee



HourlyEmployee



ExemptEmployee



More Java

If class D extends B (inherits from) B...

- Class D inherits all methods and fields from class B
- But... "all" is too strong
  - constructors are *not* inherited
    (but there is a way to use superclass constructors during object creation)
  - same is true of static methods and static fields
    although these static members are still available in inherited part of the object – technicalities we will look at later
- Class D may contain additional (new) methods and fields
  - But has no way to delete any

Never to be Forgotten

If class D extends (inherits) from B...

Every object of type D is also an object of type B

- a D can do anything that a B can do (because of inheritance)
- a D can be used in any context where a B is appropriate

Method Overriding

- If class D extends B, class D may provide an *alternative* or *replacement* implementation of any method it would otherwise inherit from B
- The definition in D is said to *override* the definition in B
- An overriding method cannot change the number of arguments or their types, or the type of the result [why?]
  - can only provide a different body (implementation)
- Can you override an instance variable?
  - Not exactly... ask after class if you're really curious

Polymorphism

- *Polymorphic*: "having many forms"
- A variable that can refer to objects of different types is said to be *polymorphic*
- Methods with polymorphic arguments are also said to be polymorphic

```
public void printPay(Employee e) {
    System.out.println(e.getPay( ));
}
```

- Polymorphic methods can be *reused* for many types

Static and Dynamic Types

- With polymorphism, we can distinguish between
  - Static type: the declared type of the variable (never changes)
  - Dynamic type: the actual run-time class of the object the variable currently refers to (can change as program executes)
  - Legal assignment depends on static type compatibility

Static and Dynamic Types

- Which of these are legal? Illegal?
  - Can you fix any of these with casts?
- What are the static and dynamic types of the variables after assignments?

```
                                          Static?   Dynamic?
HourlyEmployee bart = new HourlyEmployee(…);
ExemptEmployee homer = new ExemptEmployee(…);
Employee marge = new Employee(…)
marge = homer ;
homer = bart;
homer = marge;
```


Dynamic Dispatch

- "Dispatch" refers to the act of actually placing a method in execution at run-time
- When types are static, the compiler knows exactly what method must execute (i.e., which method from which class)
- When types are dynamic... the compiler knows the *name* of the method – but there could be ambiguity about which version of the method will actually be needed at run-time
  - In this case, the decision is deferred until run-time, and we refer to it as *dynamic dispatch*
  - The chosen method is the one matching the dynamic (actual) type of the object

Method Lookup: How Dynamic Dispatch Works

- When a message is sent to an object, the right method to run is the one in the *most specific class* that the object is an instance of
  - Makes sure that method overriding always has an effect
- Method lookup (a.k.a. *dynamic dispatch*) algorithm:
  - Start with the actual *run-time class (dynamic type)* of the receiver object (not the static type!)
  - Search that class for a matching method
  - If one is found, invoke it
  - Otherwise, go to the superclass, and continue searching
- Example:

```
Employee e = new HourlyEmployee(…)
System.out.println(e);                  // HourlyEmployee toString( )
Employee e = new ExemptEmployee(…)
System.out.println(e);                  // ExemptEmployee toString( )
```


What about getPay( )?

- Got to include it in Employee so polymorphic code can use it (why?)

```
public double getPay(Employee e) {
    …
}
```

- But no implementation really makes sense
  - Class Employee doesn't contain "pay" instance variables
  - So including an implementation of this in Employee is really bogus

```
/** Return the pay earned by this employee */
 public double getPay( ) {
    return 0.0;    // ???
 }
```

Abstract Methods and Classees

- An *abstract method* is one that is declared but not implemented in a class

```
/** Return the pay earned by this employee */
public abstract double getPay( ) ;
```

- A class that contains any abstract method(s) must itself be declared abstract

```
public abstract class Employee { … }
```

- Instances of abstract classes cannot be created
  - Usually because they are missing implementations of one or more methods

Using Abstract Classes

- An abstract class is intended to be extended
- Extending classes can override abstract methods they inherit to provide actual implementations

```
class HourlyEmployee extends Employee {
    …
    /** Return the pay of this Hourly Employee */
    public double getPay( ) { return hoursWorked * payRate; }
}
```

  - Instances of these extended classes can be created
- A class that extends an abstract class without overriding all inherited abstract methods is itself abstract (and can be further extended)
- A class that is not abstract is often called a *concrete class*

Class Object

- Object is at the root of the Java class heirarchy
- Every class extends Object, either explicitly or implicitly
  - If extends does not appear in a class declaration, “extends Object” is assumed implicitly
  - These are equivalent

```
public class Employee { … }
public class Employee extends Object { … }
```

- Object includes a small number of methods appropriate for all objects – toString, equals, a few others
  - These methods are inherited by all classes, but can be overridden – often necessary or at least a good idea

Summary

- Object-oriented programming is hugely important
  - Lots of new concepts and terms
  - Lots of new programming and modeling power
  - Used widely in real programs
- Ideas (so far!)
  - Composition ("has a") vs. specialization ("is a")
  - Inheritance
  - Method overriding
  - Polymorphism, static vs. dynamic types
  - Method lookup, dynamic dispatch
  - Abstract classes and methods