OOP Inheritance

Università di Modena e Reggio Emilia
Prof. Nicola Bicocchi (nicola.bicocchi@unimore.it)

Motivation

- They all move, have a shape, shields and weapons. Can they share the same code?

Motivation

- Frequently, a class is merely a modification of another class. Inheritance allows minimal repetition of the same code
- A new design created by changing an existing design. (The new design consists of only the changes)
- Localization of code
  - Fixing a bug in the base class automatically fixes it in the subclasses
  - Adding functionality in the base class automatically adds it in the subclasses
  - Less chances of different (and inconsistent) implementations of the same operation

Inheritance

- A class can be a sub-type of another class
- The inheriting class contains all the methods and fields of the class it inherited from plus any methods and fields it defines
- The inheriting class can override the definition of existing methods by providing its own implementation
- The code of the inheriting class consists only of the changes and additions to the base class

Example I

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isCharged;
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}

SDCar c = new SDCar();
c.turnOn();      // OK!
c.turnSDOn();    // OK!

*SD = SelfDriving
```

Example II (Override)

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isCharged;
    boolean isSelfDriving;

    /* override */
    void turnOn() {
        turnSDOff();
        /* … */
    }

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

The keyword extends

```
Class SDCar extends Car {
   boolean isCharged;
   boolean isSelfDriving;

   void turnSDOn() {…}
   void turnSDOff() {…}
}
```

SDCar

- Inherits
  - attributes (isOn, licencePlate)
  - methods (turnOn, turnOff)
- Adds
  - attributes (isCharged, isSelfDriving)
  - Methods (turnSDOn, turnSDOff)
- Modifies (overrides)
  - turnOn

Terminology

- **Class one above**
  - Parent class
- **Class one below**
  - Child class
- **Class one or more above**
  - Superclass, Ancestor class, Base class
- **Class one or more below**
  - Subclass, Descendent class

Visibility (Scope)

Visibility

```
Class Car {
    private boolean isOn;
    private string licensePlate;

    public void turnOn() {…}
    public void turnOff() {…}
}
```

```
Class SDCar extends Car {
    void print() {

    System.out.println(licencePlate);
        // Do not work! Not visible!
    }
}
```

The keyword protected

- Attributes and methods marked as
  - public are always accessible
  - private are accessible within the class only
  - protected are accessible within the class and its subclasses

Visibility

```
Class Car {
    protected boolean isOn;
    protected string licensePlate;
    public void turnOn() {…}
    public void turnOff() {…}
}
```

```
Class SDCar extends Car {
    void print() {
    System.out.println(licencePlate);
    // OK!
    }
}
```

Summary

	Method in the same **class**	Method of another class in the same **package**	Method of **subclass**	Method of another public class in the outside **world**
private	✓			
package	✓	✓		
protected	✓	✓	✓	
public	✓	✓	✓	✓

The keyword super

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isCharged;
    boolean isSelfDriving;

    /* override */
    void turnOn() {
        turnSDOff();
        super.turnOn();
    }

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

The keyword super

- this is a reference to the current object
- super is a reference to the parent class

Inheritance and constructors

Construction of child objects

- Since each object “contains” an instance of the parent class, the latter must be initialized
- Java compiler automatically inserts a call to default constructor (no params!) of parent class
- The call is inserted as the first statement of each child constructor. If parent class disabled default constructor (by defining others) parent constructor must be called explicitly!

super()

- Use super() to identify constructors of parent class
- Must be the first statement in child constructors

Example

```
class Car {
    String carName;
    // Default constructor active!
}

Class SDCar extends Car {
    SDCar() {
        // OK!
    }
}
```

Example

```
class Car {
    String carName;
    // Custom constructor. Disables default one
    Car(String carName) {
        this.carName = carName;
    }
}
Class SDCar extends Car {
    SDCar() {
        // ERROR here. No default constructor on car!
    }
}
```

Example

```
class Car {
    String carName;
    // Custom constructor. Disables default one
    Car(String carName) {
        this.carName = carName;
    }
}
Class SDCar extends Car {
    SDCar() {
        super(“Fiat”);   // OK!
    }
}
```

Construction of child objects

- Execution of constructors proceeds top-down in the inheritance hierarchy
- In this way, when a method of the child class is executed (constructor included), the super-class is completely initialized already

Example

```
class Car{
    Car() { System.out.println("New Car"); }
}
Class SDCar extends Car{
    SDCar() { System.out.println("New SDCar"); }
}
class ECar extends SDCar {
    ECar() { System.out.println("New ECar"); }
}

ECar c = new ECar();  // Which output?
```

Dynamic binding and polymorphism

```
Car[] garage = new Car[4];

garage[0] = new Car();
garage[1] = new SDCar();
garage[2] = new SDCar();
garage[3] = new Car();

for(Car c : garage) {
    c.turnOn();
    // which method is actually called?
    // not knowable at compile time!
}
```

Dynamic binding and polymorphism

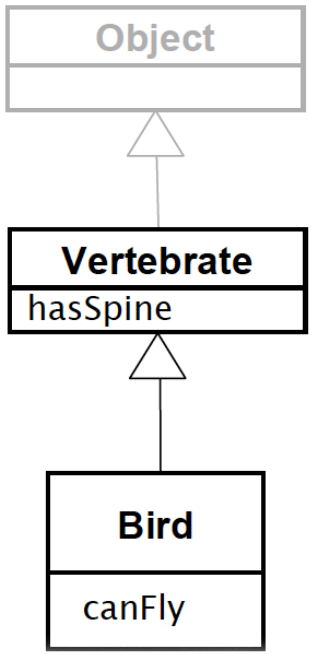
- When using collections of objects belonging to a hierarchy of classes, methods actually called are known only at runtime.
- The same call (methods with the same signature) might have different results depending on the actual class of the object.

* https://en.wikipedia.org/wiki/Late_binding

Object

Dynamic binding and polymorphism

- **`java.lang.Object`**
- All classes are subtypes of Object




```
class Vertebrate  {
   …
}
```

extends Object — Implicitly

```
class Bird extends Vertebrate{
   …
}
```

Java.lang.Object

- Each instance can be seen as an Object instance (see Collection)
- Object defines some services, which are useful for all classes
- Often, they are overridden in sub-classes

toString(), equals()

- toString()
  - Returns a string uniquely identifying the object
- equals()
  - Tests equality of values

System.out.println(Object)

```
class Car{
   String toString(){…}
}

Car c = new Car();
// equivalent calls
System.out.println(c);
System.out.println(c.toString());
```

- System.out.println() methods implicitly invoke toString() on all object parameters
- Polymorphism applies when toString() is overridden

Casting

Types

- Java is a strictly typed language, i.e., each variable has a type
- float f;
  - f = 4.7; //legal
  - f = “string”; //illegal
- Car c;
  - c = new Car(); //legal
  - c = new String(); //illegal

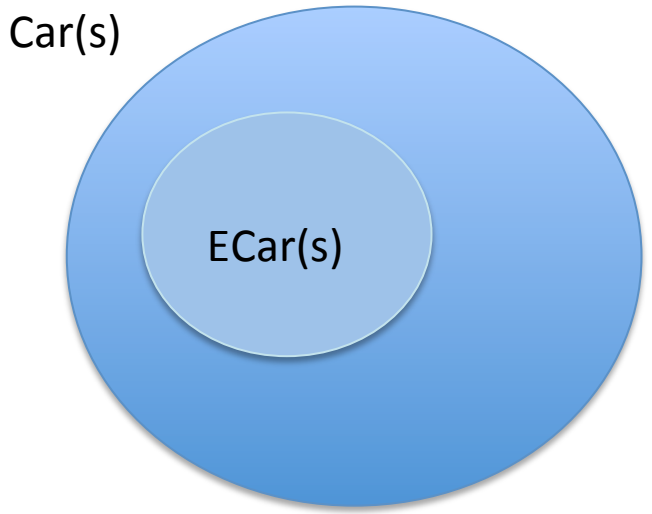
Specialization

```
class Car {};
class ECar extends Car{};

Car c1 = new Car();     // OK!
Ecar c2 = new ECar (); // OK!

But also…

Car c3 = new Ecar();    // OK?
```

Specialization

```
Car c3 = new Ecar();    // OK!
```

- Specialization defines a sub-typing relationship (is a). In Venn's terms ECar type is a subset of Car type.



Upcasting

- Assignment from a more specific type (subtype) to a more general type (supertype)

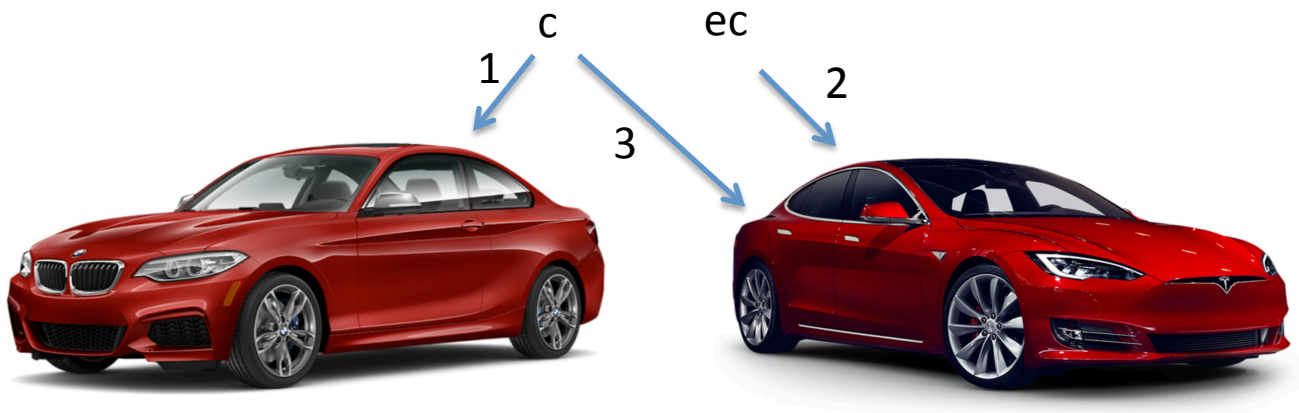
```
class Car{};
class ECar extends Car{};
Car c = new ECar ();
```

- Note well - reference type and object type are separate concepts. Object referenced by ‘c’ continues to be of ECar type! Only the interface changes!

Upcasting

- It is dependable
  - It is always true that an electric car is a car too
- It is automatic (*e.g., float f = (int) 3*)

```
(1) Car c = new Car();
(2) ECar ec = new ECar ();
(3) c = ec;
```



Example

```
Class Car {
     boolean isOn;
     string licensePlate;

     void turnOn() {…}
     void turnOff() {…}
}
```

```
Class ECar extends Car {
     boolean isCharged;
     boolean isSelfDriving;

     void turnSDOn() {…}
     void turnSDOff() {…}
}
```

```
ECar c1 = new ECar();
c1.turnSDOn() // OK!

Car c2 = c1;  // Upcast
c2.turnSDOn() // Invalid! (Car public interface does
not provide turnSDOn() call)
```

Downcasting

- Assignment from a more general type (super-type) to a more specific type (sub-type)
  - Reference type and object type do not change
- MUST be explicit
  - It's a risky operation, no automatic conversion provided by the compiler (it's up to you!)

Example

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class ECar extends Car {
    boolean isCharged;
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

```
Car c1 = new ECar();
c1.turnSDOn() // Invalid!

ECar c2 = (Ecar)c1;  // Downcast
c2.turnSDOn() // Accidentally OK!
```

Example

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class ECar extends Car {
    boolean isCharged;
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

```
Car c1 = new Car();
c1.turnSDOn() // Invalid!

ECar c2 = (Ecar)c1;  // Downcast
c2.turnSDOn() // Invalid! (Runtime!!)
```

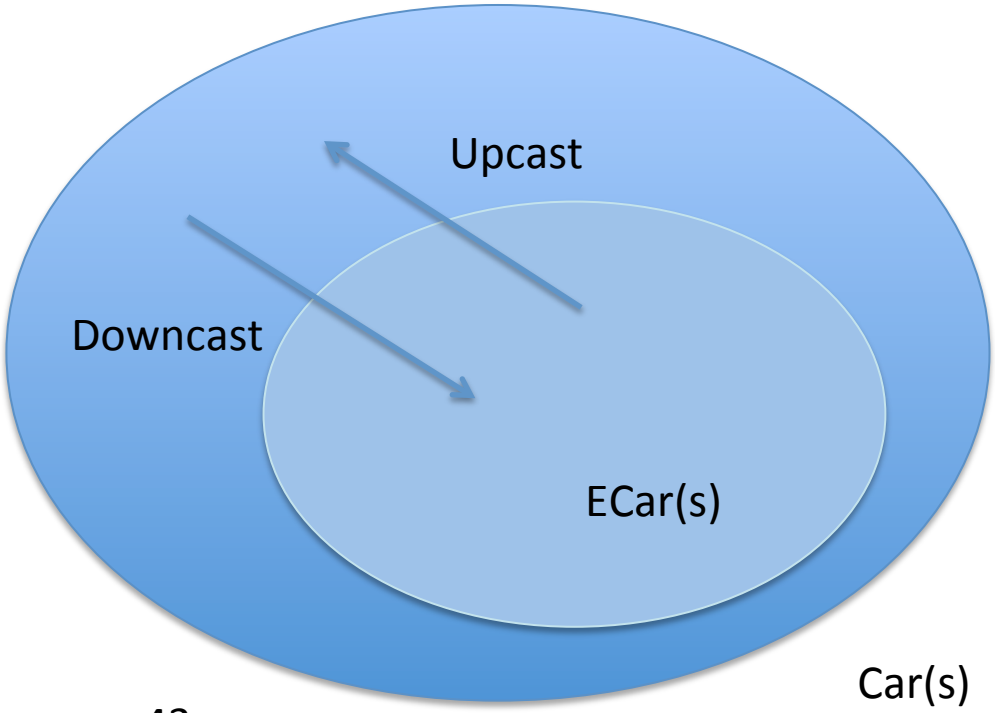
Runtime is evil

- Compilers aid developers in writing working code. Runtime errors cannot be identified by compilers. Developers must be careful!
- Use the instanceof operator

```
Car c = new Car();
ECar ec;
if (c instanceof ECar){
   ec = (ECar) c;
   ec.turnSDOn();
}
```

Specialization

- Specialization defines a sub-typing relationship (is a). ECar type is a subset of Car type. All ECar(s) are Car(s). Not all Car(s) are ECar(s).



Upcast to object

- Each class is either directly or indirectly a subclass of Object
- It is always possible to upcast any instance to Object type (see Collection)

```
AnyClass any = new AnyClass();
Object obj = (Object)any;
```

Abstract Classes and Interfaces

Abstract methods

- You can *declare* an object without *defining* it:

  Person p;

- Similarly, you can declare a *method* without defining it (i.e., the body of the method is missing):

  public abstract void draw(int size);

- A method that has been declared but not defined is an abstract method

Abstract classes

- Any class containing one or more abstract method is an abstract class
- You must declare the class with the keyword abstract:

```
abstract class MyClass {...}
```

- An abstract class is *incomplete* (It has missing method bodies)
- You cannot instantiate (create a new instance of) an abstract class

Abstract classes

- You can extend (subclass) an abstract class
  - If the subclass defines all the inherited abstract methods, it is concrete and can be instantiated
  - If the subclass does *not* define all the inherited abstract methods, it must be abstract too
- You can declare a class to be abstract even if it does not contain any abstract methods
  - This just prevents the class from being instantiated

An example abstract class

```
public abstract class Animal {
    abstract int eat();
    abstract void breathe();
}
```

- This class cannot be instantiated
- Any non-abstract subclass of Animal must provide the eat() and breathe() methods

Why use abstract classes?

- Suppose you wanted to create a class Shape, with subclasses Oval, Rectangle, Triangle, Hexagon, etc. You don't want to allow creation of a "Shape"
  - Only *particular* shapes make sense, not *generic* ones
- If Shape is abstract, you can't create a new Shape
  - You *can* create a new Oval, a new Rectangle, etc.
  - Abstract classes are good for defining a general category containing specific "concrete" classes

A problem

```
class Shape { ... }
class Star extends Shape {
    void draw() { ... }
    ...
}
class Circle extends Shape {
    void draw() { ... }
    ...
}
Shape s;
s = new Shape(); // Legal, but unwanted
s = new Star();  // Legal, because a Star is a Shape
s.draw();        // Illegal, Shape does not have draw()
```

Same problem, another view

```
Shape[] shapes = new Shape[16];
shapes[0] = new Circle();
shapes[1] = new Star();
…
for (Shape s : shapes) {
    s.draw(); // Illegal, Shape does not have draw()
}
```

A solution

```
abstract class Shape {
    abstract void draw();
}
class Star extends Shape {
    void draw() { ... }
    ...
}
class Circle extends Shape {
    void draw() { ... }
    ...
}
Shape s;
s = new Shape(); // Illegal, Shape is abstract
s = new Star();  // Legal, because a Star is a Shape
s.draw();        // Legal, Shape does have draw()
```

Interfaces

- An interface declares methods but does not supply implementations
- All the methods are implicitly public and abstract. It may also contain constants (final attributes).
- **Cannot be instantiated (An interface is like a *very* abstract class)**

```
interface AffineT {
    public void move(double x, double y);
    public void rotate(double angle);
    public void scale(double scaleFactor);
}

interface SimilarT {
    public void generateSimilar();
}
```

Implementing an interface

- You can extend a class, but you have to implement an interface
- A class can only extend (subclass) one other class, but it can implement many interfaces

```
class Star extends Shape implements AffineT, SimilarT {
    public Star() {…}
    …
}
```

Implementing an interface

```
class Star extends Shape implements AffineT, SimilarT {
   public Star() {…}

   public void move(double x, double y) {…}
   public void rotate(double angle) {…}
   public void scale(double scaleFactor) {…}

    public void generateSimilar() {…}
}
```

- When you say a class implements an interface, you are promising to *define* all the methods that were *declared* in the interface

Partially implementing an Interface

- It is possible to implement some but not all of the methods defined in an interface
  - Since this class does not supply all the methods it has promised, it must be defined abstract
- It is also possible to *extend* an interface (to add methods):
  - It is a new interface with additional methods

What are interfaces for?

- A class can only extend one other class, but it can implement multiple interfaces
  - This lets the class fill multiple *roles*
  - In graphical interfaces (GUIs), it is common to have one class implementing several listeners (i.e., interfaces)
- Example:

```
class Application extends JFrame implements
ActionListener, KeyListener {
    ...
}
```

Problem

```
public class GroudVehicle {
    activateWheels() {…}
    …
}

public class WaterVehicle {
    activateWaterFan() {…}
    …
}

// Not allowed in Java!! Only one class can be extended!
public class Anphibian extends GroudVehicle, WaterVehicle {
    …
}
```

Solution

```
public interface GroudVehicle {
     activateWheels();
     …
}

public interface WaterVehicle {
     activateWaterFan();
     …
}

// OK!
public class Anphibian implements GroudVehicle, WaterVehicle {
     activateWheels() {…}
     activateWaterFan() {…}

     …
}
```

Interfaces and instanceof

- instanceof is a keyword that tells you whether a variable "is a" member of a class or interface

```
class Dog extends Animal implements Pet {...}
Animal fido = new Dog();

fido instanceof Dog        //OK!
fido instanceof Animal     //OK!
fido instanceof Pet        //OK!
```

Adapter classes

- When you implement an interface, you promise to define *all* the functions it declares
- There can be a *lot* of methods

```
interface KeyListener {
      public void keyPressed(KeyEvent e);
      public void keyReleased(KeyEvent e);
      public void keyTyped(KeyEvent e);
}
```

- What if you only care about a couple of these methods?

Adapter classes

- Solution: use an adapter class
- An adapter class implements an interface and provides empty method bodies

```
class  KeyAdapter implements KeyListener {
     public void keyPressed(KeyEvent e) { };
     public void keyReleased(KeyEvent e) { };
     public void keyTyped(KeyEvent e) { };
}
```

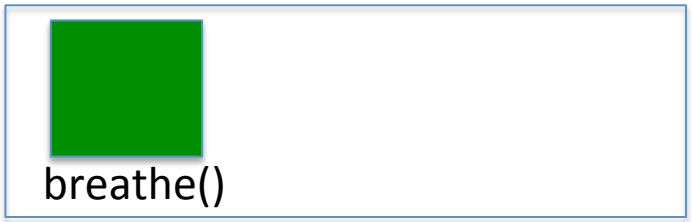
- You can override only the methods you care about. Java provides a number of adapter classes

Summary

- We design a videogame allowing dogs to breathe, bark and move

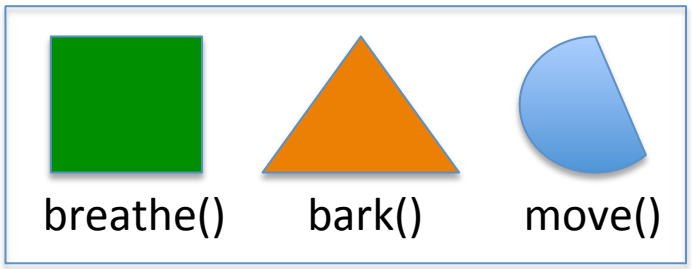
```
interface movable {
     public abstract void move(double x, double y);
}

class Animal {
     public void breathe();
}

class Dog extends Animal implements movable {
     public void bark();
}

Dog lessie = new Dog();
Animal a = lessie;
Movable m = lessie;
```

Summary

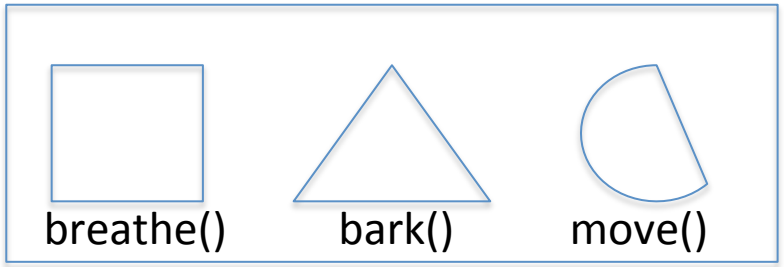


a, the Animal reference

m, the movable reference



lessie, the Dog reference



the actual Dog object

Vocabulary

- abstract method—a method which is declared but not defined (it has no method body)
- abstract class—a class which either (1) contains abstract methods, or (2) has been declared abstract
- instantiate—to create an instance (object) of a class
- interface—similar to a class, but contains only abstract methods (and possibly constants)
- adapter class—a class that implements an interface but has only empty method bodies

Complexity has nothing to do with intelligence, simplicity does.

— Larry Bossidy
Ex CEO Honeywell

Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.

— Antoine de Saint Exupery
Scrittore, aviatore francese