Inheritance

The software crisis

- **software engineering**: The practice of conceptualizing, designing, developing, documenting, and testing large-scale computer programs.
- Large-scale projects face many issues:
  - getting many programmers to work together
  - getting code finished on time
  - avoiding redundant code
  - finding and fixing bugs
  - maintaining, improving, and reusing existing code
  - targeting code to new machines
- **code reuse**: The practice of writing program code once and using it in many contexts.

Example

- You have been tasked with writing a program that handles pay for the employees of a non-profit organization.
- The organization has several types of employees on staff:
  - Full-time employees
  - Hourly workers
  - Volunteers
  - Executives

Example

- Paying an employee:
  - Full-time employees – have a monthly pay
  - Hourly workers – hourly wages + hours worked
  - Volunteers – no pay
  - Executives – receive bonuses

Design

- Need class/classes that handle employee pay (should also store employee info such as name, phone #, address).
- Possible choices:
  - A single Employee class that knows how to handle different types of employees
  - A separate class for each type of employee.
- What are the advantages/disadvantages of each design?

Design

- All types of staff members need to have some basic functionality – capture that in a class called `StaffMember`

Design

All types of staff members need to have some basic functionality – capture that in a class called `StaffMember`

```
public class StaffMember {
   private String name;
   private String address;
   private String phone;

   public StaffMember (String eName, String eAddress,
                       String ePhone) {
      name = eName;
      address = eAddress;
      phone = ePhone;
   }
  // not shown:  getters and setters
}
```

Code re-use

- We'd like to be able to do the following:

```
// A class to represent a paid employee.
public class Employee {
    <copy all the contents from StaffMember class.>

    private double payRate;
    public double pay() {
       return payRate;
     }

}
```

- All this without explicitly copying any code!

Inheritance

- **inheritance**: A way to create new classes based on existing classes, taking on their attributes/behavior.
  - a way to group related classes
  - a way to share code between classes
- A class *extends* another by absorbing its state and behavior.
  - **super-class**: The parent class that is being extended.
  - **sub-class**: The child class that extends the super-class and inherits its behavior.
    - The subclass receives a copy of every field and method from its super-class.
    - The subclass is a more specific type than its super-class (an **is-a** relationship)

Inheritance syntax

- Creating a subclass, general syntax:

  `public class` ***<name>*** `extends` ***<superclass name>*** `{`

  - Example:

```
public class Employee extends StaffMember {
    ....
}
```

- By extending `StaffMember`, each `Employee` object now:
  - has `name, address, phone instance variables and`

    `get/setName(), get/setAddress(), get/setPhone() methods` automatically
  - can be treated as a `StaffMember` by any other code (seen later)

    (e.g. an `Employee` could be stored in a variable of type `StaffMember` or stored as an element of an array `StaffMember[]`)

Single Inheritance in Java

- Creating a subclass, general syntax:
  - `public class` ***<name>*** `extends` ***<superclass name>***
  - ***Can only extend a single class in Java!***
- Extends creates an is-A relationship
  - `class` ***<name>*** `is-A` ***<superclass name>***
  - ***This means that anywhere a <superclass variable> is used, a <subclass variable> may be used.***
  - Classes get all the instance variables/methods of their ancestors, **but cannot necessarily directly access them...**

New access modifier - protected

- public - can be seen/used by everyone

- **protected** – can be seen/used within class and any subclass.

- private - can only be seen/used by code in class (not in subclass!)

Extends/protected/super

```
public class Employee extends StaffMember {
   protected String socialSecurityNumber;
   protected double payRate;
   public Employee (String name, String address,
      String phone, String socSecNumber, double rate){
      super(name, address, phone);
      socialSecurityNumber = socSecNumber;
      payRate = rate;
   }
   public double pay(){
      return payRate;
   }
}
```

StaffMember needs to change a bit

```
public class StaffMember {
   protected String name;
   protected String address;
   protected String phone;

  public StaffMember (String eName, String eAddress, String
  ePhone) {
      name = eName;
      address = eAddress;
      phone = ePhone;
   }
}
```

Overriding methods

- **override**: To write a new version of a method in a subclass that replaces the super-class's version.
  - There is no special syntax for overriding.
    To override a super-class method, just write a new version of it in the subclass. This will replace the inherited version.
  - Example:

```
public class Hourly extends Employee {
    // overrides the pay method in Employee class
    public double pay () {
    double payment = payRate * hoursWorked;
    hoursWorked = 0;
    return payment;
}
```

Calling overridden methods

- The new method often relies on the overridden one. A subclass can call an overridden method with the `super` keyword.

- Calling an overridden method, syntax:

  `super.`***<method name>*** (***<parameter(s)>***)

  -
    ```
    public class Executive extends Employee {
      public double pay() {
        double payment = super.pay() + bonus;
        bonus = 0;
        return payment;
     }
    ```

Inheritance and Polymorphism

Constructors

- Constructors are not inherited.
  - Default constructor:

```
public Employee(){
    super();      // calls StaffMember() constructor
}
```

  - Constructor needs to call super-class constructors explicitly:

```
public Employee (String name, String address, String phone,
                 String socSecNumber, double rate) {
   super (name, address, phone);
   socialSecurityNumber = socSecNumber;
   payRate = rate;
}
```

The `super` call must be the **first statement** in the constructor.

Binding: which method is called?

- Assume that the following four classes have been declared:

```
public class Foo {
    public void method1() {
        System.out.println("foo 1");
    }

    public void method2() {
        System.out.println("foo 2");
    }

    public String toString() {
        return "foo";
    }
}

public class Bar extends Foo {
    public void method2() {
        System.out.println("bar 2");
    }
}
```

Example

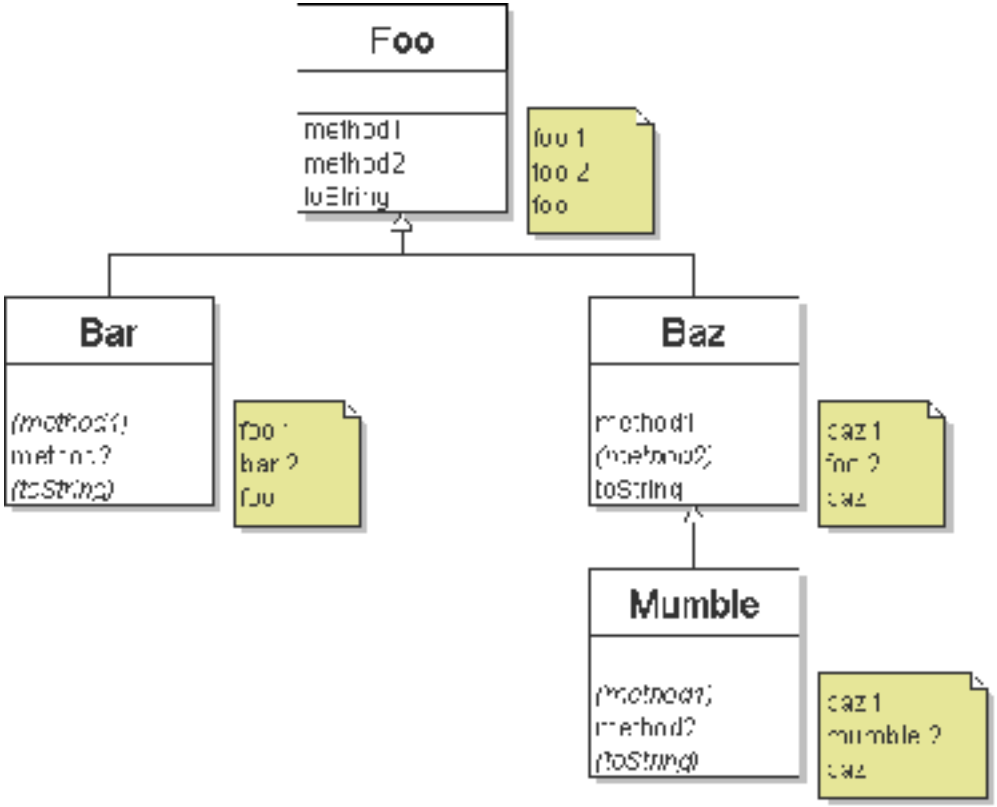
```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }
    public String toString() {
        return "baz";
    }
}
public class Mumble extends Baz {
    public void method2() {
        System.out.println("mumble 2");
    }
}
```

- The output of the following client code?

```
Foo[] a = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < a.length; i++) {
    System.out.println(a[i]);
    a[i].method1();
    a[i].method2();
    System.out.println();
}
```

Describing inheritance and binding

- UML diagram:
  Subclasses point to their super-class
- List methods (inherited methods in parenthesis)
- Method called is the nearest in the hierarchy going up the tree
  - This is a dynamic (run time) phenomenon called **dynamic binding**



Example (solved)

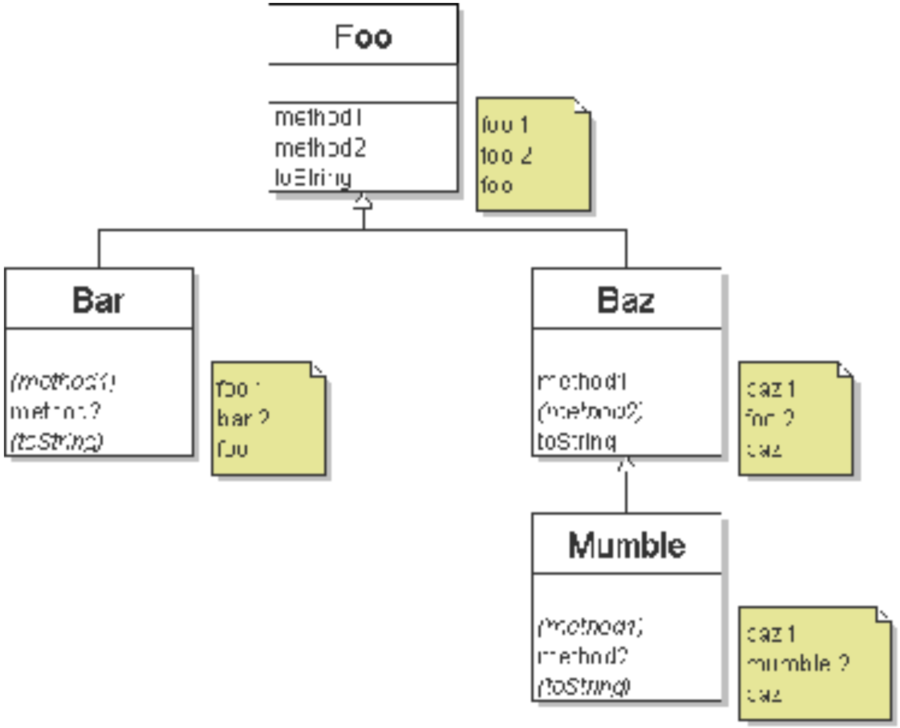
```
Foo[] a = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < a.length; i++) {
    System.out.println(a[i]);
    a[i].method1();
    a[i].method2();
    System.out.println();
}
```

Output?

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1
mumble 2
foo
foo 1
foo 2
```



Polymorphism

- It’s legal for a variable of a super-class to refer to an object of one of its subclasses.

  Example:

```
staffList = new StaffMember[6];
staffList[0] = new Executive("Sam", "123 Main Line",
     "555-0469", "123-45-6789", 2423.07);
staffList[1] = new Employee("Carla", "456 Off Line",
     "555-0101", "987-65-4321", 1246.15);
staffList[2] = new Employee("Woody", "789 Off Rocker",
     "555-0000", "010-20-3040", 1169.23);
((Executive)staffList[0]).awardBonus (500.00);
```

Arrays of a super-class type can store any subtype as elements.

Polymorphism and casting

- When a primitive type is used to store a value of another type (e.g. an `int` in a `double` variable) conversion takes place.
- When a subclass is stored in a superclass no conversion occurs!

Polymorphism defined

- **Polymorphism**: the ability for the same code to be used with several different types of objects and behave differently depending on the actual type of object used.
- Example:

```
for (int count=0; count < staffList.length; count++)
{
    amount = staffList[count].pay();  // polymorphic
}
```

Polymorphism and parameters

- You can pass any subtype of a parameter's type.

```
public class EmployeeMain {
    public static void main(String[] args) {
        Executive lisa = new Executive(…);
        Volunteer steve = new Volunteer(…);
        payEmployee(lisa);
        payEmployee(steve);
    }

    public static void payEmployee(StaffMember s) {
        System.out.println("salary = " + s.pay());
      }

}
```

Notes about polymorphism

- The program doesn’t know which pay method to call until it’s actually running. This has many names: late binding, dynamic binding, virtual binding, and dynamic dispatch.
- You can only call methods known to the super-class, unless you explicitly cast.
- You cannot assign a super-class object to a sub-class variable (a cow is an animal, **but an animal is not a cow!)**

Abstract classes

- An **abstract class:** can leave one or more method implementations unspecified
- An abstract method has no body (i.e.,no implementation).
- Hence, an abstract class is incomplete and cannot be instantiated, but can be used as a base class.

```
abstract public class abstract-base-class-name {
    public abstract return-type method-name(params);
    ...
}
public class derived-class-name {
    public return-type method-name(params)                   {
statements; }
    ...
}
```

A subclass is required to override the abstract method and provide an implementation.

Example

- Let's convert `Employee` to an abstract class....

Example

- Let’s convert `Employee` to an abstract class.

```
public abstract class Employee {
   ...
   public abstract double pay();
}
```

- Now the sub classes must override pay(), thereby implementing pay() appropriately for each sub type of Employee

Abstract classes

- When to use abstract classes
  - To represent entities that are insufficiently defined
  - Group together data/behavior that is useful for its subclasses

Inheritance: FAQ

- How can a subclass call a method or a constructor defined in a super-class?
  - Use super() or super.method()
- Does Java support multiple inheritance?
  - No. Use interfaces instead
- What restrictions are placed on method overriding?
  - Same name, argument list, and return type. May not throw exceptions that are not thrown by the overriden method, or limit the access to the method
- Does a class inherit the constructors of its super-class?
  - No. Need to call them explicitly

this and super in constructors

- `this(…)` calls a constructor of the same class.
- `super(…)` calls a constructor of the super-class.
- Both need to be the first action in a constructor.