

Inheritance

Introduction to Programming and
Computational Problem Solving - 2

CSE 8B

Lecture 9

Announcements

- Assignment 4 is due Apr 27, 11:59 PM
- Assignment 5 will be released Apr 27
 - Due May 6, 11:59 PM
- Midterm is May 2
- Reading
 - Liang
 - Chapter 11

Inheritance

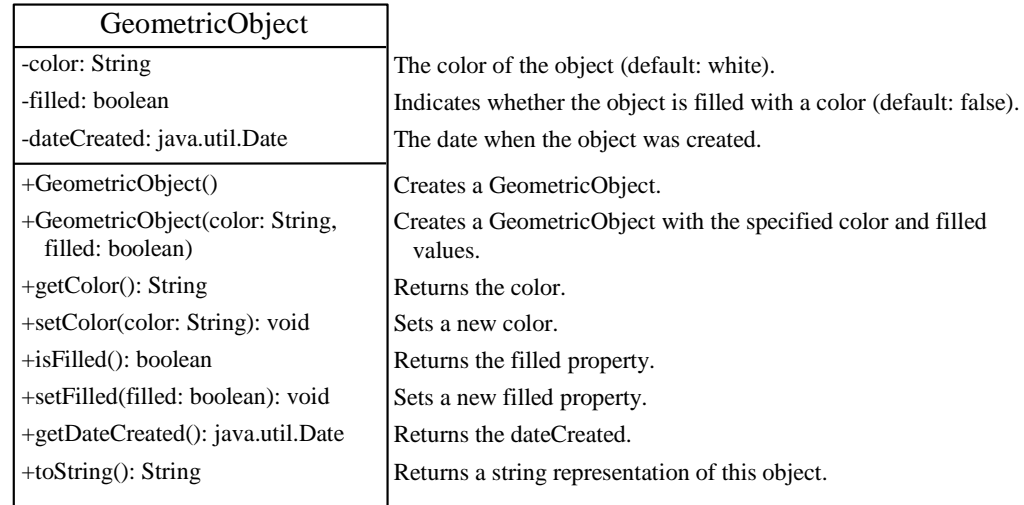
- Suppose you define classes to model circles, rectangles, and triangles
- These classes have many common features
- What is the best way to design these classes so to avoid redundancy?
- Object-oriented programming allows you to define new classes from existing classes
- This is called *inheritance*

Superclasses and subclasses

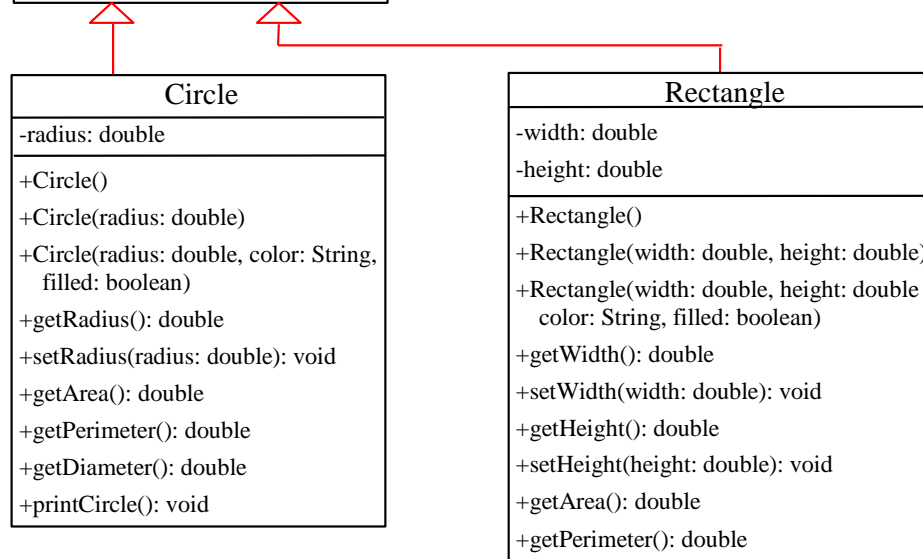
- Inheritance enables you to define a general class (i.e., a *superclass*) and later extend it to more specialized classes (i.e., *subclasses*)
- A subclass inherits from a superclass
 - For example, both a circle and a rectangle are geometric objects
 - `GeometricObject` is a superclass
 - `Circle` is a subclass of `GeometricObject`
 - `Rectangle` is a subclass of `GeometricObject`
- Models **is-a** relationships
 - For example
 - `Circle` **is-a** `GeometricObject`
 - `Rectangle` **is-a** `GeometricObject`

Superclasses and subclasses

Superclass



Subclasses



Superclasses and subclasses

- A subclass inherits accessible data fields and methods from its superclass and may also add new data fields and methods
 - **A subclass is not a subset of its superclass**
 - A subclass usually contains more information and methods than its superclass
 - For example
 - A rectangle has a width and height
 - A circle has a radius
 - Both have a color

Superclasses and subclasses

- A **superclass** is also called a *parent class* or *base class*
- A **subclass** is also called a *child class*, *extended class*, or *derived class*
 - A child class inherits from a parent class
 - A subclass extends a superclass
 - A derived class derives from a base class

Superclasses and subclasses

- Remember, a class defines a type
- A type defined by a subclass is called a *subtype*, and a type defined by its superclass is called a *supertype*
 - For example
 - Circle is a subtype of GeometricObject, and GeometricObject is a supertype for Circle

Inheritance

- The keyword `extends` tells the compiler that the (sub)class extends another (super)class
- A Java class may inherit directly from only one superclass
 - This restriction is known as *single inheritance*
 - Some other programming languages allow classes to inherit from one or more classes
 - This is known as *multiple inheritance*

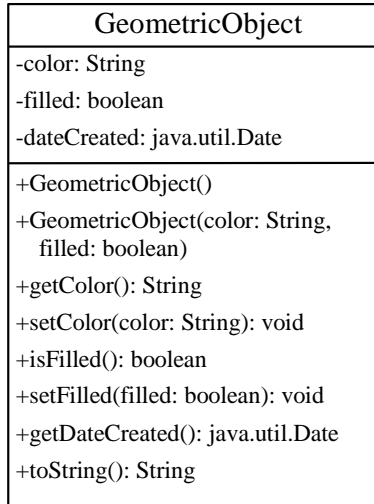
extends keyword

- The keyword `extends` tells the compiler that the (sub)class extends another (super)class
- For example
 - The `Circle` class extends the `GeometricObject` class using the syntax

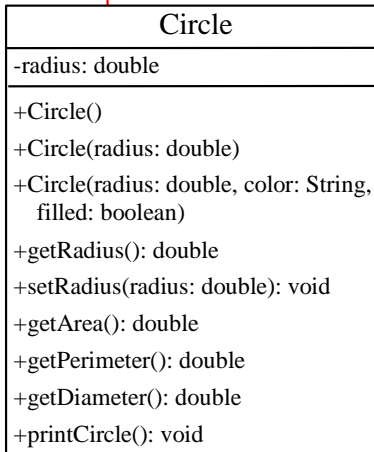
```
public class Circle extends GeometricObject
```
 - The `Circle` class inherits the **accessible** data fields and methods of `GeometricObject`

Circle extends GeometricObject

Superclass



Subclass



```
public class Circle extends GeometricObject {  
    private double radius;  
  
    public Circle() {  
    }  
  
    public Circle(double radius) {  
        this.radius = radius;  
    }  
}
```

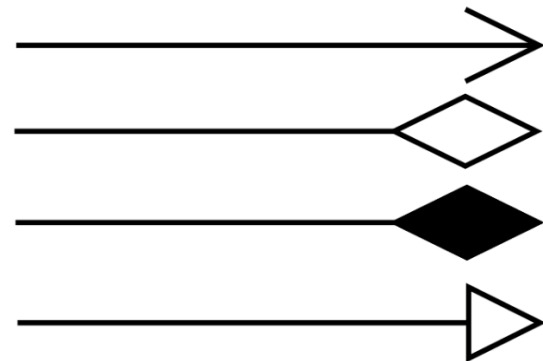
Unified Modeling Language (UML)

+ public

protected

- private

- Static variables and methods are underlined
- Open or no arrow is association
- Hollow diamond is aggregation
- Filled diamond is composition
- Hollow triangle is inheritance



Methods and data fields visibility

Modifiers on Members in a Class	Accessed from the Same Class	Accessed from the Same Package	Accessed from a Subclass in a Different Package	Accessed from a Different Package
Public	✓	✓	✓	✓
Protected	✓	✓	✓	
Default (no modifier)	✓	✓		
Private	✓			

Methods and data fields visibility

- **Private members cannot be accessed outside of a class, including one of its subclasses**
 - Use accessor (getter) and mutator (setter) methods

```
public class Circle extends GeometricObject {
    private double radius;

    public Circle() {
    }

    public Circle(double radius) {
        this.radius = radius;
    }

    public Circle(double radius, String color, boolean filled) {
        this.radius = radius;
        setColor(color);
        setFilled(filled);
    }
}
```

Superclass constructors and the super keyword

- Remember, a constructor is used to construct an instance of a class
- Unlike properties and methods, **a superclass's constructors are not inherited in the subclass**
- They can only be invoked from the subclasses' constructors, using the keyword super
- **If the keyword super is not explicitly used, the superclass's no-arg constructor is automatically invoked**

Superclass constructors and the super keyword

- For example, replace this

```
public class Circle extends GeometricObject {
    private double radius;

    public Circle(double radius, String color, boolean filled) {
        this.radius = radius;
        setColor(color);
        setFilled(filled);
    }
}
```

with this

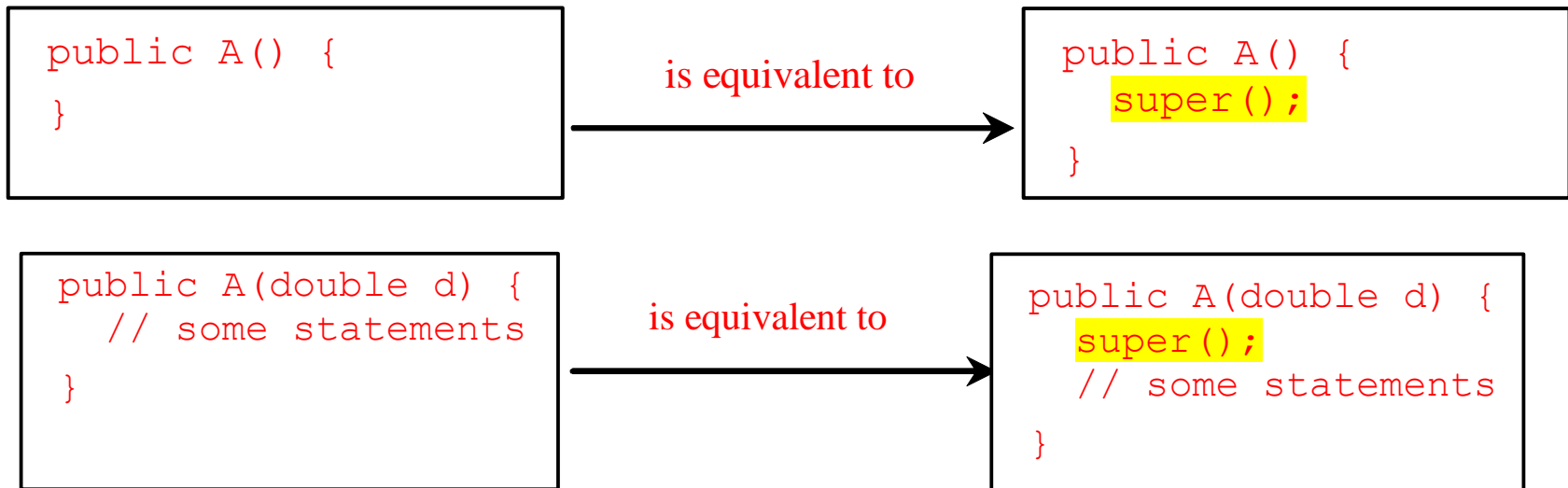
```
public class Circle extends GeometricObject {
    private double radius;

    public Circle(double radius, String color, boolean filled) {
        super(color, filled);
        this.radius = radius;
    }
}
```

Invoking the superclass constructor using super must be the first statement in the subclass's constructor

Superclass constructors and the super keyword

- If the keyword `super` is not explicitly used, the superclass's no-arg constructor is automatically invoked (as the first statement in the constructor)



Constructor chaining

- Constructing an instance of a class invokes **all** the superclasses' constructors along the inheritance chain
- This is known as *constructor chaining*

Constructor chaining

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```

1. Start from the main method

Trace code


```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```



2. Invoke Faculty constructor

Trace code

```
public class Faculty extends Employee {  
    public static void main(String[] args) {  
        new Faculty();  
    }  
}
```

```
    public Faculty() {  
        System.out.println("(4) Faculty's no-arg constructor is invoked");  
    }  
}
```

```
class Employee extends Person {  
    public Employee() {  
        this("(2) Invoke Employee's overloaded constructor");  
        System.out.println("(3) Employee's no-arg constructor is invoked");  
    }  
}
```

```
    public Employee(String s) {  
        System.out.println(s);  
    }  
}
```

```
class Person {  
    public Person() {  
        System.out.println("(1) Person's no-arg constructor is invoked");  
    }  
}
```

3. Invoke Employee's no-arg constructor

Trace code

```
public class Faculty extends Employee {  
    public static void main(String[] args) {  
        new Faculty();  
    }  
}
```

```
public Faculty() {  
    System.out.println("(4) Faculty's no-arg constructor is invoked");  
}
```

```
class Employee extends Person {  
    public Employee() {  
        this("(2) Invoke Employee's overloaded constructor");  
        System.out.println("(3) Employee's no-arg constructor is invoked");  
    }  
}
```

4. Invoke Employee(String)
constructor

```
public Employee(String s) {  
    System.out.println(s);  
}
```

```
class Person {  
    public Person() {  
        System.out.println("(1) Person's no-arg constructor is invoked");  
    }  
}
```

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```

5. Invoke Person() constructor

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```

6. Execute println

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```

7. Execute println

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```



8. Execute println

Trace code

```
public class Faculty extends Employee {
    public static void main(String[] args) {
        new Faculty();
    }

    public Faculty() {
        System.out.println("(4) Faculty's no-arg constructor is invoked");
    }
}

class Employee extends Person {
    public Employee() {
        this("(2) Invoke Employee's overloaded constructor");
        System.out.println("(3) Employee's no-arg constructor is invoked");
    }

    public Employee(String s) {
        System.out.println(s);
    }
}

class Person {
    public Person() {
        System.out.println("(1) Person's no-arg constructor is invoked");
    }
}
```



9. Execute println

Default constructor

- Remember, a class may be defined without constructors
- In this case, a no-arg constructor with an empty body is *implicitly* defined in the class
- This constructor, called a *default constructor*, is provided automatically *only if no constructors are explicitly defined in the class*
- **Best practice is to provide (if possible) a no-arg constructor for every class to make the class easy to extend and avoid compile-time errors during constructor chaining**

super keyword

- The keyword `super` refers to the superclass of the class in which `super` appears
- The keyword `super` can be used to
 - Call a superclass constructor
 - Call a superclass method
 - Similar to using `this` to reference the calling object, the keyword `super` refers to the superclass of the class which `super` appears
 - Syntax
 - `super.method(arguments);`

Defining a subclass

- A subclass inherits from a superclass
- You can also
 - Add new properties
 - Add new methods
 - Override the methods of the superclass

Add new methods

- For example
 - Add `printCircle()` method in the `Circle` class

```
public void printCircle() {  
    System.out.println("The circle is created " +  
        super.getDateCreated() + " and the radius is " + radius);  
}
```

Call superclass method



Override the methods of the superclass

- A subclass inherits methods from a superclass
- Sometimes it is necessary for the subclass to modify the implementation of a method defined in the superclass
- This is referred to as *method overriding*

Override the methods of the superclass

- To override a method, the method must be defined in the subclass using **the same signature** as in its superclass, and **same or subtype of the overridden method's return type**
- A best practice to avoid mistakes is to use a special Java syntax, called *override annotation*
 - Annotated method is required to override a method in its superclass
 - If it does not, then there will be a compile-time error

```
public class Circle extends GeometricObject {  
    // Other methods are omitted
```

```
    @Override
```

```
    public String toString() {  
        return super.toString() + "\nradius is " + radius;  
    }
```

```
}
```

Overriding vs overloading

- Overridden methods
 - Have the same signature
 - Are in different classes related by inheritance
- Overloaded methods
 - Have the same name, but different parameter lists
 - Can be either
 - In the same class
 - In different classes related by inheritance

Overriding vs overloading

```
public class Test {
    public static void main(String[] args) {
        A a = new A();
        a.p(10);
        a.p(10.0);
    }
}

class B {
    public void p(double i) {
        System.out.println(i * 2);
    }
}

class A extends B {
    // This method overrides the method in B
    public void p(double i) {
        System.out.println(i);
    }
}
```

```
public class Test {
    public static void main(String[] args) {
        A a = new A();
        a.p(10);
        a.p(10.0);
    }
}

class B {
    public void p(double i) {
        System.out.println(i * 2);
    }
}

class A extends B {
    // This method overloads the method in B
    public void p(int i) {
        System.out.println(i);
    }
}
```

Private methods of the superclass

- An instance method can be overridden only if it is accessible
- As such, a **private method cannot be overridden** because it is not accessible outside its own class
- **If a method defined in a subclass is private in its superclass, then the two methods are completely unrelated**

Static methods of the superclass

- Like an instance method, a static method can be inherited
- However, a **static method cannot be overridden**
- **If a static method defined in the superclass is redefined in a subclass, the method defined in the superclass is hidden**

this and super keywords

- **Similar to using `this` to reference the calling object, the keyword `super` refers to the superclass of the class which `super` appears**
- The keyword `this` is the name of a reference that refers to an object itself
 - One common use of the `this` keyword is to reference a hidden *class* member
- The keyword `super` refers to the superclass of the class in which `super` appears
 - One common use of the `super` keyword is to reference a hidden *superclass* member

The Object class and its methods

- Every class in Java is descended from the `java.lang.Object` class
- If no inheritance is specified when a class is defined, the superclass of the class is `Object`

```
public class Circle {  
    ...  
}
```

Equivalent

```
public class Circle extends Object {  
    ...  
}
```


The toString() method in Object

- The toString() method returns a string representation of the object
- The default implementation returns a string consisting of a class name of which the object is an instance, the at sign (@), and a number representing this object
- For example

```
Loan loan = new Loan();
System.out.println(loan.toString());
```

 - The code displays something like Loan@15037e5
 - This message is not very helpful or informative
 - Usually, you should override the toString method so that it returns a digestible string representation of the object

Next Lecture

- Polymorphism
- Reading
 - Liang
 - Chapter 11