Polymorphism

Introduction to Programming and Computational Problem Solving: Accelerated Pace

CSE 11

Lecture 13

Announcements

- Assignment 5 is due today, 11:59 PM
  - Upgrade beginning May 18, 12:01 AM
- Assignment 6 will be released today
  - Due May 22, 11:59 PM

Inheritance

- 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

Polymorphism

- 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`
- *Polymorphism* means that a variable of a supertype can refer to a subtype object
  - Greek word meaning “many forms”

Polymorphism

- An object of a *subtype* can be used wherever its *supertype* value is required
  - For example
    - Method `m` takes a parameter of the `Object` type, so you can invoke it with any object

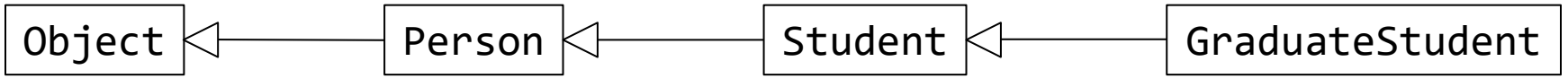
```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
}

class Person {
}
```



Declared type and actual type

- The type that declares a variable is called the variable's *declared type*
- The actual class for the object referenced by the variable is called the *actual type* of the variable
- Remember, a variable of a reference type can hold a `null` value or a reference to an instance of the declared type

```
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  public static void main(String[] args) {
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    m(new Student());
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    m(new Object());
  }

  public static void m(Object x) {
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  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
}

class Person {
}
```
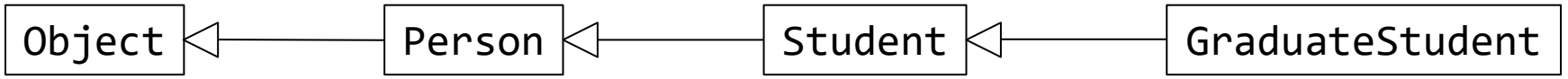
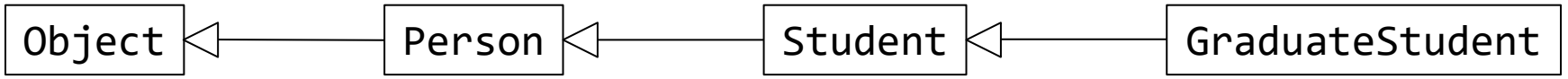



Declared type and actual type

- In all executions of `m`, the variable `x`'s *declared type* is `Object`
- In the first execution of `m`, the variable `x`'s *actual type* is `GraduateStudent`
- In the second execution of `m`, the variable `x`'s *actual type* is `Student`
- In the third execution of `m`, the variable `x`'s *actual type* is `Person`
- In the fourth execution of `m`, the variable `x`'s *actual type* is `Object`

```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
}

class Person {
}
```



Dynamic binding

- When the method `m` is executed, the argument `x`'s `toString` method is invoked
- `x` may be a reference to an instance of `GraduateStudent`, `Student`, `Person`, or `Object`
- Classes `Student`, `Person`, and `Object` have their own implementation of the `toString` method
- Which implementation is used will be determined dynamically by the JVM at *runtime*
- This capability is known as *dynamic binding*

```
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    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
  public String toString() {
    return "Student";
  }
}

class Person {
  public String toString() {
    return "Person";
  }
}
```
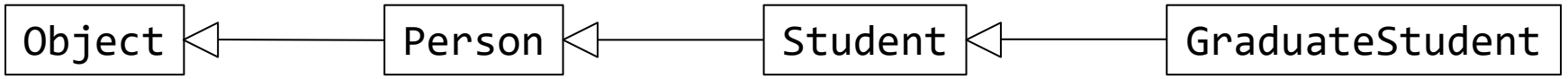
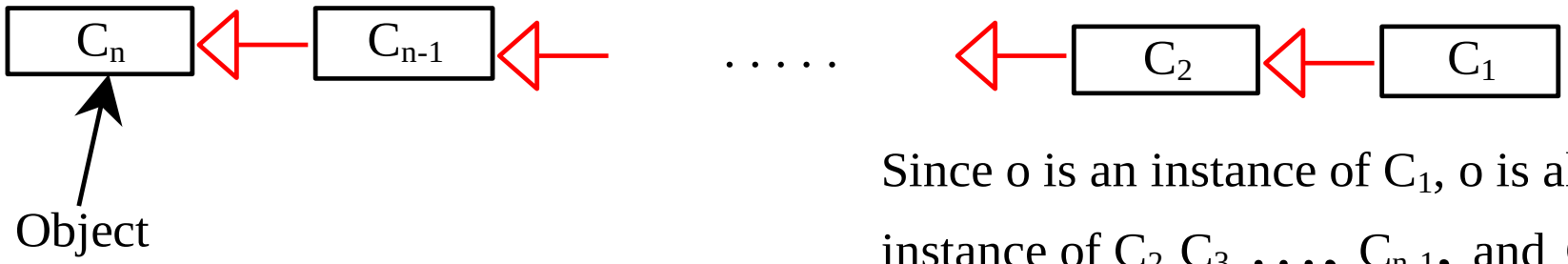

Method overridden in subclasses



Dynamic binding

- Suppose an object o is an instance of classes C_1, C_2, ..., C_{n-1}, and C_n, where C_1 is a subclass of C_2, C_2 is a subclass of C_3, ..., and C_{n-1} is a subclass of C_n
  - That is, C_n is the most general class, and C_1 is the most specific class
- In Java, C_n is the Object class
- If object o invokes a method p, the JVM searches the implementation for the method p in C_1, C_2, ..., C_{n-1} and C_n, **in this order**, until it is found
- Once an implementation is found, the search stops and the first-found implementation is invoked



Since o is an instance of C_1, o is also an instance of C_2, C_3, . . ., C_{n-1}, and C_n

Matching and binding

- *Matching* a method *signature*
  - The *declared type* of the reference variable decides which method to match at *compile time*
- *Binding* a method *implementation*
  - A method may be implemented in several classes along the inheritance chain
  - The *actual type* of the reference variable decides which implementation of the method the JVM dynamically binds at *runtime*

Matching and binding

- In all executions of `m`, the variable `x`'s *declared type* is `Object`
- In the first execution of `m`, the variable `x`'s *actual type* is `GraduateStudent`
- In the second execution of `m`, the variable `x`'s *actual type* is `Student`
- In the third execution of `m`, the variable `x`'s *actual type* is `Person`
- In the fourth execution of `m`, the variable `x`'s *actual type* is `Object`

```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
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    m(new Object());
  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
  public String toString() {
    return "Student";
  }
}

class Person {
  public String toString() {
    return "Person";
  }
}
```

Matching at compile time

Method overridden in subclasses

Binding at runtime

Casting objects

- You have been using the casting operator to convert variables of one primitive type to another
- Casting can also be used to convert an object of one class type to another within an inheritance hierarchy
  - This is called *casting object*

Upcasting is implicit

- The statement

```
m(new Student());
```

  is equivalent to

```
Object o = new Student();
m(o);
```

Implicit casting

- It is always possible to cast an instance of a subclass to a variable of a superclass
  - This is called *upcasting*

```
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  }

  public static void m(Object x) {
    System.out.println(x.toString());
  }
}

class GraduateStudent extends Student {
}

class Student extends Person {
}

class Person extends Object {
}
```

Downcasting

- **Warning: if you find yourself wanting to perform (explicit) downcasting from a superclass to a subclass, it is a sign you are likely approaching things the wrong way!**
- Override methods in subclasses instead

Downcasting

- **Downcasting is such a bad practice** that explicit casting must be used to confirm your intention to the compiler
- For example

```
Object o = new Student();
m(o);
Student b = o; // Compile error
Student c = (Student)o; // No error
```

Downcasting

- If you are downcasting a superclass object to an object that is not an instance of a subclass, then a runtime exception occurs
- Use the `instanceof` operator to avoid this
  - For example

```
void someMethod(Object myObject) {
... // Some lines of code
// Perform casting if myObject is an instance of Circle
if (myObject instanceof Circle) {
  System.out.println("The circle diameter is " +
    ((Circle)myObject).getDiameter());
  ... // Some lines of code
}
```

"Safe" downcasting

Explicit casting

Override `equals` method in `Object`

- Remember, usually a class should override the `toString` method so it returns a digestible string representation of the object
- You may also want to override the `equals` method
  - One of the few reasonable times to use downcasting

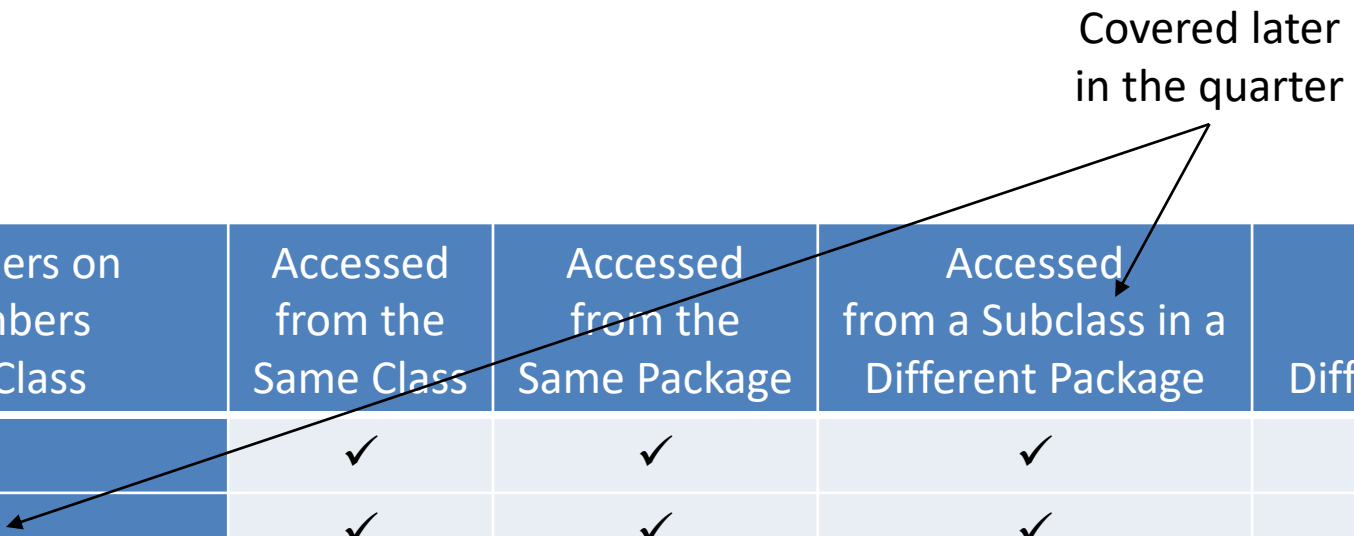
Override `equals` method in `Object`

- For example

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

  ...

  public boolean equals(Circle circle) {
    return radius == circle.radius;
  }

  @Override
  public boolean equals(Object o) {
    if (o instanceof Circle)
      return radius == ((Circle)o).radius;
    else
      return false;
  }
```

"Safe" downcasting

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	✓			

Subclass and visibility/accessibility

- If desired, a subclass **can increase accessibility** of a method defined in the superclass, but a subclass **cannot decrease accessibility** of a method defined in the superclass
  - For example, a subclass may override a `protected` method in its superclass and change its visibility to `public`
  - For example, if a method is defined as `public` in the superclass, it must be defined as `public` in the subclass

Preventing extending and overriding

- You may occasionally want to prevent classes from being extended
- In such cases, use the `final` modifier to indicate a class is final and cannot be a parent class

The `final` modifier

- A `final` class cannot be extended
  - For example

```
public final class Math {
   ...
}
```

- A `final` method cannot be overridden by its subclasses
- And remember, a `final` variable is a constant
  - For example

```
public static final double PI = 3.14159;
```

The `final` modifier

- Modifiers are used on classes and class members (data and methods), except the `final` modifier can also be used on local variables in a method
- A `final` local variable is a constant inside a method
- **A best practice is to use `final` variables liberally**

Modifiers

- Access modifiers
  - For classes
    - `public` and default (no modifier)
  - For methods (*including* constructors) and data fields
    - `public`, `protected`, default (no modifier), and `private`
- Non-access modifiers
  - For classes
    - `final` and `abstract` (covered later in the quarter)
  - For methods (*excluding* constructors)
    - `final`, `static`, and `abstract` (covered later in the quarter)
  - For data fields
    - `final` and `static`
- All modifiers
  - https://docs.oracle.com/javase/specs/jls/se8/html/jls-8.html
  - https://docs.oracle.com/javase/specs/jls/se11/html/jls-8.html

Next Lecture

- Exceptions
- Text file input/output