Polymorphism

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 11

Announcements

- Assignment 5 is due today, 11:59 PM
- Quiz 5 is Nov 4
- Assignment 6 will be released today
  - Due Nov 9, 11:59 PM
- Educational research study
  - Nov 4, weekly survey
- Reading
  - Liang
    - Chapter 11

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

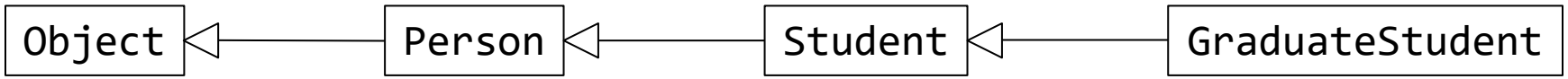
```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
    m(new Student());
    m(new Person());
    m(new Object());
  }

  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

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

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

class GraduateStudent extends Student {
}

class Student extends Person {
}

class Person {
}
```
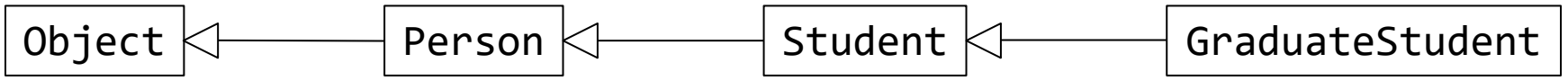
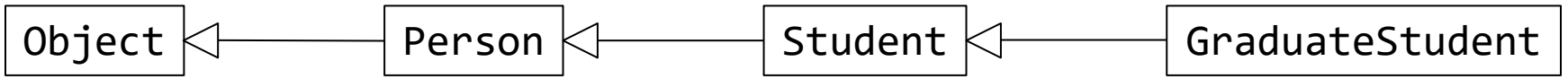



Declared type and actual type

- 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 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";
  }
}
```
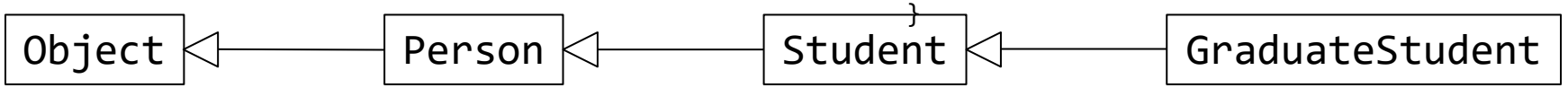
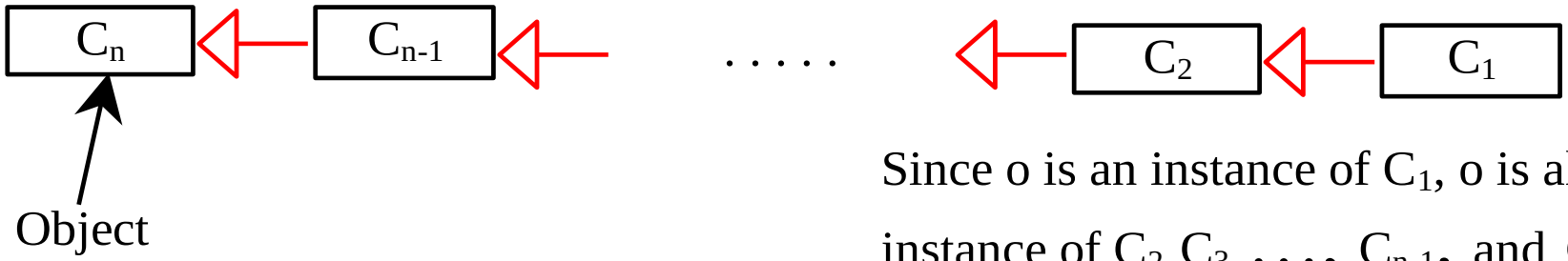

Method overridden in subclasses



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());
    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";
  }
}
```

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*

```
public class PolymorphismDemo {
  public static void main(String[] args) {
    m(new GraduateStudent());
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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 this.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

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

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

```
final static 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 in two weeks)
  - For methods (*excluding* constructors)
    - `final`, `static`, and `abstract` (covered in two weeks)
  - For data fields
    - `final` and `static`
- All modifiers
  - Liang, appendix D
  - https://docs.oracle.com/javase/specs/jls/se8/html/jls-8.html
  - https://docs.oracle.com/javase/specs/jls/se11/html/jls-8.html

The `ArrayList` class

- You can create an array to store objects, but the array's size is fixed once the array is created
- Java provides the `ArrayList` class that can be used to store an unlimited number of objects

The `ArrayList` class

java.util.ArrayList<E>	
`+ArrayList()`	Creates an empty list.
`+add(o: E) : void`	Appends a new element `o` at the end of this list.
`+add(index: int, o: E) : void`	Adds a new element `o` at the specified index in this list.
`+clear(): void`	Removes all the elements from this list.
`+contains(o: Object): boolean`	Returns true if this list contains the element `o`.
`+get(index: int) : E`	Returns the element from this list at the specified index.
`+indexOf(o: Object) : int`	Returns the index of the first matching element in this list.
`+isEmpty(): boolean`	Returns true if this list contains no elements.
`+lastIndexOf(o: Object) : int`	Returns the index of the last matching element in this list.
`+remove(o: Object): boolean`	Removes the element `o` from this list.
`+size(): int`	Returns the number of elements in this list.
`+remove(index: int) : boolean`	Removes the element at the specified index.
`+set(index: int, o: E) : E`	Sets the element at the specified index.

The `ArrayList` class

- `ArrayList` is known as a generic class with a generic type `E`
- You can specify a concrete type to replace `E` when creating an `ArrayList`
- For example
  - The below statements creates an `ArrayList` used to store strings and assigns its reference to variable cities

```
ArrayList<String> cities = new ArrayList<String>();
ArrayList<String> cities = new ArrayList<>();
```

Comparing arrays and `ArrayList`

Operation	*Array*	*ArrayList*
Creating an array/ArrayList	`String[] a = new String[10]`	`ArrayList<String> list = new ArrayList<>();`
Accessing an element	`a[index]`	`list.get(index);`
Updating an element	`a[index] = "London";`	`list.set(index, "London");`
Returning size	`a.length`	`list.size();`
Adding a new element		`list.add("London");`
Inserting a new element		`list.add(index, "London");`
Removing an element		`list.remove(index);`
Removing an element		`list.remove(Object);`
Removing all elements		`list.clear();`

Array to/from ArrayList

- Creating an `ArrayList` from an array of objects

```
String[] array = {"red", "green", "blue"};
ArrayList<String> list = new ArrayList<>(Arrays.asList(array));
```

- Creating an array of objects from an ArrayList

```
String[] array1 = new String[list.size()];
list.toArray(array1);
```

Useful methods in java.util.Collections

- Maximum element in `ArrayList`

  `java.util.Collections.max`
- Minimum element in `ArrayList`

  `java.util.Collections.min`
- Sort an `ArrayList`

  `java.util.Collections.sort`
- Shuffle an `ArrayList`

  `java.util.Collections.shuffle`

Next Lecture

- Exception handling
- Reading
  - Liang
    - Chapter 12