Chapter 3 – Polymorphism

Polymorphism

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Chapter Goals

- ✓Abstract Classes and Abstract Methods
- ✓Interfaces
- ✓defining polymorphism and its benefits
- ✓using inheritance to create polymorphic references
- ✓using interfaces to create polymorphic references
- ✓using polymorphism to implement sorting and searching algorithms
- ✓Exception

Abstract Classes

- ✓An abstract class is a placeholder in a class hierarchy that represents a generic concept
- ✓An abstract class cannot be instantiated
- ✓We use the modifier abstract on the class header to declare a class as abstract

```
public abstract class Product
{
   // class contents
}
```

Abstract Classes

- ✓An abstract class often contains abstract methods with no definitions *(like an interface)*
- ✓Unlike an interface, the abstract modifier must be applied to each abstract method
- ✓Also, an abstract class typically contains non-abstract methods with full definitions
- ✓A class declared as abstract does not have to contain abstract methods -- simply declaring it as abstract makes it so

Abstract Classes

- ✓The child of an abstract class must override the abstract methods of the parent, or it too will be considered abstract
- ✓An abstract method cannot be defined as final or static
- ✓The use of abstract classes is an important element of software design – it allows us to establish common elements in a hierarchy that are too general to instantiate

Interface Hierarchies

- ✓Inheritance can be applied to interfaces
- ✓That is, one interface can be derived from another interface
- ✓The child interface inherits all abstract methods of the parent
- ✓A class implementing the child interface must define all methods from both interfaces
- ✓Class hierarchies and interface hierarchies are distinct (they do not overlap)

Restricting Inheritance

- ✓If the final modifier is applied to a method, that method cannot be overridden in any derived classes
- ✓If the final modifier is applied to an entire class, then that class cannot be used to derive any children at all
- ✓Therefore, an abstract class cannot be declared as final

Interfaces

- ✓A Java interface is a collection of abstract methods and constants
- ✓An abstract method is a method header without a method body
- ✓An abstract method can be declared using the modifier abstract, but because all methods in an interface are abstract, usually it is left off
- ✓An interface is used to establish a set of methods that a class will implement

Interfaces

interface is a reserved word

None of the methods in an interface are given a definition (body)

```
public interface Doable
{
   public void doThis();
   public int doThat();
   public void doThis2 (float value, char ch);
   public boolean doTheOther (int num);
}
```

A semicolon immediately follows each method header

Interfaces

- ✓An interface cannot be instantiated
- ✓Methods in an interface have public visibility by default
- ✓A class formally implements an interface by:
  - stating so in the class header
  - providing implementations for each abstract method in the interface
- ✓If a class asserts that it implements an interface, it must define all methods in the interface

Interfaces

```
public class CanDo implements Doable
{
   public void doThis ()
   {
      // whatever
   }

   public void doThat ()
   {
      // whatever
   }

   // etc.
}
```

implements is a reserved word

Each method listed in Doable is given a definition

Interfaces

- ✓A class that implements an interface can implement other methods as well
- ✓In addition to (or instead of) abstract methods, an interface can contain constants
- ✓When a class implements an interface, it gains access to all its constants
- ✓One class can implement several Interfaces
- ✓Can use this to "fake" multiple inheritance

Interfaces

- ✓A class can implement multiple interfaces
- ✓The class must implement all methods in all interfaces listed in the header

```
class ManyThings implements interface1, interface2
{
   // all methods of both interfaces
}
```

Example:The Comparable Interface

- ✓Any class can implement Comparable to provide a mechanism for comparing objects of that type
- ✓Specifically, implementing Comparable means that you need a method CompareTo

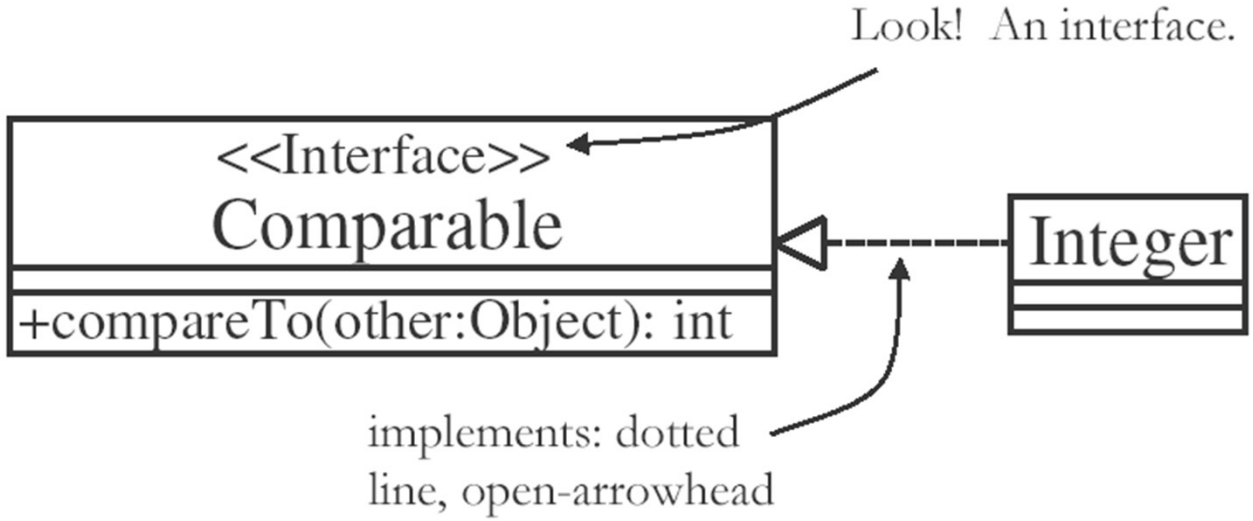
```
if (obj1.compareTo(obj2) < 0)
   System.out.println ("obj1 is less than obj2");
```

The Comparable Interface

- ✓It's up to the programmer to determine what makes one object less than another
- ✓For example, you may define the compareTo method of an Employee class to order employees by name (alphabetically) or by employee number
- ✓The implementation of the method can be as straightforward or as complex as needed for the situation

Interfaces in UML

- ✓Interfaces are easy to spot in class diagrams



Interfaces

- ✓You could write a class that implements certain methods (such as compareTo) without formally implementing the interface (Comparable)
- ✓However, formally establishing the relationship between a class and an interface allows Java to deal with an object in certain ways
- ✓Interfaces are a key aspect of object-oriented design in Java

Built-in Interfaces

- ✓The Java standard library includes lots more built-in interfaces
  - They are listed in the API with the classes
- ✓Examples:
  - Clonable – implements a clone() method
  - Formattable – can be formatted with printf

The Iterator Interface

- ✓An iterator is an object that provides a means of processing a collection of objects one at a time
- ✓An iterator is created formally by implementing the Iterator interface, which contains three methods
  - The hasNext method returns a boolean result – true if there are items left to process
  - The next method returns the next object in the iteration
  - The remove method removes the object most recently returned by the next method

The Iterator Interface

- ✓By implementing the Iterator interface, a class formally establishes that objects of that type are iterators
- ✓The programmer must decide how best to implement the iterator functions
- ✓Once established, the for-each version of the for loop can be used to process the items in the iterator

Collections

- ✓Collection is a general interface for any type that can store multiple values
- ✓Any object c that implements Collections has these methods
  - c.add(e)
  - c.remove(e)
  - c.size()

Collection Sub-Interfaces

✓Interfaces that are derived from Collection

Set: unordered, can't add the same object twice

List: ordered, adds new methods

- get(i): get the ith element
- set(i,e): set the ith element to e

Collection Implementations

- ✓Also in the standard library: many good implementations of these interfaces
- ✓List: ArrayList, Stack, LinkedList
- ✓Sets: HashSet, TreeSet
- ✓Each implementation has some differences… suitable for particular problems
  - e.g. additional methods, different type restrictions, etc.

Interfaces vs. Abstract Classes

- ✓Similarities
  - neither can be instantiated
  - both can be used as the starting point for a class
- ✓Differences
  - A class can contain implementations of methods
  - A class can implement many interfaces, but only one class

Comparison

In order of "abstractness":

- ✓Interface
  - no method implementations
  - can't be instantiated
- ✓Abstract class
  - some method implementations
  - can't be instantiated
- ✓Non-abstract class
  - all methods implemented
  - can be instantiated

Polymorphism

- ✓The term polymorphism literally means "having many forms"
- ✓A polymorphic reference is a variable that can refer to different types of objects at different points in time

```
Employee emp = null;
emp = new HourlyEmployee("1001", "Morgan, Harry", 30, 20.0);
emp = new SalariedEmployee("2001", "Lin, Sally", 52000);
```

- ✓The method called through a polymorphic reference can change from one invocation to the next
- ✓All object references in Java are potentially polymorphic

Polymorphism

- ✓Suppose we create the following reference variable:

  Employee emp

- ✓This reference can point to an Employee object, or to any object of any compatible type
- ✓This compatibility can be established using inheritance or using interfaces
- ✓Careful use of polymorphic references can lead to elegant, robust software designs

References and Inheritance

- ✓An object reference can refer to an object of any class related to it by inheritance
- ✓An object reference can refer to an object of any class related to it by inheritance
- ✓For example, if Employee is the superclass of HourlyEmployee, then a Employee reference could be used to refer to a HourlyEmployee object

References and Inheritance

- ✓These type compatibility rules are just an extension of the is-a relationship established by inheritance
- ✓Assigning a HourlyEmployee object to a Employee reference is fine because HourlyEmployee is-a Employee
- ✓Assigning a child object to a parent reference can be performed by simple assignment
- ✓Assigning a parent object to a child reference can also be done, but it must be done with a cast
- ✓After all, HourlyEmployee is a Employee but not all Employees are HourlyEmployees

Polymorphism via Inheritance

- ✓Now suppose the Employee class has a method called weeklyPay, and Manager overrides it
- ✓What method is invoked by the following?

  emp. weeklyPay();
- ✓The type of the object being referenced, not the reference type, determines which method is invoked
- ✓If employee refers to a Employee object, it invokes the Employee version of celebrate; if it refers to a Manager object, it invokes that version

Polymorphism via Inheritance

- ✓Note that the compiler restricts invocations based on the type of the reference
- ✓So if Manager had a method called getBonus that Employee didn't have, the following would cause a compiler error:

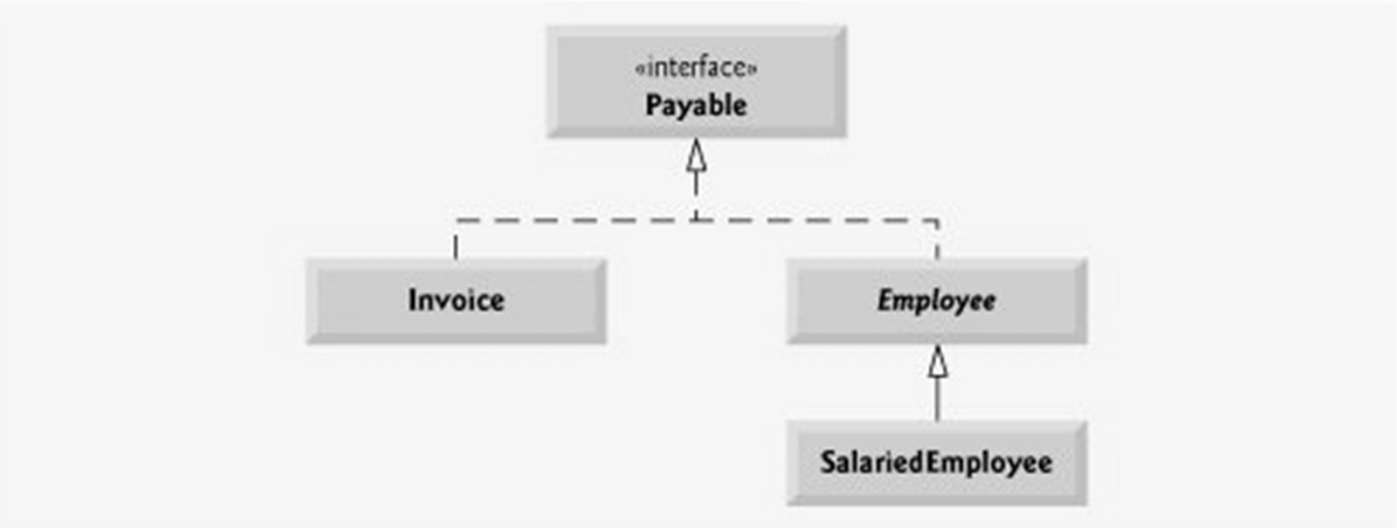
```
emp.getBonus();  // compiler error
```

- ✓Remember, the compiler doesn't "know" which type of employee is being referenced
- ✓A cast can be used to allow the call:

```
((Manager)emp).getBonus();
```

Polymorphism via Interfaces

✓Interfaces can be used to set up polymorphic references as well



Exceptions

- ✓the purpose of exceptions
- ✓exception messages
- ✓the try-catch statement
- ✓propagating exceptions
- ✓the exception class hierarchy

Exceptions

- ✓An exception is an object that describes an unusual or erroneous situation
- ✓Exceptions are thrown by a program, and may be caught and handled by another part of the program
- ✓A program can be separated into a normal execution flow and an exception execution flow
- ✓An error is also represented as an object in Java, but usually represents a unrecoverable situation and should not be caught

Exceptions

- ✓The Java API has a predefined set of exceptions that can occur during execution
- ✓A program can deal with an exception in one of three ways:
  - ▪ignore it
  - ▪handle it where it occurs
  - ▪handle it an another place in the program
- ✓The manner in which an exception is processed is an important design consideration

Exception Handling

- ✓If an exception is ignored (not caught) by the program, the program will terminate and produce an appropriate message
- ✓The message includes a call stack trace that:
  - indicates the line on which the exception occurred
  - shows the method call trail that lead to the attempted execution of the offending line
- ✓See Zero.java

The try Statement

- ✓To handle an exception in a program, use a try-catch statement
- ✓A try block is followed by one or more catch clauses
- ✓Each catch clause has an associated exception type and is called an exception handler
- ✓When an exception occurs within the try block, processing immediately jumps to the first catch clause that matches the exception type

The finally Clause

- ✓A try statement can have an optional finally clause, which is always executed
- ✓If no exception is generated, the statements in the finally clause are executed after the statements in the try block finish
- ✓If an exception is generated, the statements in the finally clause are executed after the statements in the appropriate catch clause finish

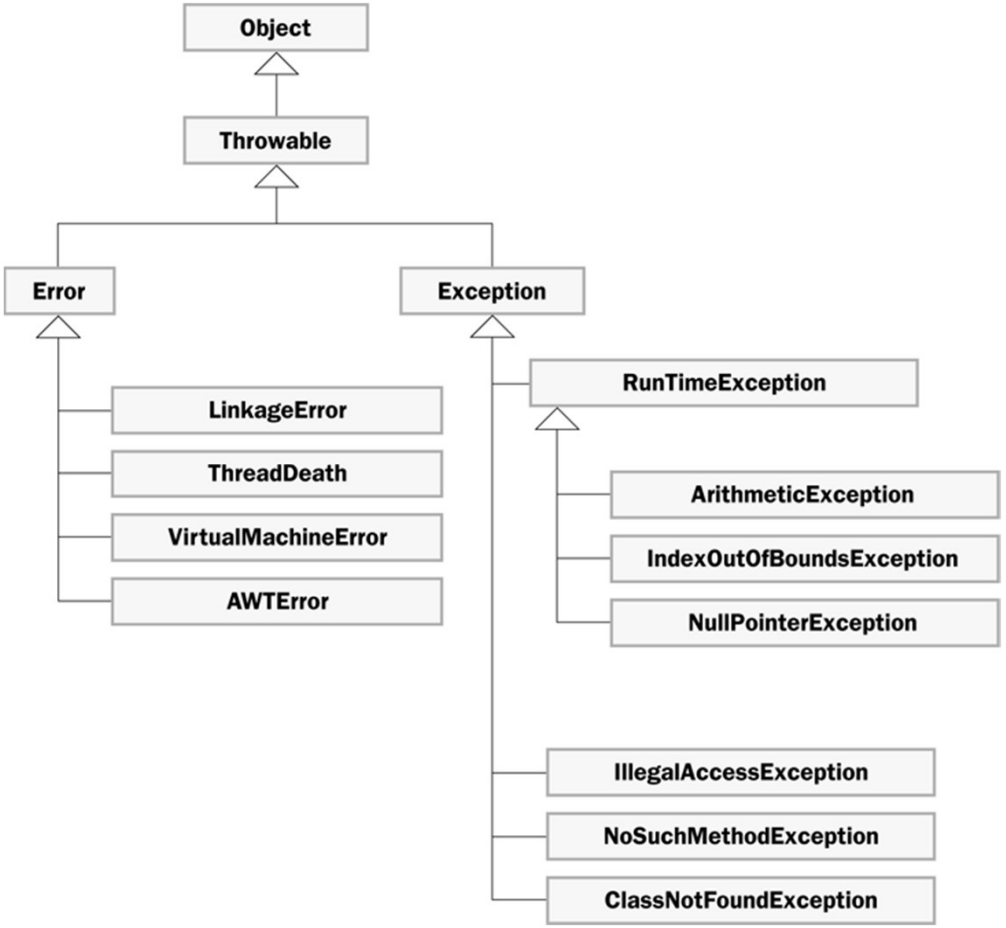
Exception Propagation

- ✓An exception can be handled at a higher level if it is not appropriate to handle it where it occurs
- ✓Exceptions propagate up through the method calling hierarchy until they are caught and handled or until they reach the level of the main method

The Exception Class Hierarchy

- ✓Exception classes in the Java API are related by inheritance, forming an exception class hierarchy
- ✓All error and exception classes are descendents of the Throwable class
- ✓A programmer can define an exception by extending the Exception class or one of its descendants
- ✓The parent class used depends on how the new exception will be used

The Exception Class Hierarchy



Checked Exceptions

- ✓An exception is either checked or unchecked
- ✓A checked exception must either be caught or must be listed in the throws clause of any method that may throw or propagate it
- ✓A throws clause is appended to the method header
- ✓The compiler will issue an error if a checked exception is not caught or listed in a throws clause

Unchecked Exceptions

- ✓An unchecked exception does not require explicit handling, though it could be processed that way
- ✓The only unchecked exceptions in Java are objects of type RuntimeException or any of its descendants
- ✓Errors are similar to RuntimeException and its descendants in that:
  - Errors should not be caught
  - Errors do not require a throws clause

The throw Statement

- ✓Exceptions are thrown using the throw statement
- ✓Usually a throw statement is executed inside an if statement that evaluates a condition to see if the exception should be thrown

I/O Exceptions

- ✓Let's examine issues related to exceptions and I/O
- ✓A stream is a sequence of bytes that flow from a source to a destination
- ✓In a program, we read information from an input stream and write information to an output stream
- ✓A program can manage multiple streams simultaneously

Standard I/O

- ✓There are three standard I/O streams:
  - standard output – defined by System.out
  - standard input – defined by System.in
  - standard error – defined by System.err
- ✓We use System.out when we execute println statements
- ✓System.out and System.err typically represent the console window
- ✓System.in typically represents keyboard input, which we've used many times with Scanner

The IOException Class

- ✓Operations performed by some I/O classes may throw an IOException
  - A file might not exist
  - Even if the file exists, a program may not be able to find it
  - The file might not contain the kind of data we expect
- ✓An IOException is a checked exception