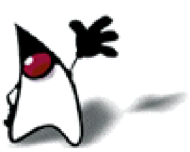
Everything You Ever Wanted To Know About Java O-O



Types

- Java has eight *primitive* types:
  - `short`, `byte`, `char`, `int`, `long` – all *integral* types
  - `float`, `double` – both *real* types, but with limited precision
  - `boolean` – the *logical* type, with only two values, `true` and `false`
- ***All*** other types are *object* types
  - A *class* defines a type
  - The objects (*instances*) of that class are values of that type

What is a class?

- A class is *primarily* a description of objects, or instances, of that class
  - A class contains one or more constructors to create objects
  - A class is a *type*
    - A type defines a set of possible values, and operations on those values
    - The type of an object is the class that created it
- But a class can also contain information about itself
  - Anything declared `static` belongs to the class itself
  - Static variables contain information about the class, not about instances of the class
  - Static methods are executed by the class, not by instances of the class
  - Anything *not* declared `static` is *not* part of the class, and cannot be used directly by the class
    - However, a static method *can* create (or be given) objects, and can send messages to them

Classes

- **class** MyClass extends ThatClass implements SomeInterface, SomeOtherInterface {...}
  - A top-level class can be public or package (default)
  - A class can be final, meaning it cannot be subclassed
  - A class subclasses exactly one other class (default: Object)
  - A class can implement any number of interfaces
- **abstract class** MyClass extends ThatClass implements SomeInterface, SomeOtherInterface {...}
  - Same rules as above, except: An abstract class *cannot* be final
  - A class *must* be declared abstract if:
    - It contains abstract methods
    - It implements an interface but does not define all the methods of that interface
  - Any class *may* be declared to be abstract
  - An abstract class can (and does) have constructors
  - You cannot instantiate an abstract class

Why inheritance?

- Java provides a huge library of pre-written classes
  - Sometimes these classes are exactly what you need
  - Sometimes these classes are *almost* what you need
  - It's easy to subclass a class and override the methods that you want to behave differently
- Inheritance is a way of providing similar behavior to different kinds of objects, without duplicating code
- You should extend a class (and inherit from it) *only* if:
  - Your new class *really is* a more specific kind of the superclass, **and**
  - You want your new class to have *most or all* of the functionality of the class you are extending, **and**
  - You need to add to or modify the capabilities of the superclass
- You *should not* extend a class merely to use *some* of its features
  - Composition is a better solution in this case

What are abstract classes for?

- Abstract classes are suitable when you can reasonably implement some, but not all, of the behavior of the subclasses
- Example: You have a game in which various kinds of animals move around and do things
  - All animals can `move()`, `eat()`, `drink()`, `hide()`, etc.
  - Since these are identical or similar, it makes sense to have a default `move()` method, a default `drink()` method, etc.
  - If you have a default `draw()` method, what would it draw?
  - Since you probably never want an `Animal` object, but just specific animals (`Zebra`, `Lion`, etc.), you don't need to be able to instantiate the `Animal` class
  - Make `Animal` abstract, with an `abstract void draw()` method

Interfaces

- interface MyInterface extends SomeOtherInterface {...}
  - An interface can be public or package
  - An interface cannot be final
  - A class can implement any number of interfaces
  - An interface can *declare* (not *define*) methods
    - All declared methods are implicitly public and abstract
  - An interface can define fields, classes, and interfaces
    - Fields are implicitly static, final, and public
    - Classes are implicitly static and public
    - An interface *cannot* declare constructors
  - It's OK (but unnecessary) to explicitly specify implicit attributes

Declarations and assignments

- Suppose `class Cat extends Animal implements Pet {...}`
  and `class Persian extends Cat {...}`
  and `Cat puff = new Cat();`
- Then the following are true:
  - `puff instanceof Cat`, `puff instanceof Animal`, `puff instanceof Pet`
- The following is *not* true: `puff instanceof Persian`
  - To form the negative test, say `!(puff instanceof Persian)`
- The following declarations and assignments are legal:
  - `Animal thatAnimal = puff;`
  - `Animal thatAnimal = (Animal)puff; // same as above, but explicit upcast`
  - `Pet myPet = puff; // a variable can be of an interface type`
  - `Persian myFancyCat = (Persian)puff; // does a runtime check`
- The following is also legal:
  - `void feed(Pet p, Food f) {...} // interface type as a parameter`

What are interfaces for?

- Inheritance lets you guarantee that subclass objects have the same methods as their superclass objects
- Interfaces let you guarantee that unrelated objects have the same methods
  - Problem: Your GUI has an area in which it needs to *draw* some object, but you don't know yet what kind of object it will be
  - Solution:
    - Define a `Drawable` interface, with a method `draw()`
    - Make your tables, graphs, line drawings, etc., implement `Drawable`
    - In your GUI, call the object's `draw()` method (legal for any `Drawable` object)
  - If you didn't have interfaces, here's what you would have to do:
    - ```
      if (obj instanceof Table) ((Table)obj).draw();
      else if (obj instanceof Graph) ((Graph)obj).draw();
      else if (obj instanceof LineDrawing) ((LineDrawing)obj).draw(); // etc.
      ```
    - Worse, to add a new type of object, you have to change a lot of code
      ```

Inner Classes I

- Inner classes are classes declared within another class
- A member class is defined immediately within another class
  - A member class may be `static`
  - A member class may be `abstract` or `final` (but not both)
  - A member class may be `public`, `protected`, package, or `private`
- A local class is declared in a constructor, method, or initializer block
  - A local class may be `abstract` or `final` (but not both)
  - A local class may access only `final` variables in its enclosing code
  - An anonymous class is a special kind of local class

Inner Classes II

- An anonymous inner class is a kind of local class
  - An anonymous inner class has one of the following forms:
    - new ***NameOfSuperclass***(***parameters***) { ***class body*** }
    - new ***NameOfInterface***() { ***class body*** }
  - Anonymous inner classes cannot have explicit constructors
- A static member class is written inside another class, but is not actually an inner class
  - A static member class has no special access to names in its containing class
  - To refer to the static inner class from a class outside the containing class, use the syntax ***OuterClassName*.*InnerClassName***
  - A static member class may contain static fields and methods

What are inner classes for?

- Sometimes a class is needed by only one other class
  - Example: A class to handle an event, such as a button click, is probably needed only in the GUI class
  - Having such a class available at the top level, where it isn't needed, just adds clutter
  - It's best to "hide" such classes from other classes that don't care about it
- Sometimes a class needs access to many variables and methods of another class
  - Again, an event handler is a good example
  - Making it an inner class gives it full access
- Sometimes a class is only needed once, for one object, in one specific place
  - Most event handlers are like this
  - An anonymous inner class is very handy for this purpose

Enumerations

- An enumeration, or "enum," is simply a set of constants to represent various values
- Here's the old way of doing it
  - ```
    public final int SPRING = 0;
    public final int SUMMER = 1;
    public final int FALL = 2;
    public final int WINTER = 3;
    ```
- This is a nuisance, and is error prone as well
- Here's the new way of doing it:
  - `enum Season { WINTER, SPRING, SUMMER, FALL }`
    ```

enums are classes

- An enum is actually a new type of class
  - You can declare them as inner classes or outer classes
  - You can declare variables of an enum type and get type safety and compile time checking
    - Each declared value is an instance of the enum class
    - Enums are implicitly public, static, and final
    - You can compare enums with either equals or ==
  - enums extend java.lang.Enum and implement java.lang.Comparable
    - Hence, enums can be sorted
  - Enums override toString() and provide valueOf()
  - Example:
    - `Season season = Season.WINTER;`
    - `System.out.println(season );  // prints WINTER`
    - `season = Season.valueOf("SPRING"); // sets season to Season.SPRING`

Enums *really are* classes

```
public enum Coin {
    // enums can have instance variables
    private final int value;
    // An enum can have a constructor, but it isn't public
    Coin(int value) { this.value = value; }
    // Each enum value you list really calls a constructor
    PENNY(1), NICKEL(5), DIME(10), QUARTER(25);
    // And, of course, classes can have methods
    public int value() { return value; }
}
```

Other features of enums

- values() returns an array of enum values
  - Season[] seasonValues = Season.values();
- switch statements can now work with enums
  - switch (thisSeason) { case SUMMER: ...; default: ...}
  - You *must* say case SUMMER:, *not* case Season.SUMMER:
  - It's still a very good idea to include a default case

Using generic classes

- A generic class is a class that is "parameterized" with a *type* (rather than a value)
  - Example: `ArrayList<String>` describes an `ArrayList` (the class) that can only hold `String`s (the type)
- You can use a genericized class anywhere you can use any other type name
  - Examples:
    - `ArrayList<Double> scores = new ArrayList<Double>();`
    - `ArrayList<Double> adjustScores(ArrayList<Double> scores) {...}`

Defining generic classes

- ```
  public class Box<T> {
      private List<T> contents;

      public Box() {
          contents = new ArrayList<T>();
      }

      public void add(T thing) { contents.add(thing); }

      public T grab() {
          if (contents.size() > 0) return contents.remove(0);
          else return null;
  }
  ```
- Sun's recommendation is to use single capital letters (such as T) for types
- This is fine if you are using only a very few types; otherwise, use more meaningful names
  ```

Access

- There are four types of access:
  - public means accessible from everywhere
    - Making a field public means that it can be changed arbitrarily from anywhere, with no protection
    - Methods should be public only if it's desirable to be able to call them from outside this class
  - protected means accessible from all classes in this same directory *and* accessible from all subclasses anywhere
  - Package (default; no keyword) means accessible from all classes in this same directory
  - private means accessible only within this class
    - Note: Making a field private does not hide it from other objects in this same class!
- In general, it's best to make all variables as private as possible, and to make methods public enough to be used where they are needed

Proper use of fields

- An object can have fields and methods
  - When an object is created,
    - It is created with all the non-`static` fields defined in its class
    - It can execute all the instance methods defined in its class
    - Inside an instance method, `this` refers to the object executing the method
  - The fields of the object should describe the *state* of the object
    - All fields should say something significant about the object
    - Variables that don't describe the object should be local variables, and can be passed from one method to another as parameters
  - The fields of an object should be impervious to corruption from outside
    - This localizes errors in an object to bugs in its class
    - Hence, fields should be a private as possible
    - All `public` fields should be documented with Javadoc
    - Getters and setters can be used to check the validity of any changes
    - If a class is designed to be subclassed, fields that the subclass needs to access are typically marked `protected`

Composition and inheritance

- Composition is when an object of one class *uses* an object of another class
  - ```
    class MyClass {
        String s;    …
    }
    ```
  - MyClass has complete control over its methods
- Inheritance is when a class *extends* another class
  - `class MyClass extends Superclass { … }`
  - MyClass gets all the static variables, instance variables, static methods, and instance methods of Superclass, whether it wants them or not
  - Constructors are *not* inherited
  - Inheritance should only be used when you can honestly say that a MyClass object ***is a*** Superclass object
    - Good: `class Secretary extends Employee`
    - Bad: `class Secretary extends AccountingSystem`
    ```

Constructors

- A constructor is the *only* way to make instances of a class
- Here's what a constructor does:
  - **First**, it calls the constructor for its superclass:
    - `public MyClass() { super(); ... } // implicit (invisible) call`
      - Note that it calls the superclass constructor with *no* arguments
      - But you can explicitly call a different superclass constructor:
        `public MyClass(int size) { super(size); ... } // explicit call`
      - Or you can explicitly call a different constructor in this class:
        `public MyClass() { this(0); ... } // explicit call`
  - **Next**, it adds the instance fields declared in this class (and possibly initializes them)
    - `class MyClass { int x; double y = 3.5; ... } // in class, not constructor`
  - **Next**, it executes the code in the constructor:
    - `public MyClass() { super(); next = 0; doThis(); doThat(); ... }`
  - **Finally**, it returns the resultant object
    - You can say `return;` but you *cannot* explicitly say what to return

Constructor chaining

- *Every* class *always* has a constructor
  - If you don't write a constructor, Java supplies a default constructor with no arguments
  - If you *do* write a constructor, Java does *not* supply a default constructor
- The first thing any constructor does (except the constructor for `Object`) is call the constructor for its superclass
  - This creates a chain of constructor calls all the way up to `Object`
  - The default constructor calls the default constructor for its superclass
- Therefore, if you write a class with an explicit constructor with arguments, and you write subclasses of that class,
  - Every subclass constructor will, by default, call the superclass constructor with no arguments (which may not still exist)
- Solutions: Either
  - Provide a no-argument constructor in your superclass, or
  - Explicitly call a particular superclass constructor with `super(`***args***`)`

Proper use of constructors

- A constructor should *always* create its objects in a *valid* state
  - A constructor should not do anything *but* create objects
  - If a constructor cannot guarantee that the constructed object is valid, it should be `private` and accessed via a factory method
  - A factory method is a `static` method that calls a constructor
    - The constructor is usually `private`
    - The factory method can determine whether or not to call the constructor
    - The factory method can throw an `Exception`, or do something else suitable, if it is given illegal arguments or otherwise cannot create a valid object
    - ```
      public static Person create(int age) {  // example factory method
          if (age < 0) throw new IllegalArgumentException("Too young!");
          else return new Person(n);
      }
      ```
      ```

References

- When you declare a primitive, you also allocate space to hold a primitive of that type
  - `int x; double y; boolean b;`
  - If declared as a field, it is initially zero (`false`)
  - If declared as a local variable, it may have a garbage value
  - When you assign this value to another variable, you *copy* the value
- When you declare an object, you also allocate space to hold *a reference to* an object
  - `String s; int[ ] counts; Person p;`
  - If declared as a field, it is initially `null`
  - If declared as a local variable, it may have a garbage value
  - When you assign this value to another variable, you *copy* the value
    - ...but in this case, the value is just a *reference* to an object
  - You *define* the variable by assigning an actual object (created by `new`) to it

Methods I

- A method may:
  - be public, protected, package, or private
  - be static or instance
    - static methods may not refer to the object executing them (this), because they are executed by the class itself, not by an object
  - be final or nonfinal
  - return a value or be void
  - throw exceptions
- The signature of a method consists of its name and the number and types (in order) of its formal parameters
- You overload a method by writing another method with the same name but a different signature
- You override an *inherited* method by writing another method with the same signature
  - When you override a method:
    - You cannot make it less public (public > protected > package > private)
    - You cannot throw additional exceptions (you can throw fewer)
    - The return types must be compatible

Methods II

- A method declares formal parameters and is "called" with actual parameters
  - `void feed(int amount) { hunger -= amount; } // amount is formal`
  - `myPet.feed(5); // 5 is actual`
- But you don't "call" a method, you send a message to an object
  - You may not know what kind of object `myPet` is
  - A dog may eat differently than a parakeet
- When you send a message, the values of the actual parameters are copied into the formal parameters
  - If the parameters are object types, their "values" are references
  - The method can access the actual object, and possibly modify it
- When the method returns, formal parameters are *not* copied back
  - However, changes made to referenced objects will persist

Methods III

- Parameters are passed by assignment, hence:
  - If a formal parameter is `double`, you can call it with an `int`
    - ...unless it is overloaded by a method with an `int` parameter
  - If a formal parameter is a class type, you can call it with an object of a subclass type
- Within an *instance* method, the keyword `this` acts as an extra parameter (set to the object executing the method)
- Local variables are not necessarily initialized to zero (or `false` or `null`)
  - The compiler *tries* to keep you from using an uninitialized variable
- Local variables, including parameters, are discarded when the method returns
- Any method, regardless of its return type, may be used as a statement

Generic methods with wildcards

- Method that takes an ArrayList of Strings:
- ```
  private void printListOfStrings(ArrayList<String> list) {
      Iterator<String> iter = list.iterator();
      while (iter.hasNext()) {
          System.out.println(iter.next());
      }
  }
  ```
- Same thing, but with wildcard:
  - ```
    private void printListOfStrings(ArrayList<?> list) {
        Iterator<?> iter = list.iterator();
        while (i.hasNext()) {
            System.out.println(i.next());
        }
     }
    ```

varargs

- You can create methods and constructors that take a variable number of arguments
  - `public void foo(int count, String... cards) {` ***body*** `}`
  - The "`...`" means *zero or more* arguments (here, zero or more `String`s)
  - Call with `foo(13, "ace", "deuce", "trey");`
  - Inside the method, treat `cards` as the array `String[ ] cards`
  - Only the *last* argument can be a vararg
  - To iterate over the variable arguments, you can use either

    `for (String card : cards) {` ***loop body*** `}`

    or

    `for (int i = 0; i < cards.length; i++) {` ***loop body*** `}`

Proper use of methods I

- Methods that are designed for use by other kinds of objects should be public
  - All public methods should be documented with Javadoc
  - public methods that can fail, or harm the object if called incorrectly, should throw an appropriate Exception
- Methods that are for internal use only should be private
  - private methods can use assert statements rather than throw Exceptions
- Methods that are only for internal use by this class, or by its subclasses, should be protected
  - This isn't great, in my opinion, but it's the best Java has
- Methods that don't use any instance variables or instance methods should be static
  - Why require an object if you don't need it?

Proper use of methods II

- Ideally, a method should do only one thing
  - You should describe what it does in one simple sentence
  - The method name should clearly convey the basic intent
    - It should usually be a verb
  - The sentence should mention every source of input (parameters, fields, etc.) and every result
  - There is no such thing as a method that's "too small"
- Methods should usually do *no* input/output
  - Unless, of course, that's the main purpose of the method
  - Exception: Temporary print statements used for debugging
- Methods should do "sanity checks" on their inputs
  - Publicly available methods should throw Exceptions for bad inputs

Proper use of polymorphism

- Methods with the same name should do the same thing
  - Method *overloading* should be used only when the overloaded methods are doing the same thing (with different parameters)
  - Classes that implement an interface should implement corresponding methods to do the same thing
  - Method *overriding* should be done to change the details of what the method does, without changing the basic idea
- Methods shouldn't duplicate code in other methods
  - An overloaded method can call its namesake with other parameters
  - A method in a subclass can call an overridden method ***m***(***args***) in the superclass with the syntax `super.`***m***(***args***)
    - Typically, this call would be made by the overriding method to do the usual work of the method, then the overriding method would do the rest

Program design

- Good program design pays for itself many times over when it comes to actually writing the code
- Good program design is an art, not a science
- Generally, you want:
  - The simplest design that could possibly work
  - Classes that stand by themselves, and make sense in isolation
  - Aptly named methods that do one thing only, and do it well
  - Classes and methods that can be tested (with JUnit)

Documentation

- There are basically three kinds of documentation:
  - User manuals, written for the user of the program, not usually written by the programmers
  - Javadoc documentation, written for other programs who need to use your code
    - They need to know how to call your code, and what results to expect
    - They do **not** want or need to know how your methods are implemented
  - Internal documentation, written for programmers who may need to read, debug, or update your code
    - Implementation needs to be clear
    - Sources should be given for complex algorithms

Testing

- Kinds of tests:
  - ***Unit test*: when it fails, it tells you what piece of your code needs to be fixed.
  - ***Integration test*: when it fails, it tells you that the pieces of your application are not working together as expected.
  - ***Acceptance test*: when it fails, it tells you that the application is not doing what the customer expects it to do.
  - ***Regression test*: when it fails, it tells you that the application no longer behaves the way it used to.
  - The more complex a program is, the more it needs to be tested
- The more mission-critical a program is, the more it needs to be tested
- Most commercial programs are millions of lines long

The End

"Make everything as simple as possible, but not simpler."

-- Albert Einstein