Principles of Software Construction:
Objects, Design, and Concurrency

Part 1: Design for change (class level)

Introduction to Java + Design for change: Information hiding

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Administrivia

- No smoking…
- Reading assignment due Tuesday: Effective Java Items 15 + 16
- Homework 1 due next Thursday 11:59 p.m.
  - Everyone must read and sign our collaboration policy
- Office hours start today

Key concepts from Tuesday

- Introduction to this course
  - Object-oriented programming (via Java)
  - Design
  - Design
  - Design
  - Concurrency
  - Real-world tools, real-world skills
- Course infrastructure
  - Git, GitHub, Gradle, Travis-CI

Key to design: Evaluation of alternatives

Version A:

```
static void sort(int[] list, boolean ascending) {
   …
   boolean mustSwap;
   if (ascending) {
      mustSwap = list[i] < list[j];
   } else {
      mustSwap = list[i] > list[j];
   }
   …
}
```

Version B':

```
interface Comparator {
  boolean compare(int i, int j);
}
final Comparator ASCENDING =  (i, j) -> i < j;
final Comparator DESCENDING = (i, j) -> i > j;

static void sort(int[] list, Comparator cmp) {
  …
  boolean mustSwap =
    cmp.compare(list[i], list[j]);
  …
}
```

Metrics of software quality

Source: Braude, Bernstein, Software Engineering. Wiley 2011

- Sufficiency / functional correctness
  - Fails to implement the specifications … Satisfies all of the specifications
- Robustness
  - Will crash on any anomalous event … Recovers from all anomalous events
- Flexibility
  - Must be replaced entirely if spec changes … Easily adaptable to changes
- Reusability
  - Cannot be used in another application … Usable without modification
- Efficiency
  - Fails to satisfy speed or storage requirement … satisfies requirements
- Scalability
  - Cannot be used as the basis of a larger version … is basis for much larger version…
- Security
  - Security not accounted for at all … No manner of breaching security is known

Design challenges/goals

Today

- Introduction to Java
  - Java's bipartite type system: primitives and object references
  - Java collections framework: data structures and algorithms
- Information hiding: Design for change, design for reuse
  - Encapsulation: Visibility modifiers in Java
  - Interface types vs. class types

A simple Java program

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Java: A virtual machine architecture

- You first compile the source file:
  - `javac HelloWorld.java`
    - Produces `HelloWorld.class`
- Then run the class file with a Java Virtual Machine (JVM):
  - `java HelloWorld`
    - Executes the `main` method

Java type system

- Primitive types
  - `int`, `long`, `double`, `boolean`, `char`, `byte`, `short`, `float`
- Object types
  - Classes, interfaces, arrays, enums, annotations
  - Identity (==) is conceptually distinct from equality (`.equals(…)`)

Java type system

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- Object types
  - Classes, interfaces, arrays, enums, annotations
  - Identity (==) is conceptually distinct from equality (`.equals(…)`)
- Java sometimes converts between primitive and object types
  - `Integer`, `Long`, `Double`, `Boolean`, `Short`, `Char`, `Float`, `Byte`
  - "Autoboxing" and "unboxing"

Java type system

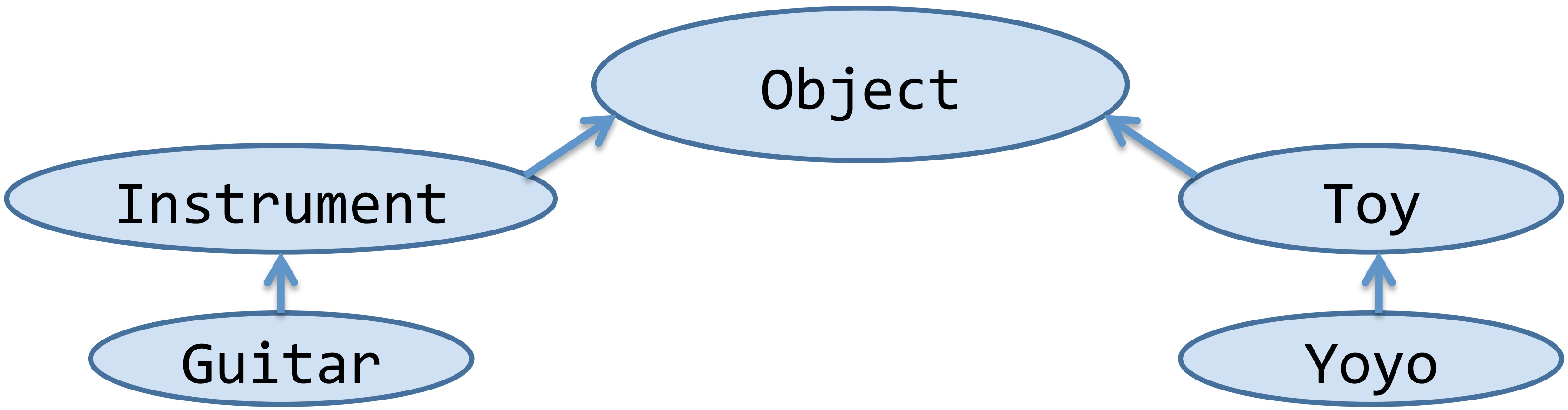
- Primitive types
  - int, long, double, boolean, char, byte, short, float
- Object types
  - Classes, interfaces, arrays, enums, annotations
  - Identity (==) is conceptually distinct from equality (.equals(…))
- Java sometimes converts between primitive and object types
  - Integer, Long, Double, Boolean, Short, Char, Float, Byte
  - "Autoboxing" and "unboxing"
- *Generic* types (a.k.a. Parameterized types)
  - e.g. List<Integer>, HashMap<Bicycle,Double>

Some methods are present on all `Objects`

- `equals`: returns true if the two objects are conceptually equal
- `hashCode`: returns an `int` that must be equal for equal objects, and is likely to differ on unequal objects
- `toString`: returns a printable string representation

The class hierarchy

- The root is `Object` (all non-primitives are `Object`s)
- All classes except `Object` have one parent class
  - Specified with an `extends` clause:
    ```
    class Guitar extends Instrument { ... }
    ```
  - If `extends` clause is omitted, defaults to `Object`
- A class is an instance of all its superclasses



Java interfaces

- Defines a type without an implementation
- More flexible than class types
  - An interface can extend multiple other interfaces
  - A class can implement multiple interfaces

```
interface Comparator {
  boolean compare(int i, int j);
}

class AscendingComparator  implements Comparator {
  public boolean compare(int i, int j) { return i < j; }
}
class DescendingComparator implements Comparator {
  public boolean compare(int i, int j) { return i > j; }
}
```

Java arrays

- Conceptually represented as an object
  - Provides `.length`, runtime bounds-checking

```
String[] answers = new String[42];
if (answers.length == 42) {
    answers[42] = "no"; // ArrayIndexOutOfBoundsException
}
```

Java enums

- Like C enumerations, but represented as an object
  – Provides many object-oriented features, type safety, …

```
enum Planet { MERCURY, VENUS, EARTH, MARS,
              JUPITER, SATURN, URANUS, NEPTUNE; }
```

```
Planet location = …;
if (location.equals(Planet.EARTH)) {
    System.out.println("Honey, I'm home!");
}
```

Java annotations

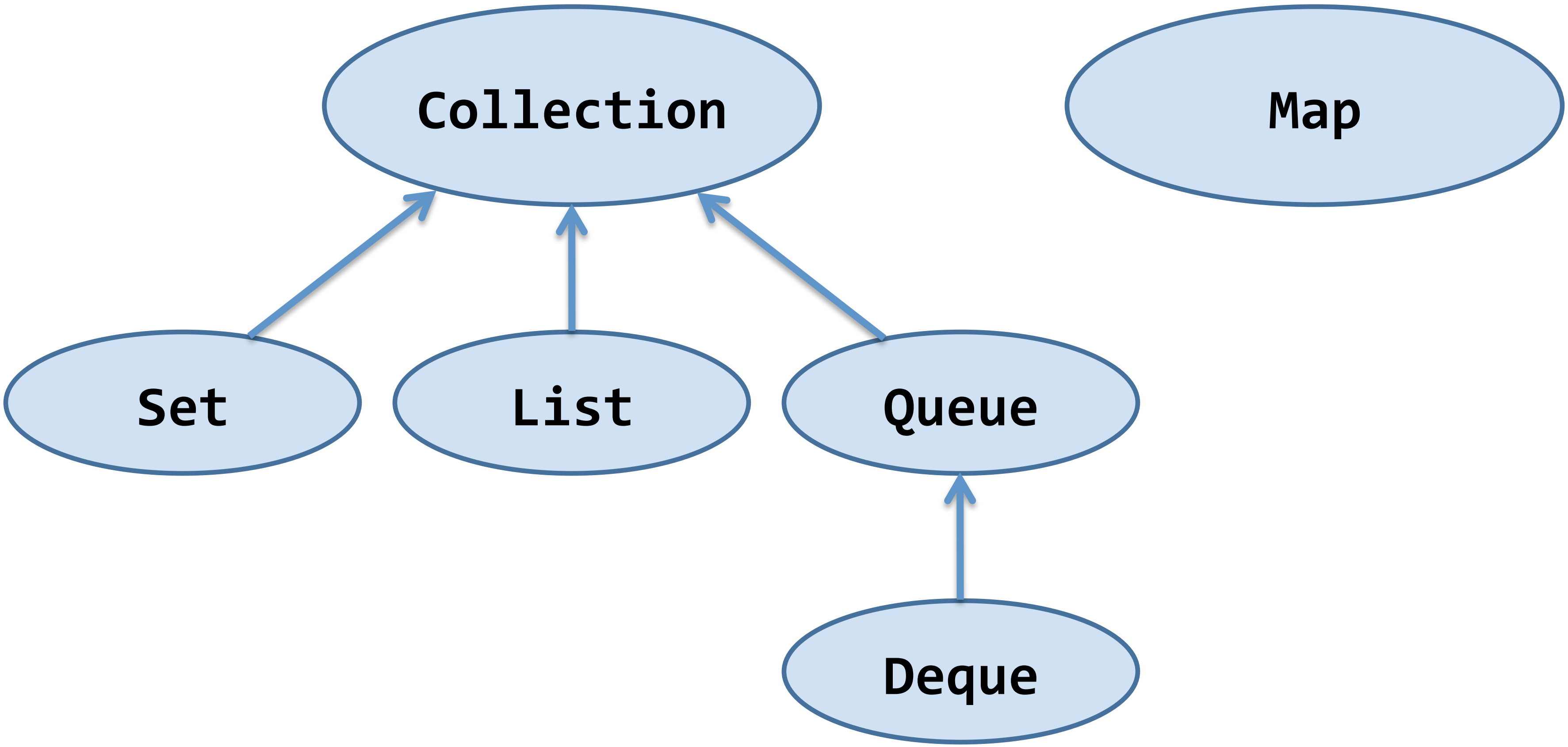
- Annotations mark code without any immediate functional effect

```
class Bicycle {
    ...
    @Override
    public String toString() {
        return ...;
    }
}
```

Java's built-in class library

- `java.lang`: Many basic tools, library features
- `java.util`: Data structures and algorithms, other utilities
- `java.io`: Input/output
- `java.net`: Networking
- …

Primary collection interfaces (in `java.util`)



Primary collection implementations

Interface	Implementation
`Set`	`HashSet`
`List`	`ArrayList`
`Queue`	`ArrayDeque`
`Deque`	`ArrayDeque`
`[stack]`	`ArrayDeque`
`Map`	`HashMap`

Other noteworthy collection implementations

Interface	Implementation(s)

`Set`	`LinkedHashSet`
	`TreeSet`
	`EnumSet`

`Queue`	`PriorityQueue`

`Map`	`LinkedHashMap`
	`TreeMap`
	`EnumMap`

Collections usage example 1

Squeeze duplicate words out of command line

```
public class Squeeze {
   public static void main(String[] args) {
       Set<String> s = new LinkedHashSet<>();
       for (String word : args)
           s.add(word);
       System.out.println(s);
   }
}

$ java Squeeze I came I saw I conquered
[I, came, saw, conquered]
```

Collections usage example 2

Print unique words in lexicographic order

```
public class Lexicon {
   public static void main(String[] args) {
       Set<String> s = new TreeSet<>();
       for (String word : args)
           s.add(word);
       System.out.println(s);
   }
}
```

```
$ java Lexicon I came I saw I conquered
[I, came, conquered, saw]
```

Collections usage example 3

Print index of first occurrence of each word

```
class Index {
    public static void main(String[] args) {
        Map<String, Integer> index = new TreeMap<>();

        // Iterate backwards so first occurrence wins
        for (int i = args.length - 1; i >= 0; i--) {
            index.put(args[i], i);
        }
        System.out.println(index);
    }
}

$ java Index if it is to be it is up to me to do it
{be=4, do=11, if=0, is=2, it=1, me=9, to=3, up=7}
```

Java arrays are not `Collections`

- Arrays and collections don't mix
  - If you get compiler warnings, take them seriously
- Generally speaking, prefer collections to arrays
  - See *Effective Java* Item 28 for details

More information on collections

- For much more information on collections, see: https://docs.oracle.com/javase/tutorial/collections/index.html

Today

- Introduction to Java
  - Java's bipartite type system: primitives and object references
  - Java collections framework: data structures and algorithms
- Information hiding: Design for change, design for reuse
  - Encapsulation: Visibility modifiers in Java
  - Interface types vs. class types

Visibility modifiers in Java ("encapsulation")

- `private`: Accessible only from declaring class
- "package private": Accessible from any class in package
  - a.k.a. default access, no visibility modifier
- `protected`: Accessible from package and also from subclasses
- `public`: Accessible anywhere

Visibility modifier example

- Consider:

```
public class Point {
    private double x, y;
    public Point(double x, double y) {
        this.x = x;
        this.y = y;
    }
    public void translateBy(Point p) {
        x += p.x;
        y += p.y;
    }
}
```

Visibility modifier example

- Consider:

```
public class Point {
    private double x, y;
    public Point(double x, double y) {
        this.x = x;
        this.y = y;
    }
    public void translateBy(Point p) {
        x += p.x; // This is OK.  p.x and p.y are
        y += p.y; // accessible from the Point class!
    }
    public double getX() { return x; }
    public double getY() { return y; }
}
```

Information hiding is more general than visibility

- Use interfaces to separate expectations from implementation
  - Create interfaces to define your API
  - Declare variables, arguments, and return values as interface type
    - Write API in terms of other interfaces, not implementations
- Do not publicly document implementation details

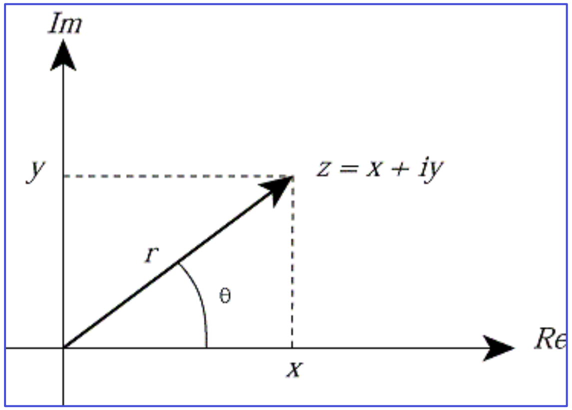
A more complex example

```
public class Complex {
  private final double re;  // Real part
  private final double im;  // Imaginary part

  public Complex(double re, double im) {
    this.re = re;
    this.im = im;
  }

  public double realPart()      { return re; }
  public double imaginaryPart() { return im; }
  public double r()             { return Math.sqrt(re * re + im * im); }
  public double theta()         { return Math.atan(im / re); }

  public Complex add(Complex c) {
    return new Complex(re + c.re, im + c.im);
  }
  public Complex subtract(Complex c) { ... }
  public Complex multiply(Complex c) { ... }
  public Complex divide(Complex c)   { ... }
}
```



Using the Complex class

```
public class ComplexUser {
    public static void main(String args[]) {
        Complex c = new Complex(-1, 0);
        Complex d = new Complex(0, 1);

        Complex e = c.plus(d);
        System.out.println(e.realPart() + " + "
                              + e.imaginaryPart() + "i");
        e = c.times(d);
        System.out.println(e.realPart() + " + "
                              + e.imaginaryPart() + "i");
    }
}
```

When you run this program, it prints

```
-1.0 + 1.0i
-0.0 + -1.0i
```

Extracting an interface from our class

```
public interface Complex {
    // No constructors, fields, or implementations!

    double realPart();
    double imaginaryPart();
    double r();
    double theta();

    Complex plus(Complex c);
    Complex minus(Complex c);
    Complex times(Complex c);
    Complex dividedBy(Complex c);
}
```

An interface defines but does not implement API

Modifying our earlier class to use the interface

```
public class OrdinaryComplex implements Complex {
  private final double re;  // Real part
  private final double im;  // Imaginary part

  public OrdinaryComplex(double re, double im) {
    this.re = re;
    this.im = im;
  }

  public double realPart()      { return re; }
  public double imaginaryPart() { return im; }
  public double r()             { return Math.sqrt(re * re + im * im); }
  public double theta()         { return Math.atan(im / re); }

  public Complex add(Complex c) {
    return new OrdinaryComplex(re + c.realPart(), im + c.imaginaryPart());
  }
  public Complex subtract(Complex c) { ... }
  public Complex multiply(Complex c) { ... }
  public Complex divide(Complex c)   { ... }
}
```

Modifying our earlier client to use the interface

```
public class ComplexUser {
    public static void main(String args[]) {
        Complex c = new OrdinaryComplex(-1, 0);
        Complex d = new OrdinaryComplex(0, 1);

        Complex e = c.plus(d);
        System.out.println(e.realPart() + " + "
                           + e.imaginaryPart() + "i");
        e = c.times(d);
        System.out.println(e.realPart() + " + "
                           + e.imaginaryPart() + "i");
    }
}
```

When you run this program, it still prints

```
-1.0 + 1.0i
-0.0 + -1.0i
```

Interfaces permit multiple implementations

```
public class PolarComplex implements Complex {
  private final double r;      // Radius
  private final double theta;  // Angle

  public PolarComplex(double r, double theta) {
    this.r = r;
    this.theta = theta;
  }

  public double realPart()      { return r * Math.cos(theta) ; }
  public double imaginaryPart() { return r * Math.sin(theta) ; }
  public double r()             { return r; }
  public double theta()         { return theta; }

  public Complex plus(Complex c)      { ... } // Completely new impls
  public Complex minus(Complex c)     { ... }
  public Complex times(Complex c)     { ... }
  public Complex dividedBy(Complex c) { ... }
}
```

Interface decouples client from implementation

```
public class ComplexUser {
    public static void main(String args[]) {
        Complex c = new PolarComplex(Math.PI,   1);  // -1
        Complex d = new PolarComplex(Math.PI/2, 1);  //  i

        Complex e = c.plus(d);
        System.out.println(e.realPart() + " + "
                           + e.imaginaryPart() + "i");
        e = c.times(d);
        System.out.println(e.realPart() + " + "
                           + e.imaginaryPart() + "i");
    }
}
```

When you run this program, it STILL prints

```
-1.0 + 1.0i
-0.0 + -1.0i
```

Coming next Tuesday

- The information hiding punchline
- Specifications
- Introduction to testing