SOFTWARE ENGINEERING

Lecture 4

CS2110 Spring 2013

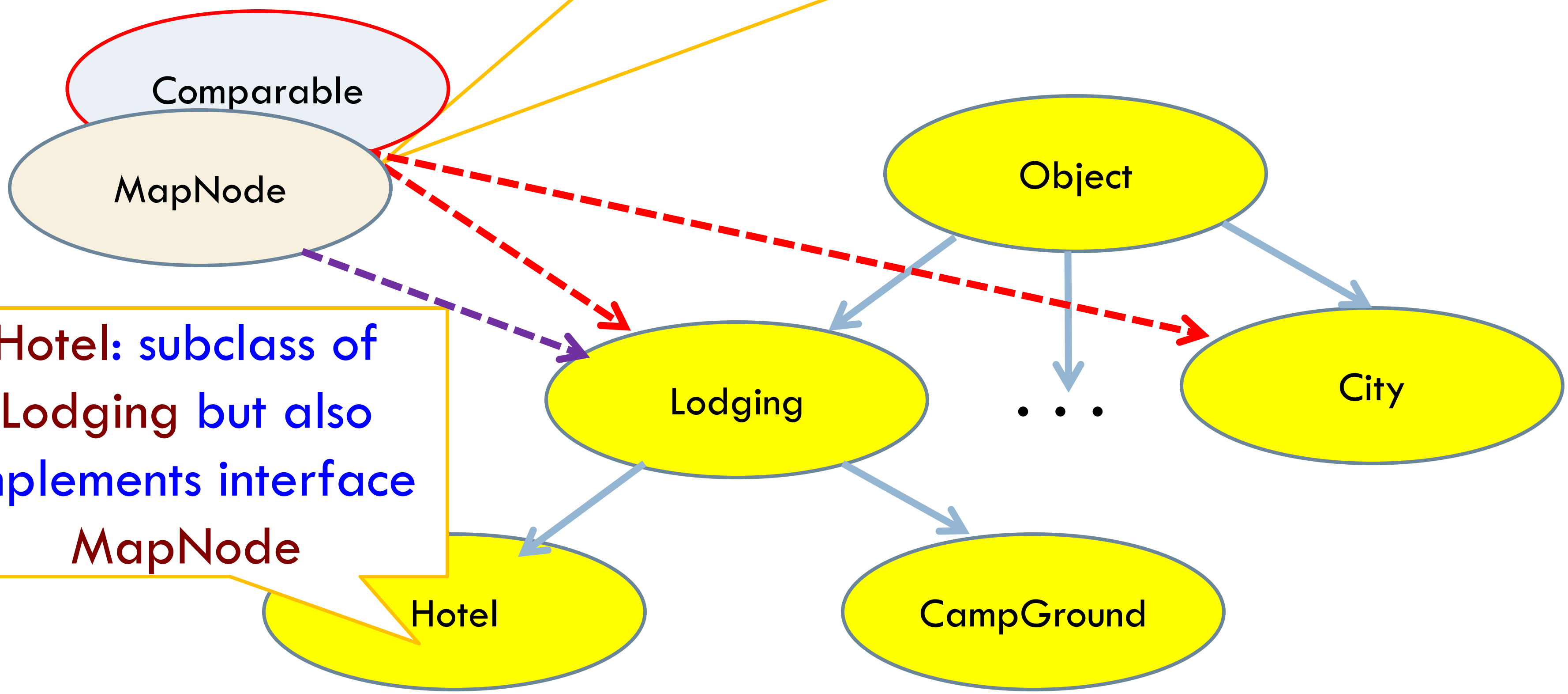
… picking up where we stopped

- We were discussing the class hierarchy

- We had been focused on extending a class by creating a new child class
  - We looked at “overloading” methods
  - Allows us to have multiple methods with the same name but with different type signatures
  - Used when some arguments have default values. The “short” versions just call the “ultimate” one with default values for any unspecified parameters

Interfaces

Interface: “fully abstract” class listing *type signatures* for fields and methods. A class implementing the interface must define all methods but in its own specialized way.



A class has only one parent but can implement many interfaces.
Decide on class hierarchy and what interfaces to support as part of process of developing clean, elegant code

Example: **Overriding** "toString"

- Similar terms but over<u>load</u> and over<u>ride</u> differ
  - Overload: A class with multiple methods having the same name but different type signatures
  - Override: A class that redefines some method that its parent defined, and that it would have inherited

- Overload has nothing to do with extending a class
- Override is used only when extending a class

Example: **Overriding** “toString”

- Class Object defines toString, so every object of every class contains toString.
  - toString in Object: prints name@Address
  - Most classes override toString()
  - toString() in an object usually returns a string that contains values of the fields of the object, printed in a nice way.

```
@Override      // An “attribute”: tells Eclipse what we intend
public string toString() {
    return this.name + “:” + this.value;
}
```

Example: **Overriding** “toString”

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```
// Putting it right into the declaration can increase clarity
public @Override string toString() {
    return this.name + “:” + this.value;
}
```

Example: **Overriding** "toString"

- Class Object defines toString, so every object of every class contains toString.
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  - toString() in an o ontains values of the fields of the object, printed in a nice way.

Method ToString should override some inherited method.

```
// If you make a mistake, now Eclipse will notice & warn you
public @Override string ToString() {   // Mistake: to, not To
      return this.name + ":" + this.value;
}
```

Is toString() the only use for override?

- This the most common use!

- But there is one other very common case
  - Java has many pre-defined classes for making lists or other kinds of collections
  - It can search and sort within them
  - These need a way to compare elements
  - Again, there are default comparison rules but they don't often do exactly what you would want

Example: Overloading "compareTo"

- Interface Comparable has three methods:
  - a.equals(b): returns true/false
  - a.compareTo(b): returns -/0/+
  - a.hashCode(): returns a number (ideally unique and randomized) representing object a. Usually return data.hashCode() for some data object in a that represents a's "value" (perhaps a string or a number)
  - Warning: Override one method? Must override *all*. Otherwise, get mix of inherited and override versions, and Java utilities that depend on them malfunction

Accessing Overridden Methods

Suppose a class overrides method m

Like toString() in the examples we just saw

- Sometimes it is useful to be able to call the parent version. E.g. maybe you still want to print the Name@Address using Object.toString()
- In subclass, call overridden method using super.m()

- Example:

```
Public @Override String toString() {
     return super.toString() + ": " + name + ", price=" + price;
}
 ....  "ns@0xAF402: Hotel Bates, price=37.50"
```

Shifting gears

- We've focused on the type hierarchy.

- Now let's look at a different but related question: how things get initialized in Java
  - For a single object
  - ... for static variables, and then for instance variables
  - ... then for objects in a subclass of a parent class
  - ... and then for two classes that refer to one another

Drill down: Initializing an object

- Questions to ask about initialization in Java:
  - When do things have default values? What are those?
  - What happens if you touch an uninitialized object?
  - What if you need a more complicated initialization that requires executing some code?
  - Who gets initialized first in an parent/subclass situation?
  - Who gets initialized first if two different classes have initializers that each refer to the other?

Constructors

Java automatically calls two.toString()
It works: class Thing inherits Object.toString().
Won't print value in field val *[Why not?]*

- Called to create new instances of a class.
- A class can define multiple constructors
- Default constructor initializes all fields to default values (0, false, null…)

```
class Thing {
    int val;
    Thing(int val) {
        this.val = val;
    }
    Thing() {
        this(3);
    }
```

```
Thing one = new Thing(1);
Thing two = new Thing(2);
Thing three = new Thing();
System.out.println("Thing two = " + two);
```

Constructors in class hierarchy

- Principle: initialize superclass fields first.
- Implementation: First statement of constructor must be call on constructor in this class or superclass Java syntax or is:
  this(arguments); or
  super(arguments);
- If you don't do this, Java inserts call
  super();

```
public class Hotel extends Lodging { … }
```

Hotel@xy

Object fields, methods

Lodging fields, methods

Hotel fields, methods

Example

Prints: Csuper constructor called.
Constructor in A running.


```
public class CSuper {
    public CSuper() {
        System.out.println("CSuper constructor called.");
    }
}
public class A extends CSuper {
    public A() {
        super();
        System.out.println("Constructor in A running.");
    }
    public static void main(String[] str) {
        ClassA obj = new ClassA();
    }
}
```

What arelocal variables?

- Local variable: variable declared in method body
- Not initialized, you need to do it yourself!
- Eclipse should detect these mistakes and tell you

```
class Thing {
    int val;
    public Thing(int val) {
        int undef;
        this.val = val + undef;
    }
    public Thing() {
        this(3);
    }
}
```

What happens here?

- If you access an object using a reference that has a **null** in it, Java throws a NullPointerException.
- Thought problem: what did developer intend?
  - Probably thinks myFriend points to an existence of class RoomMate.
  - RoomMate object created only with new-expression

```
class Thing {
    RoomMate myFriend;

    Thing(int val) {
        myFriend.value = val;
    }
}
```

Static Initializers

- An initializer for a static field runs once, when the class is loaded
- Used to initialize static objects

```
class StaticInit {
   static Set<String> courses = new HashSet<String>();
   static {
      courses.add("CS 2110");
      courses.add("CS 2111");
   }

    …
}
```

Glimpse of a "generic"

Reminder: Static vs Instance Example


```
class Widget {
    static int nextSerialNumber = 10000;
    int serialNumber;
    Widget() {  serialNumber = nextSerialNumber++; }
    public static void main(String[] args) {
        Widget a = new Widget();
        Widget b = new Widget();
        Widget c = new Widget();
        System.out.println(a.serialNumber);
        System.out.println(b.serialNumber);
        System.out.println(c.serialNumber);
    }
}
```

Accessing static versus instance fields

- If name is unique and in scope, Java knows what you are referring to. In scope: in this object and accessible. Just use the (unqualified) name:
  - serialNumber
  - nextSerialNumber
- Refer to <u>static</u> fields/methods in <u>another</u> class using name of class
  - Widget.nextSerialNumber
- Refer to <u>instance</u> fields/methods of another object using name of object
  - a.serialNumber

Hair-raising initialization

- Suppose a is of type A and b is of type B
  - … and A has static field myAVal,
  - ….and B has field myBVal.

- Suppose we have static initializers:

```
public static int myAVal = B.myBVal+1;
public static int myBVal = A.myAVal+1;
```

Hair-raising initialization

- What happens depends on which class gets loaded first. Assume program accesses A.
  - Java "loads" A and initializes all its fields to 0/false/null
  - Now, static initializers run. A accesses B. So Java loads B and initializes all its fields to 0/false/null.
  - Before we can access B.myBVal we need to initialize it.
- B sets myBVal = A.myAVal+1 = 0+1 = 1
- Next A sets A.myAVal = B.myBVal+1=1+1=2

- (Only lunatics write code like this but knowing how it works is helpful)

Some Java « issues »

- An overriding method cannot have more restricted access than the method it overrides

```
class A {
    public int m() {...}
}
class B extends A {
    private @Override int m() {...} //illegal!
}

A foo = new B();  // upcasting
foo.m();          // would invoke private method in
                  // class B at runtime
```

Can we override a field?

- … Yes, Java allows this. There are some situations where it might even be necessary.
- We call the technique "shadowing"
- But it isn't normally a good idea.

… a nasty example


```
class A {
    int i = 1;
    int f() { return i; }
}
class B extends A {
    int i = 2;                                    // Shadows variable i in class A.
    int @Override f() { return -i; }              // Overrides method f in class A.
}
public class override_test {
    public static void main(String args[]) {
        B b = new B();
        System.out.println(b.i);                  // Refers to B.i; prints 2.
        System.out.println(b.f());                // Refers to B.f(); prints -2.
        A a = (A) b;                              // Cast b to an instance of class A.
        System.out.println(a.i);                  // Now refers to A.i; prints 1;
        System.out.println(a.f());                // Still refers to B.f(); prints -2;
    }
}
```

The “runtime” type of “a” is “B”!

Shadowing

- Like overriding, but for fields instead of methods
  - Superclass: variable v of some type
  - Subclass: variable v perhaps of some other type
  - Subclass method: access shadowed variable using super.v
  - Variable references are resolved using static binding (i.e. at compile-time), not dynamic binding (i.e. not at runtime)
- Variable reference r.v uses the static (declared) type of variable r, not runtime type of the object referred to by r
- Shadowing is bad medicine. Don't do it. CS2110 does not allow it

… back to our nasty example


```
class A {
    int i = 1;
    int f() { return i; }
}
class B extends A {
    int i = 2;                                  // Shadows variable i in class A.
    int @Override f() { return -i; }            // Overrides method f in class A.
}
public class override_test {
    public static void main(String args[]) {
        B b = new B();
        System.out.println(b.i);                // Refers to B.i; prints 2.
        System.out.println(b.f());              // Refers to B.f(); prints -2.
        A a = (A) b;                            // Cast b to an instance of class A.
        System.out.println(a.i);                // Now refers to A.i; prints 1;
        System.out.println(a.f());              // Still refers to B.f(); prints -2;
    }
}
```

The “declared” or “static” type of “a” is “A”!

Software Engineering

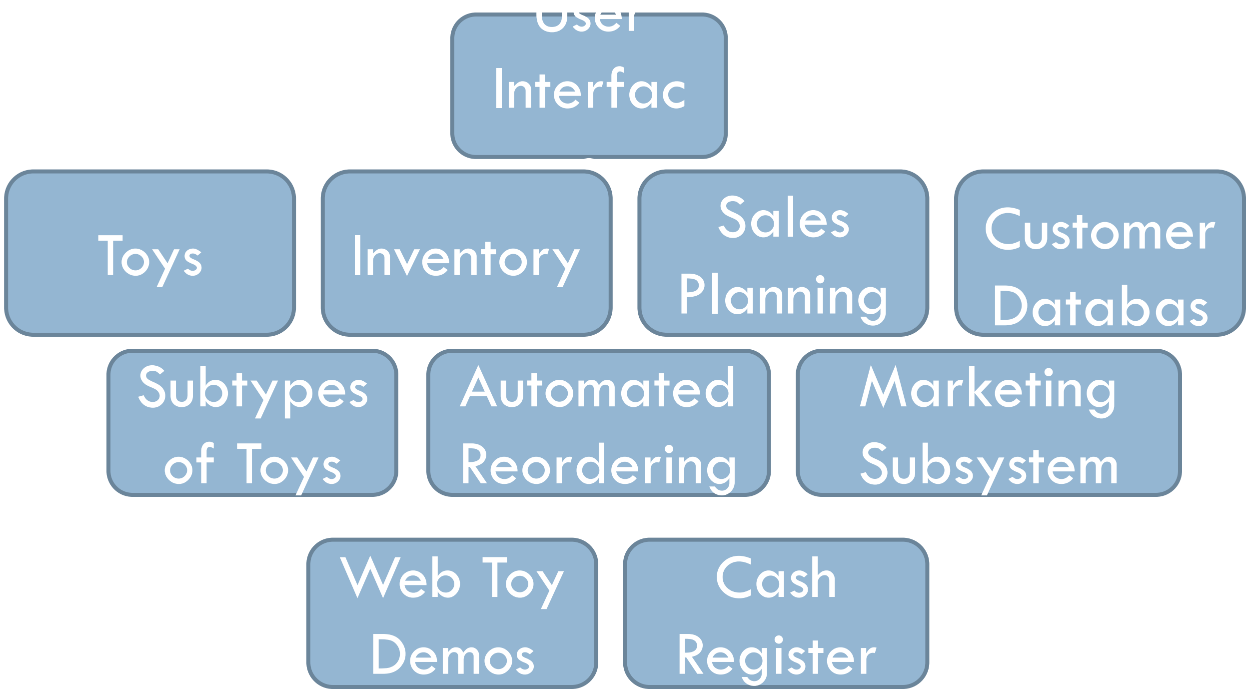
- The art by which we start with a problem statement and gradually evolve a solution
- There are whole books on this topic and most companies try to use a fairly uniform approach that all employees are expected to follow
- The class hierarchy you design is a step in this process

The software design cycle

- Some ways of turning a problem statement into a program that we can debug and run
  - Top-Down, Bottom-Up Design
  - Software Process (briefly)
  - Modularity
  - Information Hiding, Encapsulation
  - Principles of Least Astonishment and “DRY”
  - Refactoring

Top-Down Design

- Start with big picture:



- Invent abstractions at a high level
- Decomposition / "Divide and Conquer"

Not a perfect, pretty picture

- It is often easy to take the first step but not the second one

- Large abstractions come naturally. But details often work better from the ground up

- Many developers work by building something small, testing it, then extending it
  - It helps to not be afraid of needing to recode things

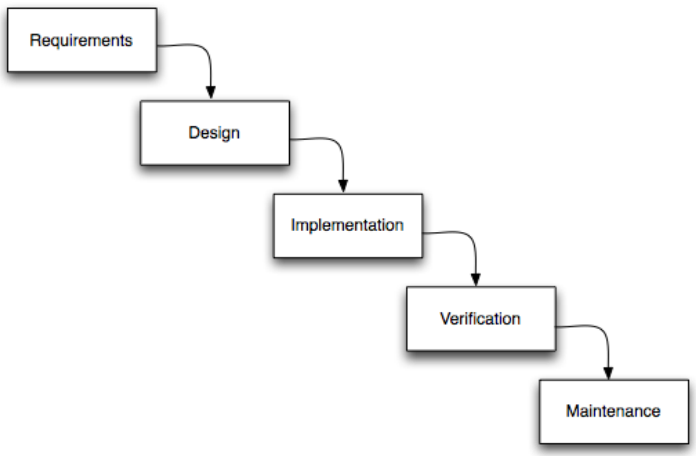
Top-Down vs. Bottom-Up

- Is one way better? Not really!
  - It's sometimes good to alternative
  - By coming to a problem from multiple angles you might notice something you had previously overlooked
  - Not the only ways to go about it

- Top-Down: harder to test early because parts needed may not have been designed yet
- Bottom-Up: may end up needing things different from how you built them

Software Process

- For simple programs, a simple process…

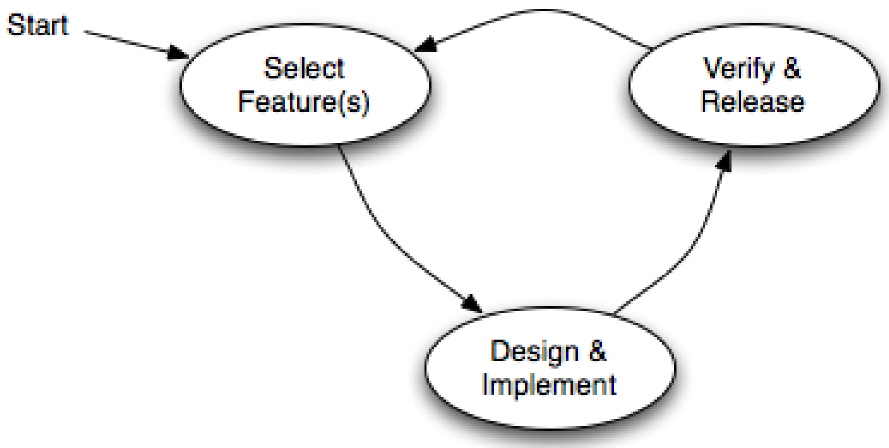


"Waterfall"

- But to use this process, you need to be sure that the requirements are fixed and well understood!
  - Many software problems are not like that
  - Often customer refines requirements when you try to deliver the initial solution!

Incremental & Iterative

- Deliver versions of system in several small cycles



- Recognizes that for some settings, software development is like gardening
- You plant seeds… see what does well… then replace the plants that did poorly

Information Hiding

- What "information" do classes hide?
  "Internal" design decisions.

```
public class Set {
     …
   public void add(Object o) ...

      public boolean contains(Object o) ...

      public int size() ...
}
```

- Class'es interface: everything in it that is externally accessible

Encapsulation

- By hiding code and data behind its interface, a class encapsulates its "inner workings"
- Why is that good?
  - Can change implementation later without invalidating the code that uses the class

```
class LineSegment {
  private Point2D p1, p2;
  ...
  public double length() {
    return p1.distance(p2);
  }
}
```

```
class LineSegment {
  private Point2D p;
  private double length;
  private double phi;
  ...
  public double length() {
    return length;
  }
}
```

Degenerate Interfaces

- Public fields are usually a Bad Thing:

```
class Set {
      public int count = 0;

   public void add(Object o) ...

      public boolean contains(Object o) ...

      public int size() ...
}
```

- Anybody can change them; the class has no control

Use of interfaces?

- When team builds a solution, interfaces can be valuable!
  - Rebecca agrees to implement the code to extract genetic data from files
  - Tom will implement the logic to compare DNA
  - Willy is responsible for the GUI
- By agreeing on the interfaces between their respective modules, they can all work on the program simultaneously

Principle of Least Astonishment

- Interface should “hint” at its behavior

Bad:

```
public int product(int a, int b) {
    return a*b > 0 ? a*b : -a*b;
}
```

Better:

```
/** Return absolute value of a * b */
public int absProduct(int a, int b) {
    return a*b > 0 ? a*b : -a*b;
}
```

- Names and comments matter!

Outsmarting yourself

- A useful shorthand... Instead of

```
something = something * 2;
```

... use

```
something *= 2;
```

- All such operators:

```
+=    -=    *=    /=    %=    ^=
```

Principle of Least Astonishment

- Unexpected side effects are a Bad Thing

```
class MyInteger {
    private int value;
    ...
    public MyInteger times(int factor) {
        value *= factor;
        return new MyInteger(value);
    }
}
...
MyInteger i = new MyInteger(100);
MyInteger j = i.times(10);
```

Developer trying to be clever. But what does code do to i?

Duplication

- It is common to find some chunk of working code, make a replica, then edit the replica
- But this makes your software fragile: later, when code you copied needs to be revised, either
  - The person doing that changes all instances, or
  - some become inconsistent
- Duplication can arise in many ways:
  - constants (repeated “magic numbers”)
  - code vs. comment
  - within an object’s state
  - …

“DRY” Principle

- Don’t Repeat Yourself

- Nice goal: have each piece of knowledge live in one place
- But don’t go crazy over it
  - DRYing up at any cost can increase dependencies between code
  - “3 strikes and you refactor” (i.e. clean up)

Refactoring

- Refactor: improve code's internal structure without changing its external behavior
- Most of the time we're modifying existing software
- "Improving the design after it has been written"
- Refactoring steps can be very simple:

```
public double weight(double mass) {
  return mass * 9.80665;
}
```

```
static final double GRAVITY = 9.80665;
public double weight(double mass) {
  return mass * GRAVITY;
}
```

- Other examples: renaming variables, methods, classes

Why is refactoring good?

- If your application later gets used as part of a Nasa mission to Mars, it won't make mistakes
- Every place that the gravitational constant shows up in your program a reader will realize that this is what they are looking at
- The compiler may actually produce better code

Common refactorings

- Rename something
  - Eclipse will do it all through your code
  - Warning: Eclipse doesn't automatically fix comments!

- Take a chunk of your code and turn it into a method
  - Anytime your "instinct" is to copy lines of code from one place in your program to another and then modify, consider trying this refactoring approach instead...
  - ... even if you have to modify this new method, there will be just one "version" to debug and maintain!

Extract Method

- A comment explaining what is being done usually indicates the need to extract a method

```
public double totalArea() {
    ...
    // add the circle
    area +=
           PI * pow(radius,2);
    ...
}
```

```
public double totalArea() {
    ...
    area += circleArea(radius);
    ...
}

private double circleArea
                          (double radius) {
    return PI * pow(radius, 2);
}
```

- One of most common refactorings

Extract Method

Before

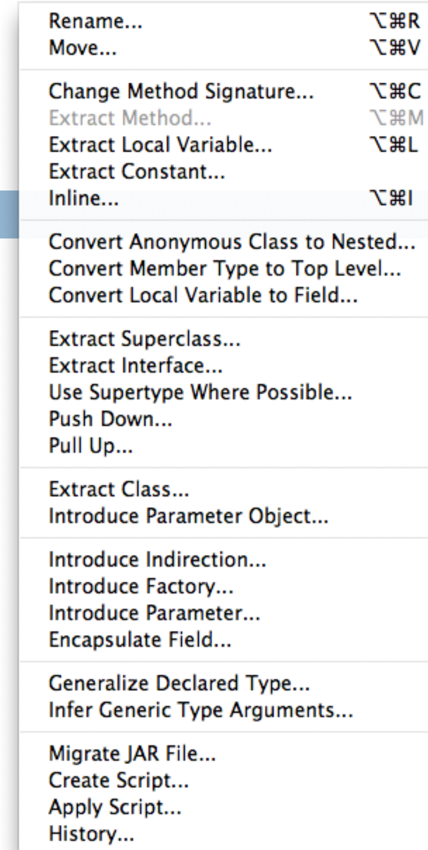
```
if (date.before(SUMMER_START) ||
                date.after(SUMMER_END)) {
    charge = quantity * winterRate + winterServiceCharge;
}
else {
    charge = quantity * summerRate;
}
```

After

```
if (isSummer(date)) {
      charge = summerCharge(quantity);
}
else {
      charge = winterCharge(quantity);
}
```

Refactoring & Tests

- Eclipse supports various refactorings



- You can refactor manually
  - Automated tests are essential to ensure external behavior doesn't change
  - Don't refactor manually without retesting to make sure you didn't break the code you were "improving"!

- More about tests and how to drive development with tests next week

Summary

- We've seen that Java offers ways to build general classes and then to created specialized versions of them
  - In fact we saw several ways to do this
- Our challenge is to use this power to build clean, elegant software that doesn't duplicate functionality in confusing ways
- The developer's job is to find abstractions and use their insight to design better code!