Design Patterns

Creational, Structural, Behavioral

where were we?

- Talking about generics

- Discovering flaws in Java

```
Integer[] li = new Integer[5];
Number[] ln = li;
Ln[0] = new Float(0.0);
```

- Learning about design patterns

Why care about design patterns?

- You could come up with these solutions on your own
- You shouldn't have to!
- A design pattern is a known solution to a known problem

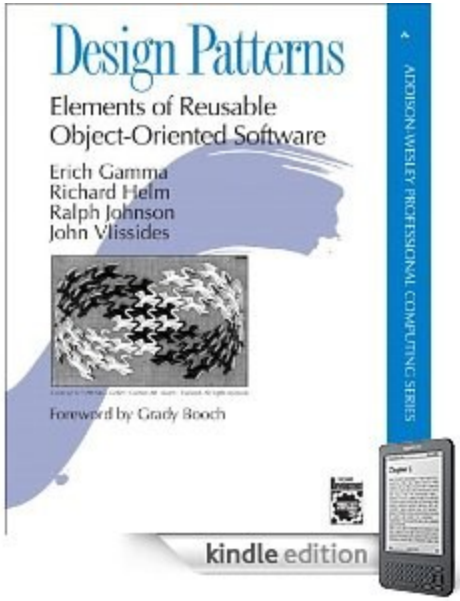
When not to use a design pattern

- Rule 1: delay
- Design patterns can increase or decrease understandability

– add indirection	+ improve modularity
– increase code size	+ separate concerns
	+ ease description

If your design or implementation has a problem, consider design patterns that address that problem

Design pattern references



- Canonical reference: the "Gang of Four" book
  - *Design Patterns: Elements of Reusable Object-Oriented Software*, by Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides, Addison-Wesley, 1995.
- Another good reference for Java
  - *Effective Java: Programming Language Guide (2nd ed.)*, by Joshua Bloch, Addison-Wesley, 2008.

Creational patterns

- Constructors in Java are inflexible
  - Can't return a subtype of the class they belong to
  - Always return a fresh new object, never re-use one

- Sharing
  - Singleton
  - Interning
  - Flyweight
- Factories
  - Factory method
  - Factory object
  - Prototype

Sharing

- Java constructors always return a new object

- Three solutions:
  - Singleton: only one object exists at runtime
  - Interning: only one object with a particular (abstract) value exists at runtime
  - Flyweight: separate intrinsic and extrinsic state, and intern the intrinsic state

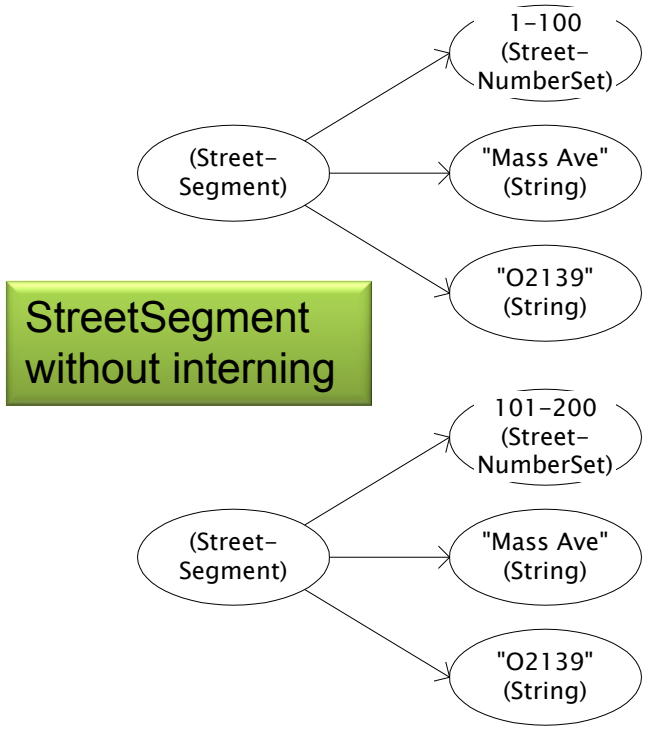
Singleton

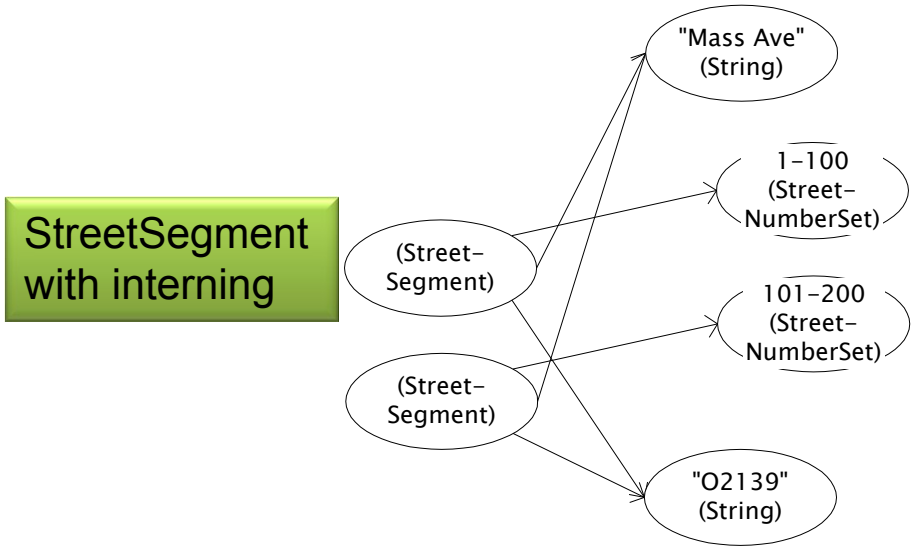
Only one object of the given type exists

```
class Bank {
  private static bank theBank;

  // private constructor
  private Bank() { ... }

  // factory method
  public static getBank() {
    if (theBank == null) {
      theBank = new Bank();
    }
    return theBank;
  }
  ...
}
```

Interning pattern

- Reuse existing objects instead of creating new ones
  - Less space
  - May compare with == instead of `equals()`
- Permitted only for immutable objects





Interning mechanism

- Maintain collection of all objects
- If an object already appears, return that instead

why HashMap and not HashSet?

```
HashMap<String, String> segnames;
String canonicalName(String n) {
  if (segnames.containsKey(n)) {
    return segnames.get(n);
  } else {
    segnames.put(n, n);
    return n;
  }
}
```

`Set` supports `contains` but not `get`

- Java builds this in for strings: `String.intern()`

Failure to use the Interning pattern: java.lang.Boolean

```
– public class Boolean {
–   private final boolean value;
–   // construct a new Boolean value
–   public Boolean(boolean value) {
–     this.value = value;
–   }

–   public static Boolean FALSE = new Boolean(false);
–   public static Boolean TRUE = new Boolean(true);
–   // factory method that uses interning
–   public static valueOf(boolean value) {
–     if (value) {
–       return TRUE;
–     } else {
–       return FALSE;
–     }
–   }
– }
```

Recognition of the problem

- Javadoc for Boolean constructor:
  - Allocates a Boolean object representing the value argument.
  - **Note: It is rarely appropriate to use this constructor. Unless a new instance is required, the static factory valueOf(boolean) is generally a better choice. It is likely to yield significantly better space and time performance.**
- Josh Bloch (JavaWorld, January 4, 2004):
  - The Boolean type should not have had public constructors. There's really no great advantage to allow multiple trues or multiple falses, and I've seen programs that produce millions of trues and millions of falses, creating needless work for the garbage collector.
  - So, in the case of immutables, I think factory methods are great.

Why not intern mutable objects?

```
// interned class Team represents a set of Students
Team team1 = team.getTeam("Bobby", "Mary");
Team fightingMongooses = Team.getTeam("Bobby", "Mary");

team1.addStudent("Clair");

fightingMongooses.teamSize() == 2 ?
```

What if objects are mostly the same?

A car has:

- engine
  - cylinders
  - crankcase
  - pistons
- wheels
  - spokes
  - diameter
  - required pressure
- …

Model T

Separate out the constant stuff from the stuff that changes.

Intern the constant stuff.

Flyweight pattern

- Good when many objects are mostly the same
  - Interning works only if objects are entirely the same (and immutable!)
- Intrinsic state: same across all objects
  - intern it
- Extrinsic state: different for different objects
  - if possible, make it implicit: don't represent it!
  - making it implicit also requires immutability
  - represent immutable parts explicitly

Example without flyweight: bicycle spoke

```
class Wheel {
  FullSpoke[] spokes;
  ...
}
class FullSpoke {
  int length;
  int diameter;
  bool tapered;
  Metal material;
  float weight;
  float threading;
  bool crimped;
  int location;   // rim and hub holes this is installed in
}
```

- Typically 32 or 36 spokes per wheel, but only 3 varieties per bicycle.
- In a bike race, hundreds of spoke varieties, millions of instances

Alternatives to FullSpoke

```
class IntrinsicSpoke {
  int length;
  int diameter;
  boolean tapered;
  Metal material;
  float weight;
  float threading;
  boolean crimped;
}
```

- This doesn't work: it's the same as FullSpoke

```
class InstalledSpokeFull extends IntrinsicSpoke {
  int location;
}
```

- This works, but flyweight version uses even less space

```
class InstalledSpokeWrapper {
  IntrinsicSpoke s;     // refer to interned object
  int location;
}
```

Original code to true (align) a wheel

```
– class FullSpoke {
–   // Tension the spoke by turning the nipple the
–   // specified number of turns.
–   void tighten(int turns) {
–     ... location ...    // location is a field
–   }
– }

– class Wheel {
–   FullSpoke[] spokes;
–   void align() {
–     while (wheel is misaligned) {
–       // tension the i^th spoke
–       ... spokes[i].tighten(numturns) ...
–     }
–   }
– }
```

Flyweight code to true (align) a wheel

```
– class IntrinsicSpoke {
–   void tighten(int turns, int location) {
–     ... location ...    // location is a parameter
–   }
– }

– class Wheel {
–   IntrinsicSpoke[] spokes;

–   void align() {
–     while (wheel is misaligned) {
–       // tension the i^th spoke
–       ... spokes[i].tighten(numturns, i) ...
–     }
–   }
– }
```

Flyweight discussion

- What if `FullSpoke` contains a `wheel` field pointing at the `Wheel` containing it?

`Wheel` methods pass this to the methods that use the **`wheel`** field.

- What if `FullSpoke` contains a `boolean` broken field?

Add an array of **`boolean`** in **`Wheel`**, parallel to the array of **`Spokes`**.

- Flyweight is manageable only if there are very few mutable (extrinsic) fields.
- Flyweight complicates the code.
- Use flyweight only when profiling has determined that space is a *serious* problem.

Factories

- Problem: client desires control over object creation
- Factory method
  - Hides decisions about object creation
  - Implementation: put code in methods in client
- Factory object
  - Bundles factory methods for a family of types
  - Implementation: put code in a separate object
- Prototype
  - Every object is a factory, can create more objects like itself
  - Implementation: put code in clone methods

Motivation for factories: Changing implementations

- Supertypes support multiple implementations
  - `interface Matrix { ... }`
  - `class SparseMatrix implements Matrix { ... }`
  - `class DenseMatrix implements Matrix { ... }`

- Clients use the supertype (Matrix)
  - Still need to use a SparseMatrix or DenseMatrix constructor
  - Switching implementations requires code changes

Use of factories

- Factory
  - `class MatrixFactory {`
  - `  public static Matrix createMatrix() {`
  - `    return new SparseMatrix();`
  - `  }`
  - `}`
- Clients call createMatrix, not a particular constructor
- Advantages
  - To switch the implementation, only change one place
  - Can decide what type of matrix to create

Example: bicycle race

```
– class Race {

–   // factory method
–   Race createRace() {
–
–     Bicycle bike1 = new Bicycle();
–     Bicycle bike2 = new Bicycle();
–
–     ...
–   }

– }
```

Example: Tour de France

```
– class TourDeFrance extends Race {

–   // factory method
–   Race createRace() {
–     Bicycle bike1 = new RoadBicycle();
–     Bicycle bike2 = new RoadBicycle();
–     ...
–   }

– }
```

Example: Cyclocross

```
– class Cyclocross extends Race {

–   // factory method
–   Race createRace() {
–     Bicycle bike1 = new MountainBicycle();
–     Bicycle bike2 = new MountainBicycle();
–     ...
–   }

– }
```

Factory method for Bicycle

```
– class Race {
–   Bicycle createBicycle() { ... }
–   Race createRace() {
–     Bicycle bike1 = createBicycle();
–     Bicycle bike2 = createBicycle();
–     ...
–   }
– }
```

Code using factory methods

```
– class Race {
–   Bicycle createBicycle() { ... }
–   Race createRace() {
–     Bicycle bike1 = createBicycle();
–     Bicycle bike2 = createBicycle();
–     ...
–   }
– }

– class TourDeFrance extends Race {
–   Bicycle createBicycle() {
–     return new RoadBicycle();
–   }
– }

– class Cyclocross extends Race {
–   Bicycle createBicycle(Frame) {
–     return new MountainBicycle();
–   }
– }
```

Factory objects/classes encapsulate factory methods

```
- class BicycleFactory {
-   Bicycle createBicycle() { ... }
-   Frame createFrame() { ... }
-   Wheel createWheel() { ... }
-   ...
- }

- class RoadBicycleFactory extends BicycleFactory {
-   Bicycle createBicycle() {
-     return new RoadBicycle();
-   }
- }

- class MountainBicycleFactory extends BicycleFactory {
-   Bicycle createBicycle() {
-     return new MountainBicycle();
-   }
- }
```

Using a factory object

```
class Race {
  BicycleFactory bfactory;
  // constructor
  Race() { bfactory = new BicycleFactory(); }
  Race createRace() {
    Bicycle bike1 = bfactory.createBicycle();
    Bicycle bike2 = bfactory.createBicycle();
    ...
  }
}

class TourDeFrance extends Race {
  // constructor
  TourDeFrance() { bfactory = new RoadBicycleFactory(); }
}

class Cyclocross extends Race {
  // constructor
  Cyclocross() { bfactory = new MountainBicycleFactory(); }
}
```

Separate control over bicycles and races

```
class Race {
  BicycleFactory bfactory;
  // constructor
  Race(BicycleFactory bfactory) { this.bfactory = bfactory; }
  Race createRace() {
    Bicycle bike1 = bfactory.completeBicycle();
    Bicycle bike2 = bfactory.completeBicycle();
    ...
  }
}
// No special constructor for TourDeFrance or for Cyclocross
```

-
- Now we can specify the race and the bicycle separately:

```
  new TourDeFrance(new TricycleFactory())
```

DateFormat factory methods

- DateFormat class encapsulates knowledge about how to format dates and times as text
  - Options: just date? just time? date+time? where in the world?
  - Instead of passing all options to constructor, use factories.
  - Tidy, and the subtype created doesn't need to be specified.

- `DateFormat df1 = DateFormat.getDateInstance();`
- `DateFormat df2 = DateFormat.getTimeInstance();`
- `DateFormat df3 = DateFormat.getDateInstance(DateFormat.FULL, Locale.FRANCE);`
- `Date today = new Date();`
- `System.out.println(df1.format(today)); // "Jul 4, 1776"`
- `System.out.println(df2.format(today)); // "10:15:00 AM"`
- `System.out.println(df3.format(today)); // "juedi 4 juillet 1776"`

Prototype pattern

- Every object is itself a factory
- Each class contains a `clone` method that creates a copy of the receiver object

```
class Bicyle {
  Bicycle clone() { ... }
}
```

- You will often see `Object` as the return type of `clone`
  - This is due to a design flaw in Java 1.4 and earlier
  - `clone` is declared in `Object`
  - Java 1.4 did not permit the return type to change in an overridden method

Using prototypes

```
class Race {
  Bicycle bproto;
  // constructor
  Race(Bicycle bproto) { this.bproto = bproto; }
  Race createRace() {
    Bicycle bike1 = (Bicycle) bproto.clone();
    Bicycle bike2 = (Bicycle) bproto.clone();
    ...
  }
}
```

- Again, we can specify the race and the bicycle separately:

```
new TourDeFrance(new Tricycle())
```