Creational Patterns

CSCI 4448/5448: Object-Oriented Analysis & Design
Lecture 26 — 11/29/2012

Goals of the Lecture

- Cover material from Chapters 20-22 of the Textbook
  - Lessons from Design Patterns: Factories
  - Singleton Pattern
  - Object Pool Pattern
- Also discuss
  - Builder Pattern
  - Lazy Instantiation

Pattern Classification

- The Gang of Four classified patterns in three ways
  - The **behavioral** patterns are used to manage variation in behaviors (think Strategy pattern)
  - The **structural** patterns are useful to integrate existing code into new object-oriented designs (think Bridge)
  - The **creational** patterns are used to create objects
    - Abstract Factory, Builder, Factory Method, Prototype & Singleton

Factories & Their Role in OO Design

- It is important to manage the creation of objects
  - Code that **mixes** object *creation* with the *use* of objects can become quickly non-cohesive
  - A system may have to deal with a variety of different contexts
    - with each context requiring a different set of objects
      - In design patterns, the context determines which concrete implementations need to be present

Factories & Their Role in OO Design

- The code to determine the current context, and thus which objects to instantiate, can become complex
    - with many different conditional statements
- If you mix this type of code with the **use** of the instantiated objects, your code becomes cluttered
    - often the use scenarios can happen in a **few lines of code**
        - if combined with creational code, the operational code **gets buried** behind the creational code

Factories provide Cohesion

- The use of factories can address these issues
  - The conditional code can be hidden within them
    - pass in the parameters associated with the current context
    - and get back the objects you need for the situation
      - Then use those objects to get your work done
- Factories concern themselves just with creation, letting your code focus on other things

The Object Creation/Management Rule

- This discussion brings us to this general design rule
  - An object should either create/manage a set of objects OR it should use other objects
    - it should never do both

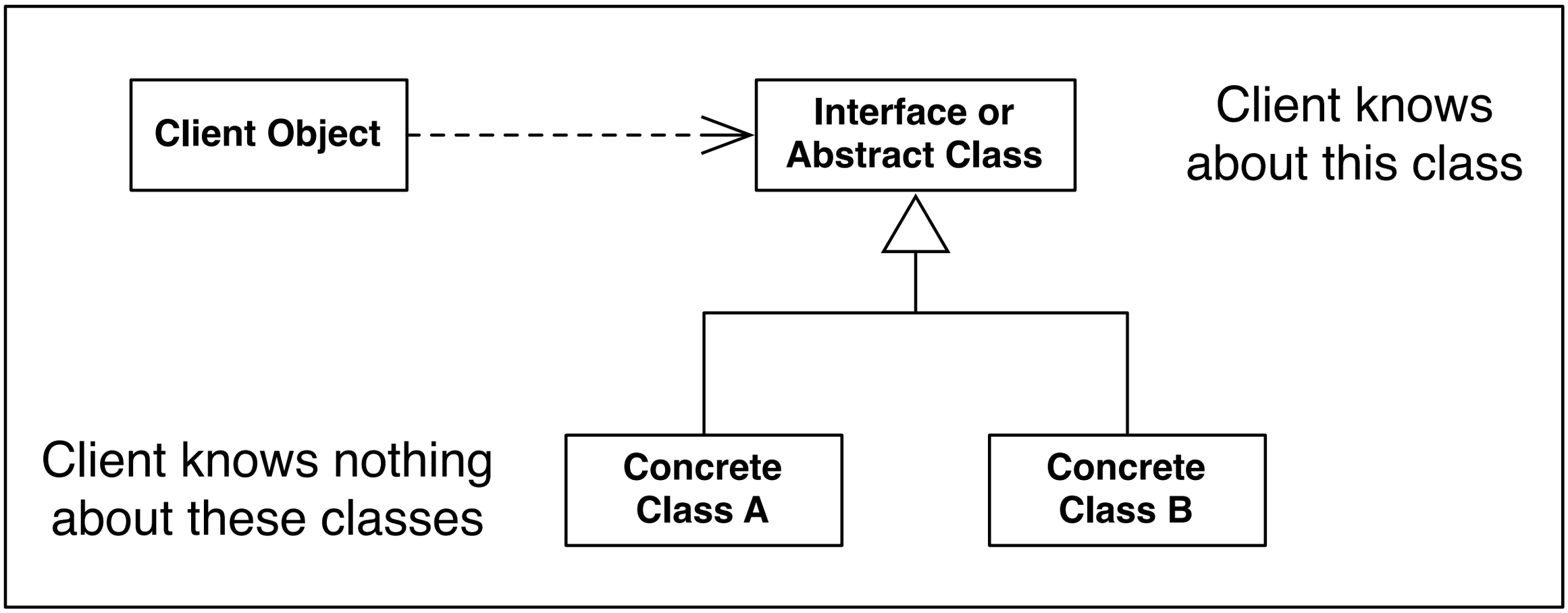
Discussion (I)

- This rule is a **guideline** not an absolute
    - The latter is too difficult; think of iOS view controllers
        - They exist to create a view and then respond to requests related to that view (which may involve making queries on the view)
        - This violates the rule, strictly speaking, as it both creates AND uses its associated view

Discussion (II)

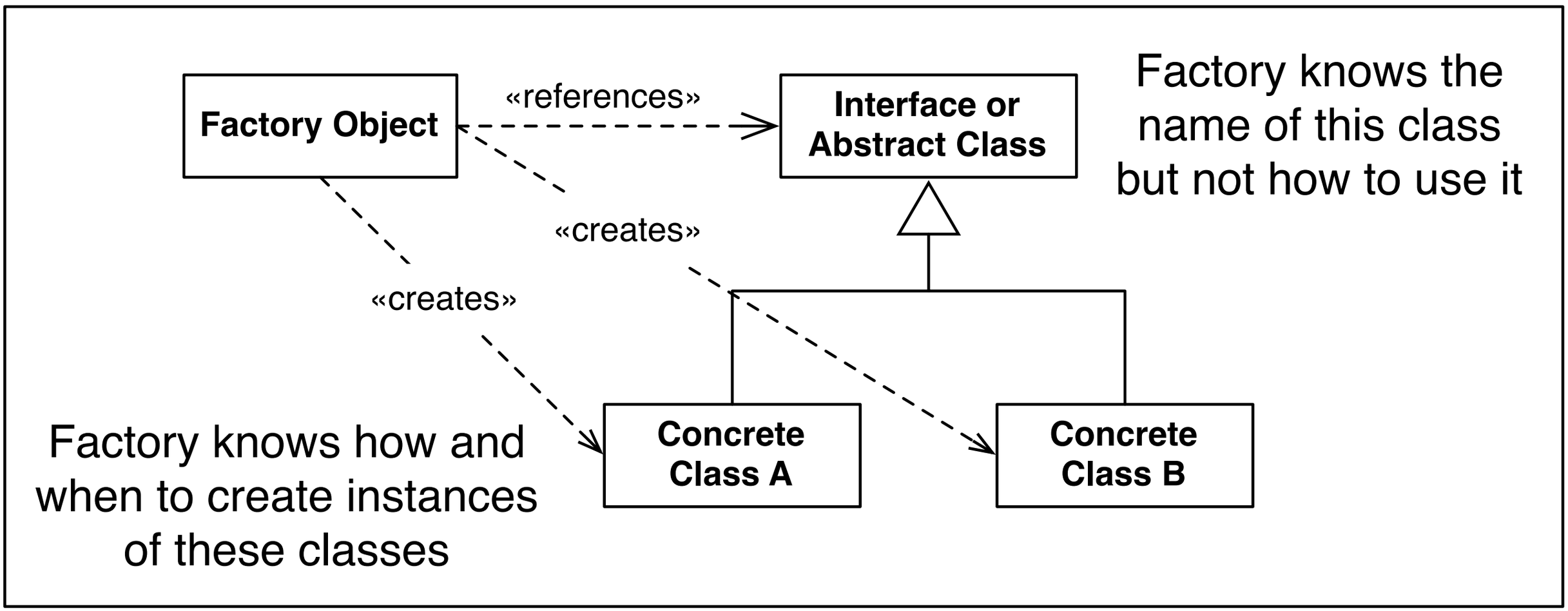
- But as a guideline, the rule is useful
  - Look for ways to separate out the creation of objects from the code that makes use of those objects
    - encapsulate the creation process and you can change it as needed without impacting the code that then uses those objects
  - The book demonstrates the advantages of the rule with the following two diagrams

The perspective of a client object



The client is completely shielded from the concrete classes and only changes if the abstract interface changes

The perspective of a factory object



The factory knows nothing about how to use the abstract interface; it just creates the objects that implement it

Factories help to limit change

- If a change request relates to the creation of an object, the change will likely occur in a factory
    - all client code will remain unaffected
- If a change request does not relate to the creation of objects, the change will likely occur in the use of an object or the features it provides
    - your factories can be ignored as you work to implement the change

Abstract Factory and Factory Method

- We've already seen several factory pattern examples
  - **Factory Method**: Pizza and Pizza Store example
    - Have client code use an abstract method that returns a needed instance of an interface
    - Have a subclass implementation determine the concrete implementation that is returned
- **Abstract Factory**: Pizza Ingredients Example
  - Pattern that creates groups of related objects

Singleton Pattern

- Used to ensure that only one instance of a particular class ever gets created and that there is just one (global) way to gain access to that instance
- Let's derive this pattern by starting with a class that has no restrictions on who can create it

Deriving Singleton (I)

- `public class Ball {`
  - `private String color;`
  - `public Ball(String color) { this.color = color; }`
  - `public void bounce() { System.out.println(“boing!”); }`
- `}`
- `Ball b1 = new Ball(“red”);`
- `Ball b2 = new Ball(“green”);`
- `b1.bounce();`
- `b2.bounce();`

Problem: Universal Instantiation

- As long as a client object “knows about” the name of the class Ball, it can create instances of Ball
  - `Ball b1 = new Ball(“orange”);`
- This is because the constructor is public.
  - We can stop unauthorized creation of Ball instances by making the constructor private

Deriving Singleton (II)

```
• public class Ball {
    • private String color;
    • private Ball(String color) { this.color = color; }
    • public void bounce() { System.out.println(“boing!”); }
• }
• // next line now impossible by any method outside of Ball
• Ball b2 = new Ball(“red”);
```

Problem: No Point of Access!

- Now that the constructor is private, no class can gain access to instances of Ball
    - But our requirements were that there would be **at least one way** to get access to an instance of Ball
- We need a method to return an instance of Ball
    - But since there is no way to get access to an instance of Ball, the method can **NOT** be an *instance method*
        - This means it needs to be a *class method*, aka a static method

Deriving Singleton (III)

```
• public class Ball {
    • private String color;
    • private Ball(String color) { this.color = color; }
    • public void bounce() { System.out.println("boing!"); }
    • public static Ball getInstance(String color) {
        • return new Ball(color);
    • }
• }
```

Problem: Back to Universal Instantiation

- We are back to the problem where any client can create an instance of Ball; instead of saying this:
  - `Ball b1 = new Ball(“blue”);`
- they just say
  - `Ball b1 = Ball.getInstance(“blue”);`
- Need to ensure only one instance is ever created
  - Need a static variable to store that instance
    - No instance variables are available in static methods

Deriving Singleton (IV)

```
• public class Ball {
    • private static Ball ball;
    • private String color;
    • private Ball(String color) { this.color = color; }
    • public void bounce() { System.out.println(“boing!”); }
    • public static Ball getInstance(String color) {
        • return ball;
    • }
• }
```

Problem: No instance!

- Now the getInstance() method returns null each time it is called
  - Need to check the static variable to see if it is null
    - If so, create an instance
  - Otherwise return the single instance

Deriving Singleton (V)

```
• public class Ball {
    • private static Ball ball;
    • private String color;
    • private Ball(String color) { this.color = color; }
    • public void bounce() { System.out.println(“boing!”); }
    • public static Ball getInstance(String color) {
        • if (ball == null) { ball = new Ball(color); }
        • return ball;
    • }
• }
```

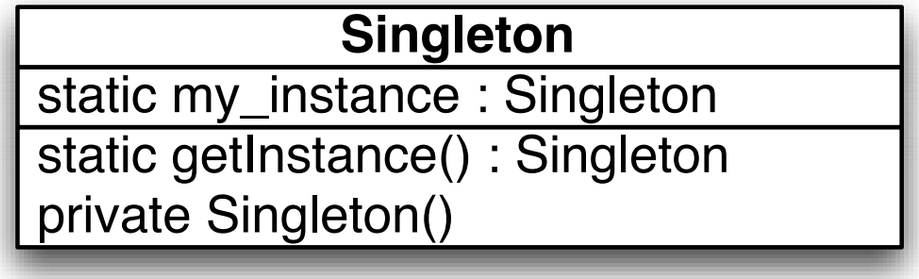
Problem: First Parameter Wins

- The code on the previous slide shows the Singleton pattern
  - private constructor
  - private static instance variable to store the single instance
  - public static method to gain access to that instance
    - this method creates object if needed; returns it
- But this code ignores the fact that a parameter is being passed in; so if a “red” ball is created all subsequent requests for a “green” ball are ignored

Solution: Use a Map

- The solution to the final problem is to change the private static instance variable to a Map
  - `private Map<String, Ball> toybox = new HashMap…`
- Then check if the map contains an instance for a given value of the parameter
  - this ensures that only one ball of a given color is ever created
  - this is an acceptable variation of the Singleton pattern
    - indeed, it is VERY similar to the Flyweight pattern
- **DEMO**

Singleton Pattern: Structure



Singleton involves only a single class (not typically called Singleton). That class is a full-fledged class with other attributes and methods (not shown)

The class has a static variable that points at a single instance of the class.

The class has a private constructor (to prevent other code from instantiating the class) and a static method that provides access to the single instance

World's Smallest Java-based Singleton Class

```
1  public class Singleton {
2
3          private static Singleton uniqueInstance;
4
5          private Singleton() {}
6
7          public static Singleton getInstance() {
8                  if (uniqueInstance == null) {
9                          uniqueInstance = new Singleton();
10                 }
11                 return uniqueInstance;
12         }
13 }
14
```

Meets Requirements: static var, static method, private constructor

Thread Safe?

- The Java code just shown is not thread safe
  - This means that it is possible for two threads to attempt to create the singleton for the first time simultaneously
  - If both threads check to see if the static variable is empty at the same time, they will both proceed to creating an instance and you will end up with two instances of the singleton object (not good!)
  - Example Next Slide

Program to Test Thread Safety

```
1  public class Creator implements Runnable {
2
3      private int id;
4
5      public Creator(int id) {
6          this.id = id;
7      }
8
9      public void run() {
10         try {
11             Thread.sleep(200L);
12         } catch (Exception e) {
13         }
14         Singleton s = Singleton.getInstance();
15         System.out.println("s" + id + " = " + s);
16     }
17
18     public static void main(String[] args) {
19         Thread[] creators = new Thread[10];
20         for (int i = 0; i < 10; i++) {
21             creators[i] = new Thread(new Creator(i));
22         }
23         for (int i = 0; i < 10; i++) {
24             creators[i].start();
25         }
26     }
27
28 }
29
```

Creates a “runnable” object that can be assigned to a thread.

When its run, its sleeps for a short time, gets an instance of the Singleton, and prints out its object id.

The main routine, creates ten runnable objects, assigns them to ten threads and starts each of the threads

Output for Non Thread-Safe Singleton Code

- s9 = Singleton@45d068
- s8 = Singleton@45d068
- s3 = Singleton@45d068
- s6 = Singleton@45d068
- s1 = Singleton@45d068
- s0 = Singleton@ab50cd
- s5 = Singleton@45d068
- s4 = Singleton@45d068
- s7 = Singleton@45d068

Whoops!

Thread 0 created an instance of the Singleton class at memory location ab50cd at the same time that another thread (we don't know which one) created an additional instance of Singleton at memory location 45d068!

How to Fix?

```
1  public class Singleton {
2
3          private static Singleton uniqueInstance;
4
5          private Singleton() {}
6
7          public static synchronized Singleton getInstance() {
8                  if (uniqueInstance == null) {
9                          uniqueInstance = new Singleton();
10                 }
11                 return uniqueInstance;
12         }
13
14 }
15
```

In Java, the **easiest** fix is to add the **synchronized** keyword to the getInstance() method.

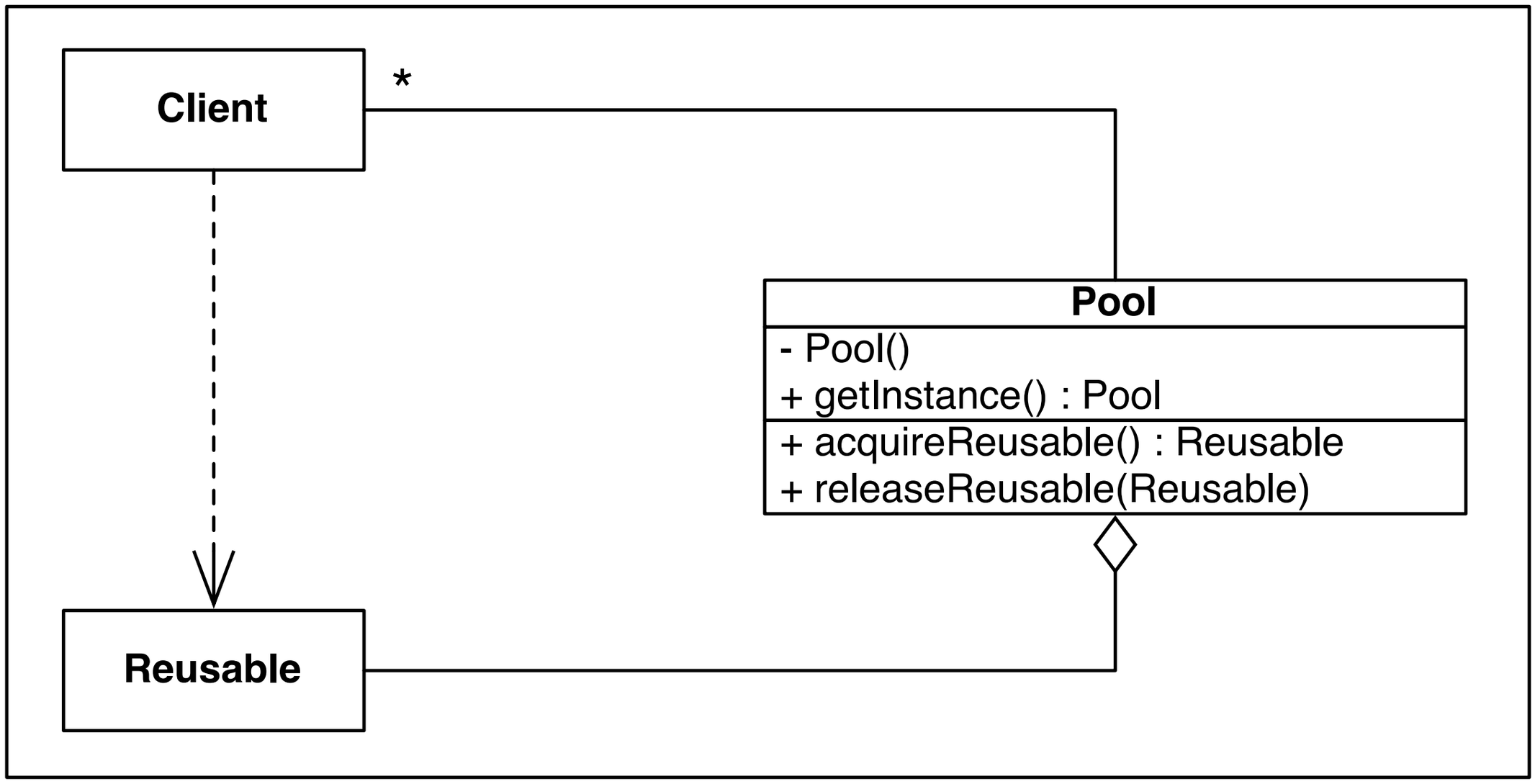
Objective-C Singleton

- Add a class method to your class that looks like this
  - `+ (MyClass *)sharedInstance {`
  - `    static MyClass *sharedInstance = nil;`
  - `    static dispatch_once_t onceToken;`
  - `    dispatch_once(&onceToken, ^{`
  - `        sharedInstance = [[MyClass alloc] init];`
  - `        // Do any other initialisation stuff here`
  - `    });`
  - `    return sharedInstance;`
  - `}`
- Make calling code use sharedInstance by convention

Object Pool

- A variant of the Singleton Pattern is known as the Object Pool pattern
  - This allows some instances (x) of an object to be created up to some maximum number (m)
    - where $1 < x \leq m$
  - In this case, each instance provides a reusable service (typically tied to system resources such as network connections, printers, etc.) and clients don’t care which instance they receive

Object Pool Structure Diagram



Common Use: Thread Pool

- One place in which the Object Pool pattern is used frequently is in multithreaded applications
  - where each thread is a “computation resource” that can be used to execute one or more tasks associated with the system
  - when a task needs to be done, a thread is pulled out of the pool and assigned the task; it executes the task and is then released back to the pool to (eventually) work on other tasks

Examples (1)

- First, a “homegrown” example
  - ThreadPool implemented as a blocking queue of Thread subclasses called Processors
  - Goal is to calculate the number of primes between 1 and 20M (20,000,000).
  - Producer creates tasks to calculate primes between a subset of numbers, say 1 to 250,000; 250,001 to …
  - Processor calculates in separate thread
  - Consumer joins with Processors and merges the results

Examples (2)

- An example that makes use of a thread pool provided by the Java Concurrency API (example taken from this excellent book)
  - The class that implements the object pool pattern is known as an ExecutorService
    - You pass it instances of a class called Callable
    - It returns instances of a class called Future
      - You hold onto the Future object while Callable executes in the background (using threads managed by the Executor Service)
        - then retrieve Callable's result from the Future object

Builder (I)

- We encountered the Builder pattern earlier this semester during our Android lectures
  - There are so many ways that an AlertDialog can be customized
    - that Android offers a class called AlertDialog.Builder
    - that makes the customization process easier

Builder (II)

- Here's an example of using AlertDialog.Builder
  - `AlertDialog.Builder builder = new AlertDialog.Builder(this);`
  - `builder.setMessage("Do you want to cancel the download?").setTitle("Cancel Download?");`
  - `builder.setNegativeButton("No!", ...);`
  - `builder.setPositiveButton("YES!", ...);`
  - `return builder.create();`

Note the ability to chain calls to builder; each method on builder simply returns the builder object

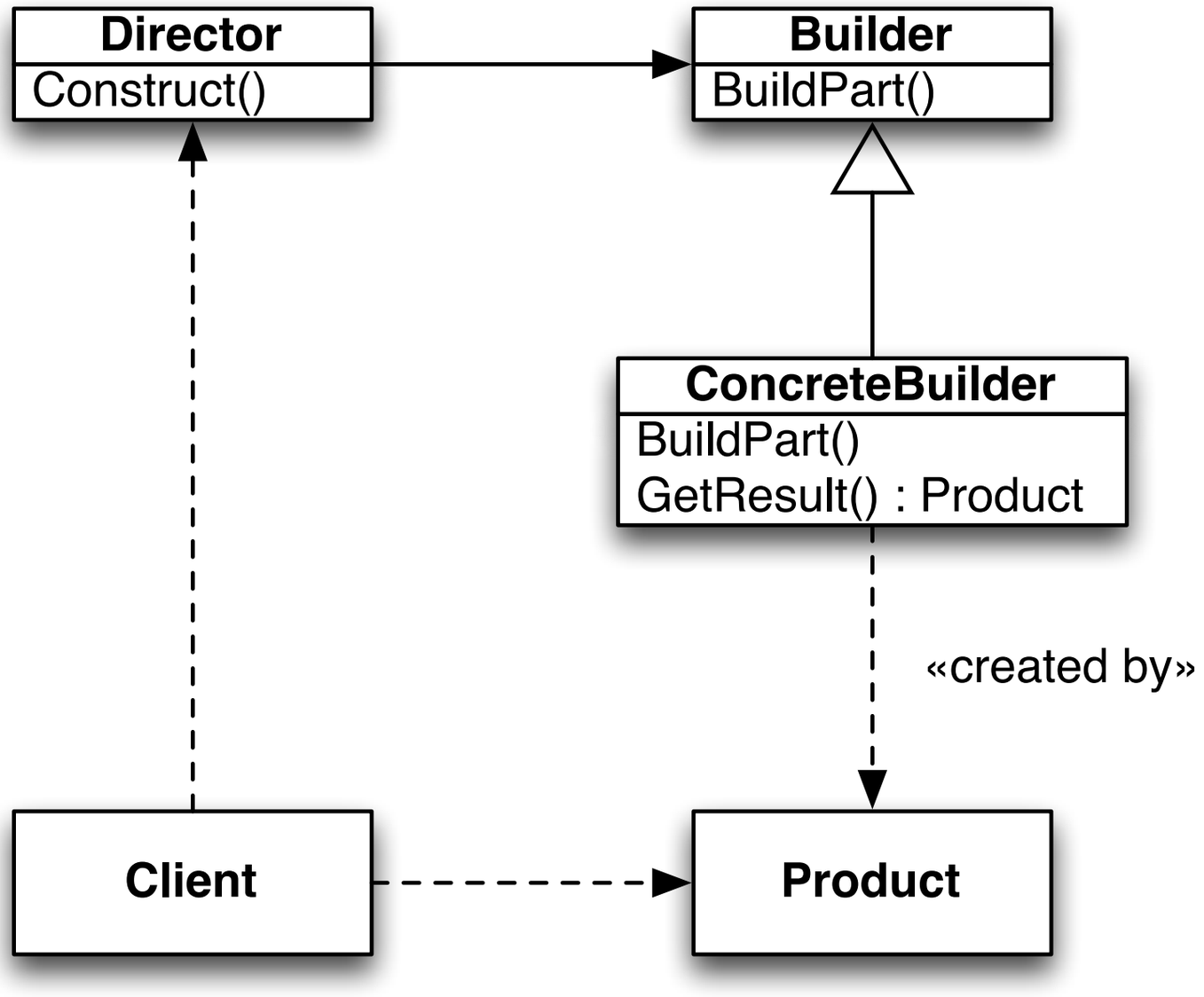
- The **create()** method returns an instance of AlertDialog configured to match the results of the calls on the builder object
  - As you can see, this pattern can greatly simplify the creation/configuration process of complex objects

Builder (III)

- The Builder pattern comes from the Gang of Four book
- It’s intent is
  - Separate the construction of a complex object from its representation so that the same construction process can create different representations
- Use the Builder pattern when
  - the algorithm for creating a complex object should be independent of the parts that make up the object and how they’re assembled
  - the construction process must allow different representations for the object that’s constructed

Builder (IV)

- The structure diagram for Builder identifies the following abstract roles



A Director interacts with a Builder to guide the creation of a Product. The Client creates the Director and a specific Builder and then asks the Director to create the Product. The Client retrieves the Product directly from the ConcreteBuilder

Builder (V)

- How does this map back to the Android example?
  - AlertDialog.Builder is a ConcreteBuilder used to create/configure instances of AlertDialog (the Product)
  - Our Main activity played the roles of Client and Director
    - It created an instance of the Builder (Client responsibility)
    - It configured the Builder (Director responsibility)
    - It retrieved and used the Product (Client responsibility)
- This emphasizes the point I've been making for most of the semester
  - **Design Patterns outline the shape of a solution; they can be implemented in multiple ways**

Lazy Instantiation (I)

- Lazy Instantiation is NOT a design pattern
    - but rather a software engineering best practice
        - especially in the context of mobile apps running with limited memory
- The best practice can be summarized as:
    - always access instance variables via their getter method
    - never instantiate an instance variable until it is accessed

Lazy Instantiation (II)

- To implement, your calling code would look like this
  - `myObject.getEmployees().append(new Employee());`
- Your getter method would look similar to
  - `public List getEmployees() {`
    - `if (_employees == null) {`
      - `_employees = new LinkedList<Employee>();`
    - `}`
    - `return _employees;`
  - `}`

Lazy Instantiation (III)

- Lazy Instantiation can be used in all programming languages
  - It shouldn't be applied blindly however
    - Use it when your dealing with a class that might have thousands of instances at run-time but not all of the instances are guaranteed to be accessed
      - Such a situation might occur when searching a large number of objects
- Don't use it on classes that have only a handful of instances generated each time the program is run and all of those instances are guaranteed to be used each time

Wrapping Up

- Looked at
  - the use of Factories in OO Design
  - the Singleton and Object Pool Design Patterns
    - saw example of thread-safe singletons
    - saw use of thread pools in java.util.concurrent
  - the Builder Design Pattern
  - the concept of Lazy Instantiation to minimize the amount of memory allocated at run-time

Coming Up Next

- Lecture 27: Patterns of Patterns; Textbook Wrap-Up
- Lectures 28, 29, 30: Some combination of
    - Refactoring; Test Driven Design
    - Dependency Injection
    - Object-Relational Mapping