SWEN20003
Object Oriented Software Development

Design Patterns

Semester 1, 2019

The Road So Far

- Java Foundations
- Object Oriented Principles
  - Encapsulation
  - Information Hiding (Privacy)
  - Inheritance and Polymorphsm
  - Abstract Classes
  - Interfaces
- Modelling classes and relationships
- Advanced Java
  - Generics
  - Exceptions

Lecture Objectives

After this lecture you will be able to:

- Describe what **design patterns** are, and why they are useful
- Analyse and understand **design pattern specifications**
- Make use of (some) design patterns

Software Design

Are you already a good software designer?

If not, how do you become a good software designer?

Follow three simple steps...

How to become a good software designer

Step 1: Learn the fundamentals of programming

- Programming Languages
- Algorithms and Data Structures

Step 2: Learn design paradigms and principles

- Structured Design
- Object Oriented Design

Step 3: Study and mimic the designs of experienced designers

- Good designers reuse solutions - they do not design everything from scratch
- **Design Patterns** systematically document re-occurring design solutions so that they can be reused

Design Patterns

A Software *Design Pattern* is a description of a solution to a recurring problem in software design.

The recurring nature of the problems makes the solution useful to software developers.

Publishing it in the form of a Pattern enables the solution to be used without reinventing the wheel.

Pioneering work on design patterns was done by Eric Gamma and the team who authored the classic book on design patterns (Gang of Four):

Analysing and Publishing a Pattern

Intent	The goal of the pattern, why it exists
Motivation	A scenario that highlights a need for the pattern
Applicability	General situations where you can use the pattern
Structure	Graphical representations of the pattern, likely a UML class diagram
Participants	List of classes/objects and their roles in the pattern
Collaboration	How the objects in the pattern interact
Consequences	A description of the results, side effects, and tradeoffs when using the pattern
Implementation	Example of "solving a problem" with the pattern
Known Uses	Specific, real-world examples of using the pattern

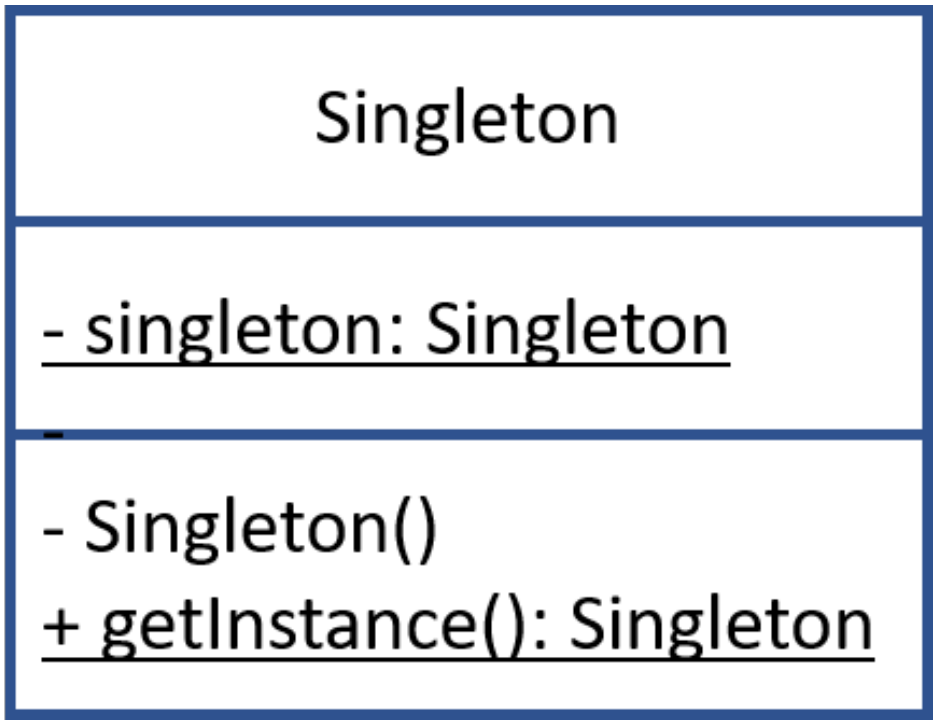
Design Patterns

Thousands of design patterns exist today.

Let us take a look as some common design patterns...

Singleton Pattern

Ensure that a class has only one instance and provide a global point of access to it.



Singleton Pattern - Implementation

```
class Singleton {
    private static Singleton _instance = null;
    private Singleton() {
        //fill in the blank
    }

    public static Singleton getInstance() {
        if (  _instance == null )
            _instance = new Singleton();
        return _instance;
    }

    public void otherOperations() {    }
}
```

Singleton Pattern - Collaboration

```
class TestSingleton {

    public void method1(){
        X = Singleton.getInstance();
    }


    public void method2(){
        Y = Singleton.getInstance();
    }

}
```

Singleton Pattern Analysis

Intent	Ensure that a class has only one instance and provide a global point of access to it.
Motivation	There are cases where only one instance of a class must be enforced with easy access to the object.
Applicability	Use when a single instance of a class is required.
Structure	See previous slides
Participants	Singleton class.
Collaboration	See previous slides.
Consequences	Use it with caution because inappropriate use could result in a bad design.
Implementation	See previous slides.
Known Uses	e.g. `CacheManager` class, `PrinterSpooler` class.

Template Method and Strategy Patterns

Building generic components that can be *extended*, *adapted* and *re-used* is key to good design.

The two main techniques that are used for developing generic components are *refactoring* and *generalizing*.

- identifying recurring code and replacing with generic code

Inheritance and *delegation* are the two main OO design techniques that are used for building generic components.

Template Method and Strategy Patterns

Template Method and *Strategy* are two design patterns that solve the problem of separating a generic algorithm from a detailed design.

Template Method pattern uses *Inheritance*.

Strategy pattern uses *Delegation*.

Template Method Pattern Motivation

```
public class BubbleSorter {
    static int operations = 0;
    public static int sort(int[] array){
        operations = 0;
        if (array.length <= 1)
            return operations;
        for (int i = array.length - 2; i >=0; i --){
            for (int j = 0; j <= i; j++){
                compareAndSwap(array, j);
            }
        }
        return operations;
    }
```

contd...

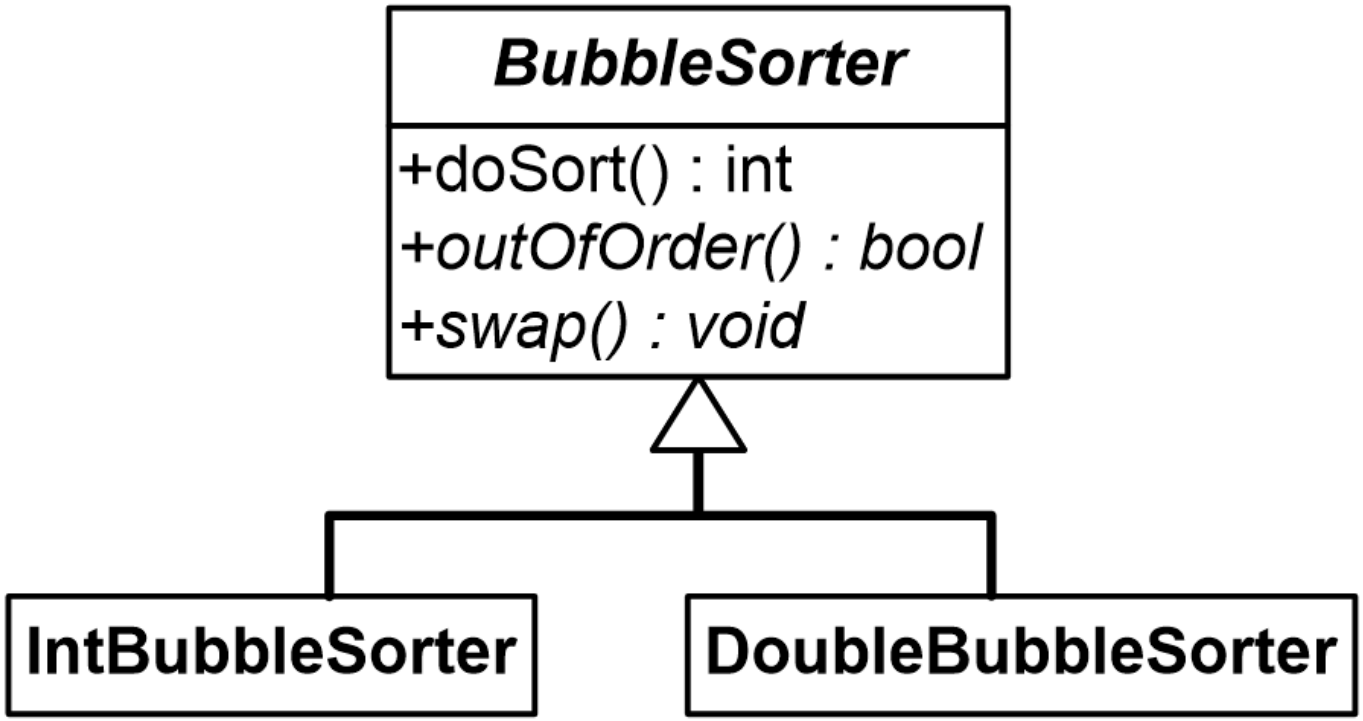
Template Method Pattern Motivation

```
    public static void compareAndSwap(int[] array, int index){
        if (array[index] > array[index+1])
            swap(array,index);
        operations++;
    }

    public static void swap(int[] array, int index){
        int temp = array[index];
        array[index] = array[index+1];
        array[index+1] = temp;
    }
}
```

Template Method Pattern Example

```
public abstract class AbstractBubbleSorter {
    private static int operations = 0;
    protected int length = 0;
    protected int doSort(){
        operations = 0;
        if (length <= 1)
            return operations;
        for (int i = length - 2; i >=0; i--){
            for (int j = 0; j <= i; j++){
                if (outOfOrder(j))
                    swap(j);
                operations++;
            }
        }
        return operations;
    }
    protected abstract void swap(int index);
    protected abstract boolean outOfOrder(int index);
}
```

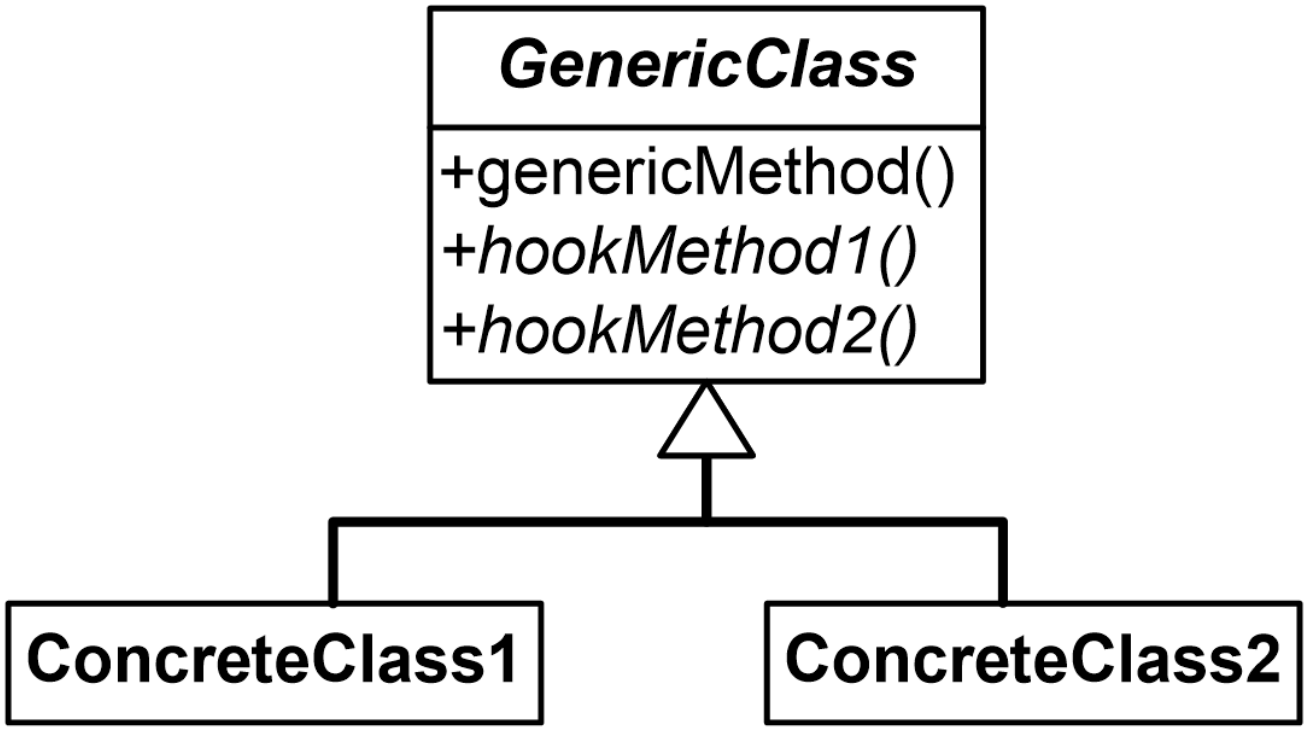
Template Method Pattern Example



Template Method Pattern Example

```
public class IntBubbleSorter extends AbstractBubbleSorter {
    private int[] array = null;
    public int sort(int[] a){
        array = a;
        length = array.length;
        return doSort();
    }
    @Override
    protected boolean outOfOrder(int index) {
        return (array[index] > array[index+1]);
    }
    @Override
    protected void swap(int index) {
        int temp = array[index];
        array[index] = array[index+1];
        array[index+1] = temp;
    }
}
```

Template Method Pattern Structure



Template Method Pattern Analysis

Intent	Define a family of algorithms, encapsulate each one, and make them interchangeable.
Motivation	Build generic components that are easy to extend and reuse.
Applicability	Allows the implementation of invariant parts of an algorithm once and leave it to the subclass to implement the behavior that can vary.
Structure	See previous slides.
Participants	See previous slides.
Collaboration	See previous slides.
Consequences	All algorithms must use the same interface.
Implementation	See previous slides.
Known Uses	See previous slides.

Strategy Pattern

Template method is an example of using inheritance as a mechanism for re-use.

- Generic algorithm is placed in the base class
- Specific implementation is deferred to the sub class

The design tradeoff of using inheritance is the strong dependency to the base class.

- Although the methods outOfOrder and swap are generic methods they cannot be re-used because they inherit the AbstractBubbleSorter class

The Strategy pattern in an alternative.

Strategy Pattern Example

```
public class BubbleSorterS {

    static int operations = 0;
    private int length = 0;
    private SortHandle itsSortHandle = null;

    public BubbleSorterS(SortHandle handle){
        itsSortHandle = handle;
    }
```

Contd..

Strategy Pattern Example

```
    public int sort(Object array){
        itsSortHandle.setArray(array);
        length = itsSortHandle.length();
        operations = 0;
        if (length <= 1)
            return operations;

        for(int nextToLast = length - 2; nextToLast >=0;nextToLast--){
            for (int index=0; index <= nextToLast; index++){
                if (itsSortHandle.outOfOrder(index))
                    itsSortHandle.swap(index);
                operations++;
            }
        }
        return operations;
    }
}
```

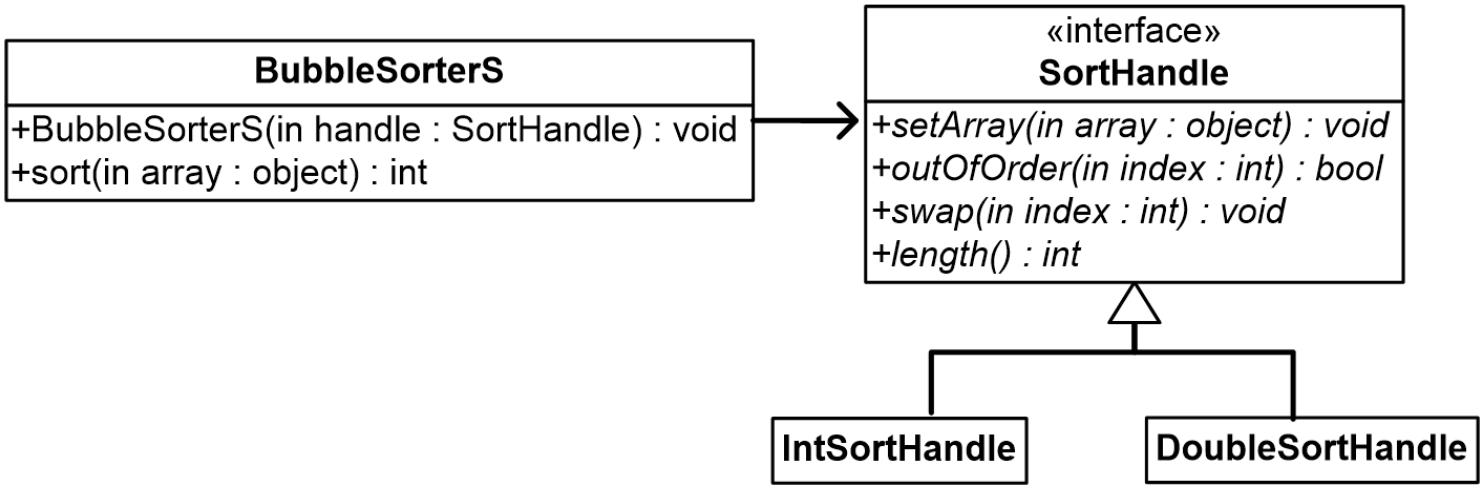
Strategy Pattern Example

```
public interface SortHandle {
    public void swap(int index);
    public boolean outOfOrder(int index);
    public int length();
    public void setArray(Object array);
}
```

Strategy Pattern Example

```
public class IntSortHandle implements SortHandle {
    private int[] array = null;

    public int length() {
        return array.length;
    }
    public boolean outOfOrder(int index) {
        return (array[index] > array[index+1]);
    }
    public void setArray(Object array) {
        this.array = (int [])array;
    }
    public void swap(int index) {
        int temp = array[index];
        array[index] = array[index + 1];
        array[index + 1] = temp;
    }
}
```

Strategy Pattern Example



Strategy Pattern Example

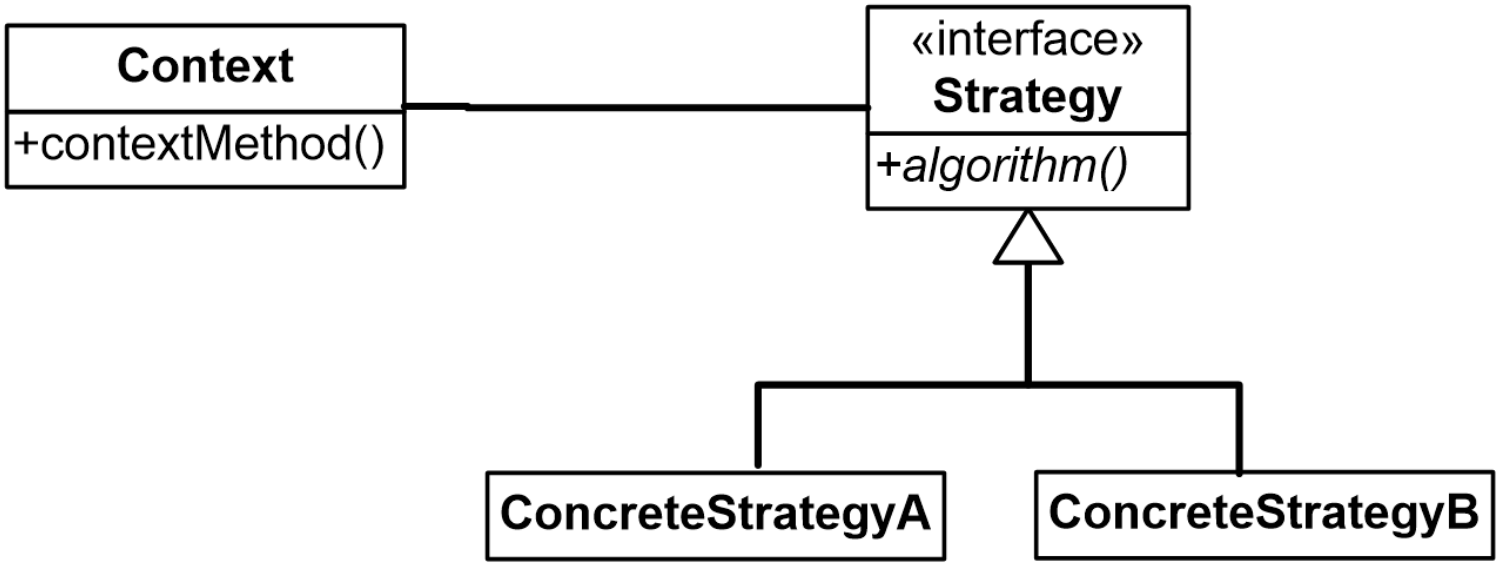
```
public class QuickBubbleSorterS {
    static int operations = 0;
    private int length = 0;
    private SortHandle itsSortHandle = null;

    public QuickBubbleSorterS(SortHandle handle){
        itsSortHandle = handle;
    }

    public int sort(Object array){
        itsSortHandle.setArray(array);
        length = itsSortHandle.length();
        operations = 0;
```

Contd...

Strategy Pattern Analysis

```
        if (length <= 1)
            return operations;
        boolean thisPassInOrder = false;
        for(int nextToLast = length - 2; nextToLast >=0 &&
                !thisPassInOrder; nextToLast--){
            thisPassInOrder = true;
            for (int index=0; index <= nextToLast; index++){
                if (itsSortHandle.outOfOrder(index)){
                    itsSortHandle.swap(index);
                    thisPassInOrder = false;
                }
                operations++;
            }
        }
        return operations;
    }
}
```

Strategy Pattern Structure



Factory Method Pattern

Creating objects in the class that requires (uses) the objects is inflexible.

- It commits the class to a particular object
- Makes it impossible to change the instantiation without having to change the class.

Factory Method pattern solves this problem by:

- Defining a separate operation for creating an object.
- Creating an object by calling a factory method.

Factory Method Pattern

Keyword

Factory: A *general* technique for *manufacturing* (creating) objects.

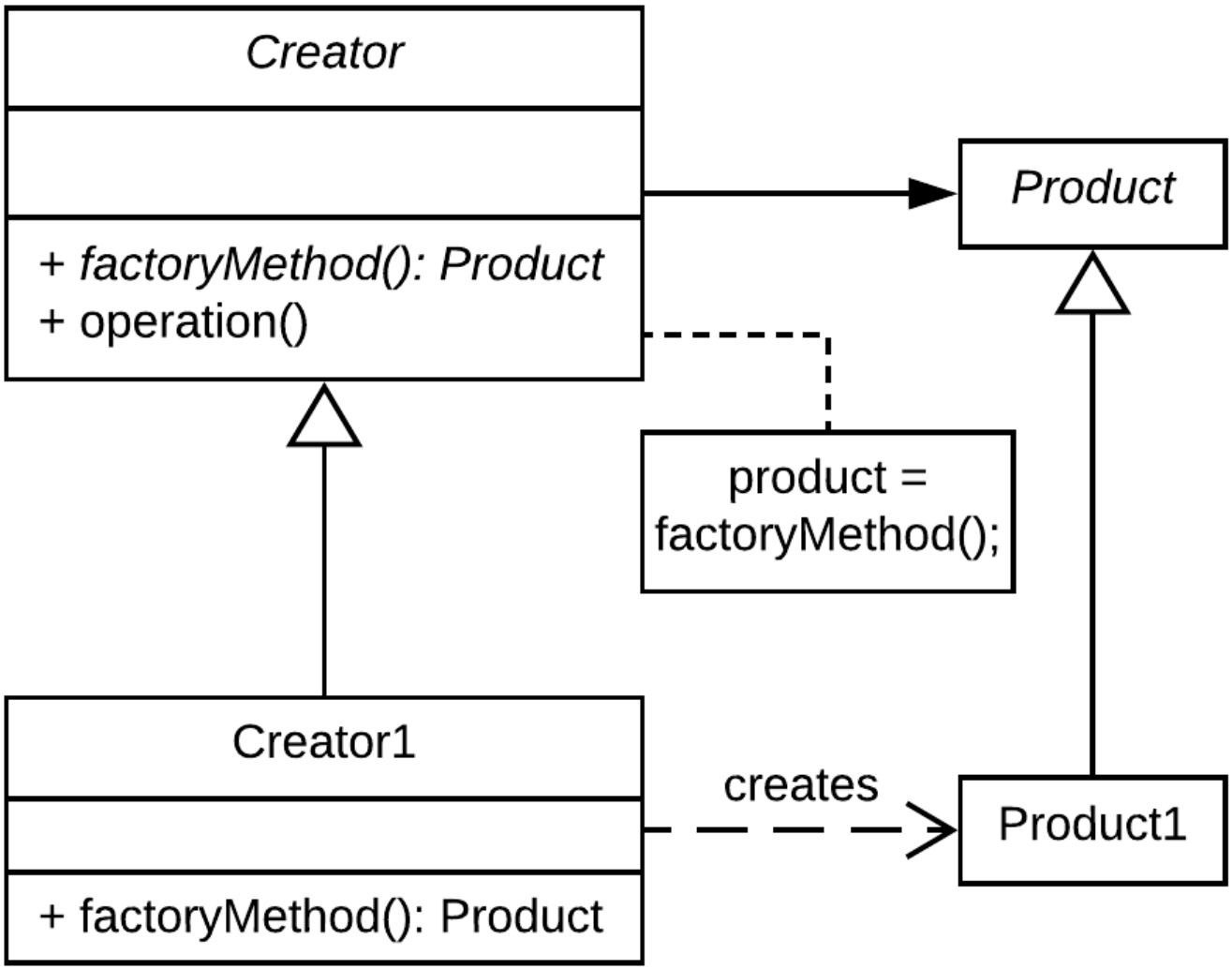
Keyword

Product: An abstract class that generalises the objects *being created/produced* by the factory.

Keyword

Creator: An abstract class that generalises the objects that *will consume/produce* products; generally have some *operation* (e.g. the constructor) that will invoke the factory method.

Factory Method Pattern Structure



Factory Method Pattern Motivation

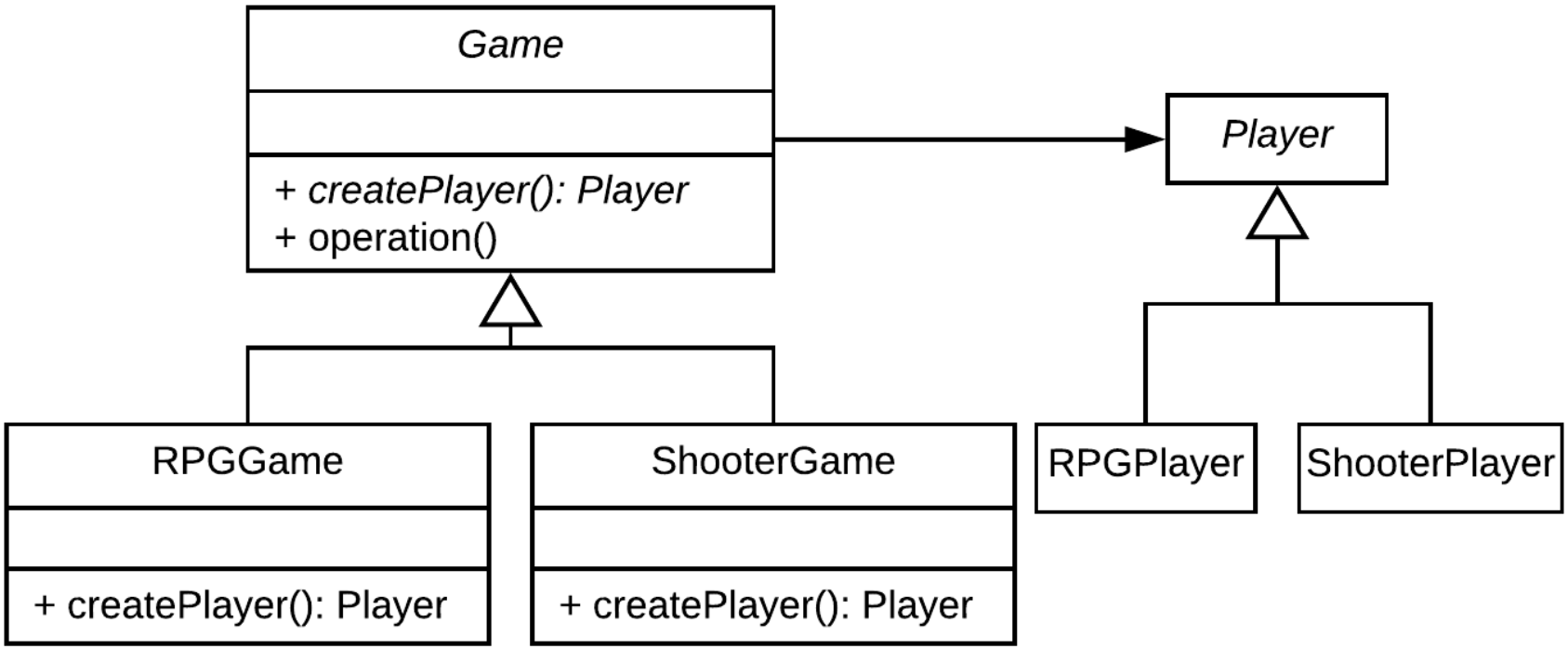
But... What's wrong with how we'd normally do this?

- Can cause significant *code duplication*
- May require *inaccessible* information
- Not very well *abstracted*
- "Figuring out" which object to instantiate is not a primary concern for most classes
- Can make classes very *rigid* and *fragile*

Advantages of the Factory Method Pattern:

- *Delegates* object creation (and the decision process) to subclasses
- *Abstracts* object creation by using a factory (object production) method
- *Encapsulates* objects by allowing *subclasses* to determine what they need

Factory Method Pattern Example



Factory Method Pattern Example

```
public abstract class Game {
    private final List<Player> players = new ArrayList<>();

    public Game(int nPlayers) {
        for (int i = 0; i < nPlayers; i++) {
            players.add(createPlayer());
        }
    }

    public abstract Player createPlayer();
}
```

Factory Method Patter Example

```
public class RPGGame extends Game {
    @Override
    public Player createPlayer() {
        return new RPGPlayer();
    }
}

public class ShooterGame extends Game {
    @Override
    public Player createPlayer() {
        return new ShooterPlayer();
    }
}
```

```
RPGGame shadowQuest = new RPGGame();
ShooterGame callOfDuty = new ShooterGame();
```

Factory Method Pattern Analysis

Intent	To generalise object creation
Motivation	Loading player objects when a game loads
Applicability	When sister classes depend on (and create) similar objects
Structure	See previous slides
Participants	See previous slides
Collaboration	Concrete creator objects invoke the factory method in order to produce their desired product
Consequences	Object creation in the superclass is now *decoupled* from the specific object required
Implementation	See previous slides
Known Uses	See previous slides

Observer Pattern

There are situations where many objects (observers) depend on the state of one object (subject).

A single object managing a one-to-many dependency between objects is inflexible.

- It commits (tightly couples) the subject to particular dependent objects.
- Such tightly coupled objects are hard to implement, test and maintain.

Observer pattern decouples the subject and observers using a publish-subscribe style communication pattern.

Observer Pattern

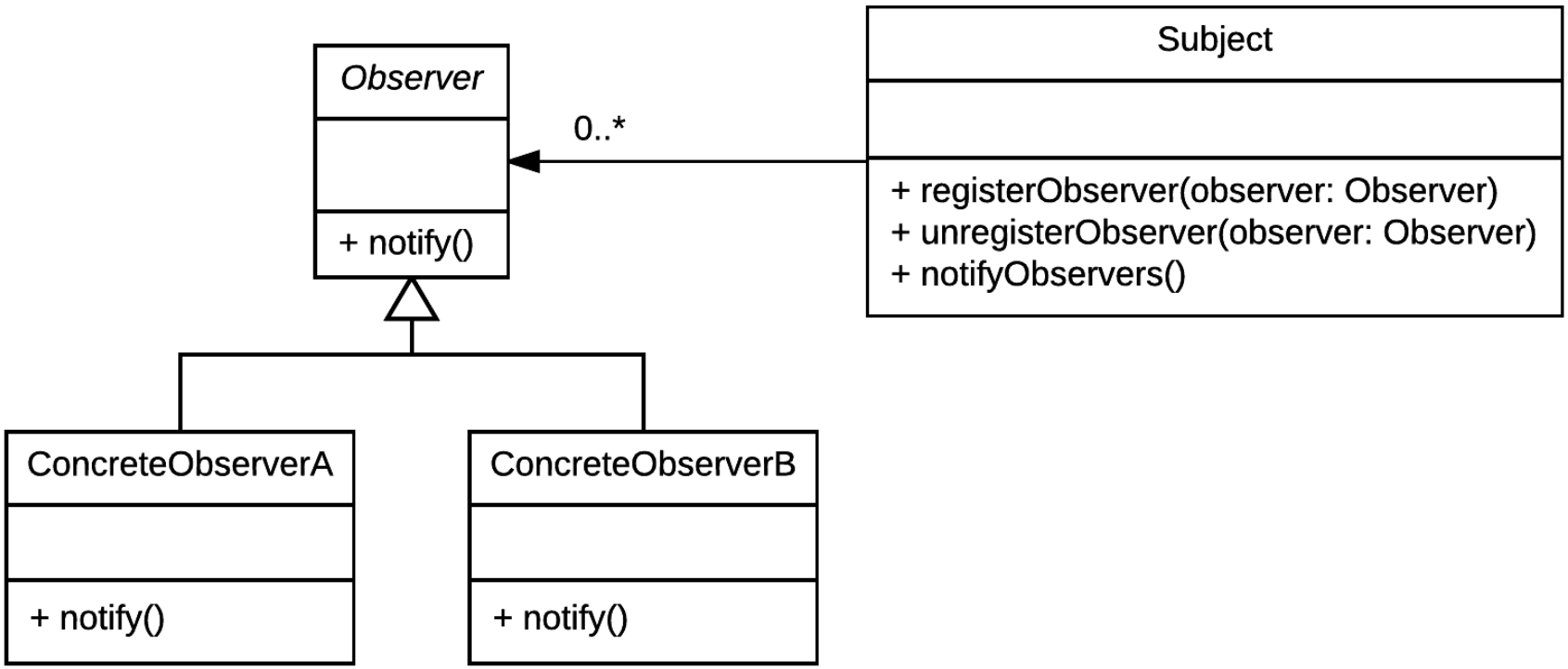
Keyword

Subject: An "important" object, whose state (or *change* in state) determines the actions of other classes.

Keyword

Observer: An object that monitors the subject in order to respond to its state, and any changes made to it.

Observer Pattern Structure

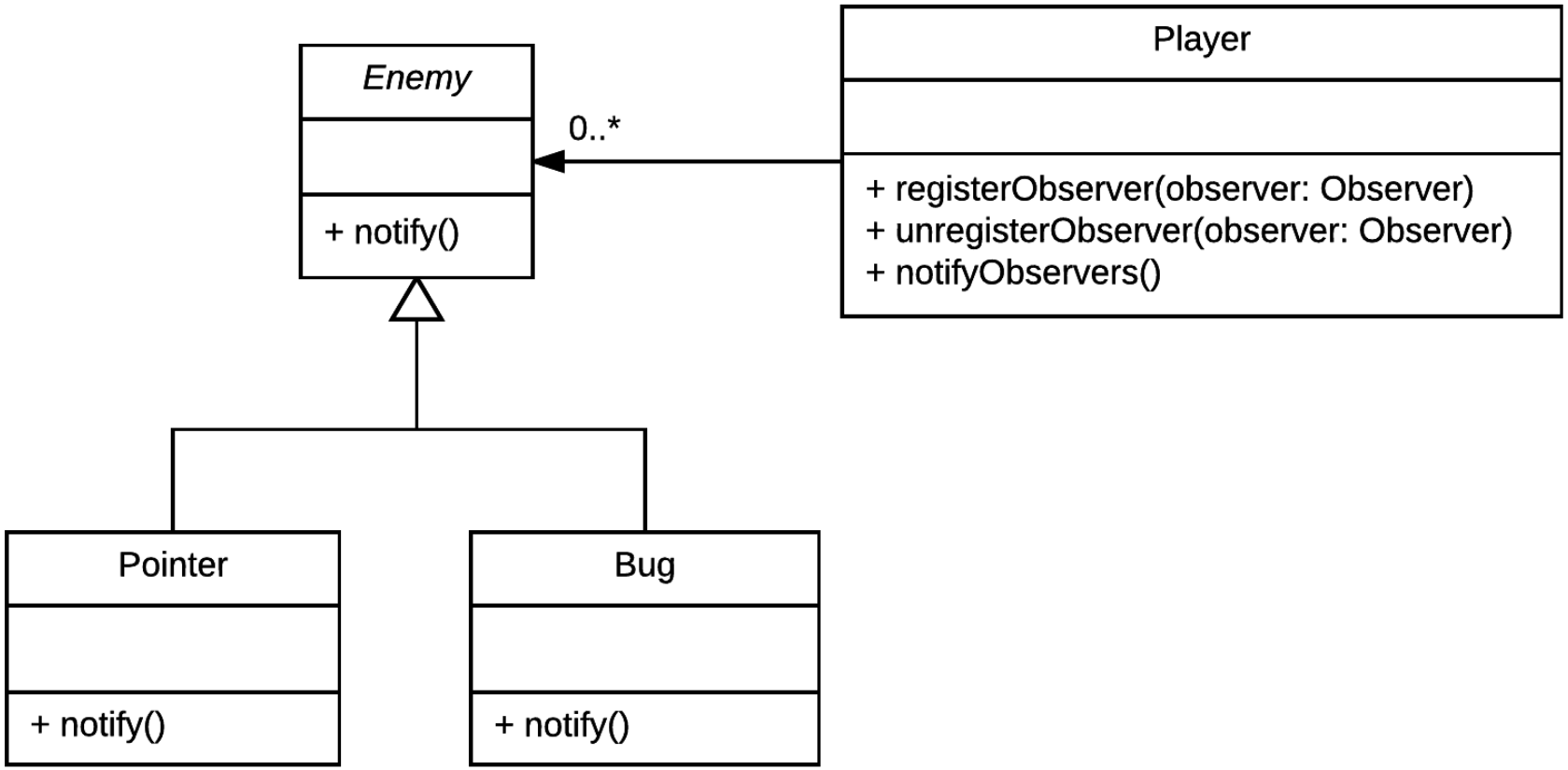


Observer Pattern

Why do we like this way better?

- Automatically notifies observers of *state changes*
- *Decouples* the subject and the observer
- With some extra tools, powers a great deal of *event-driven* programs
- Clear responsibilities: subjects (ideally) know nothing about the observers, except that they exist
- Observers can be added and removed from subjects at will, with zero effect (also known as the *publish-subscribe* model)
- Can be extended in various ways to improve messaging, decoupling, and event-handling

Observer Pattern Example



Note: this isn't actually a "Java-ready" design

Observer Pattern Example

```
import java.util.Observer;

public abstract class Enemy implements Observer {

    public abstract update(Observable o, Object arg);

}

public class Pointer extends Enemy {

    public update(Observable o, Object arg) {
        ...
    }

}

public class Bug extends Enemy {

    public update(Observable o, Object arg) {
        ...
    }

}
```

Observer Pattern Example

```
import java.util.Observable;

public class Player extends Observable {
    public Player(..., ArrayList<Observer> observers) {
        ...
        for (Observer o : observers) {
            this.addObserver(o);
        }
        notifyObservers("Player created");
    }
}
```

However, in most cases it makes more sense for `Subject` (or `Observable`) to be an interface, so we can write it ourself.

Design Patterns

Design Patterns: Elements of Reusable Object-Oriented Software, a book written by the *Gang of Four* (or GoF) describing 23 common software design patterns.

All good developers have *seen* most of the patterns, and have an understanding of what they do, and what common problems have already been solved.

Don't reinvent the wheel... You'll learn more about patterns in SWEN30006.

Design Patterns

Commonly solved *classes* of problems:

Creational Solutions related to object creation,
e.g. Singleton, Factory Method

Structural Solutions dealing with the structure of classes and their relationships,
e.g. Adapter, Bridge

Behavioural Solutions dealing with the interaction among classes,
e.g. Strategy, Template Method, Observer

Review

1. Identify where the patterns covered in the lecture can be applied to the project
2. Describe the advantages of using design patterns (in general)
3. Describe the core components (the analysis) of the patterns covered in the lecture

Lecture Objectives

You should be able to:

- Describe what **design patterns** are, and why they are useful
- Analyse and understand **design pattern specifications**
- Make use of (some) design patterns