# Design Patterns I

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# GoF Form of a Design Pattern

- The Pattern Name
  - Pattern name and classification, Intent, and Also-Known-As
- The Problem
  - Motivation, and Applicability
- The Solution
  - Structure (graphical), Participants (their classes/ objects/ responsibilities), Collaborations (of the participants), Implementation (hints, techniques), Sample code, Known uses, and Related patterns
- The Consequences
  - Consequences (trade-offs, concerns)

# Creational Patterns

- Concerns the process of object creation

- Will cover
  - Abstract Factory / Factory Method
  - Singleton
- Will not cover
  - Builder
  - Prototype

# Structural Patterns

- Deals with composition of classes or objects

- Will cover
  - Adapter
  - Façade
  - Composite
  - Decorator
  - Proxy
- Will not cover
  - Bridge
  - Flyweight

# Behavioral Patterns

- Characterizes the ways in which classes or objects interact and distribute responsibility

- Will cover
  - Visitor
  - Observer
  - Strategy
  - Command
  - Chain of Responsibility

- Will not cover
  - Interpreter
  - Iterator
  - Mediator
  - Memento
  - State
  - Template

# Observer Pattern

# Observer

- A key part of the MVC that we studied earlier
- *Intent*
  - Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically
- *Also Known As* – Dependents, Publish-Subscribe

# Non-Software Problem

- A professor wants to notify the secretary and the students every time there is a new exam
  - The secretary would then book the rooms
  - The students would (hopefully) prepare for the exam
- 1st pass: The prof knows who is interested, and call them directly

```
void setExam(...) {
  // let the secretary know
  mySecretary.bookRoom(...);

  // let the students know
  while (students.hasNext()) {
    Student s = (Student)students.next();
    s.study(...);
  }
}
```

# Non-Software Problem

- The prof needs to know about all the categories of people interested (the observers)
- What if a new person is interested?
  - What if a janitor needs to know room schedule?
- What if a given student is *not* interested?
- The prof needs to know what method to invoke on each interested party (e.g., study, clean, bookRoom)

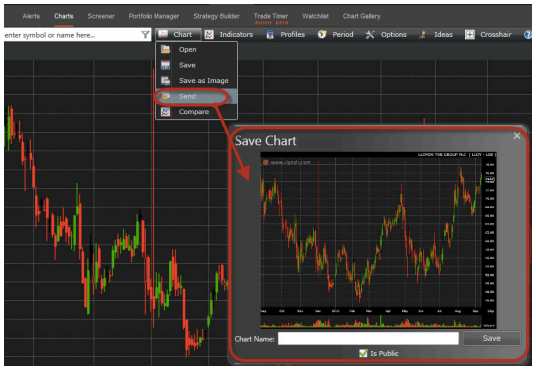
- We need a more generalized solution…

# Motivation

- We want to notify objects
  - Without having to know how many there are
  - Without having to know who they are
- In the previous example, we want to "decouple" the professor from the people who should be notified

# Stock Data Notification



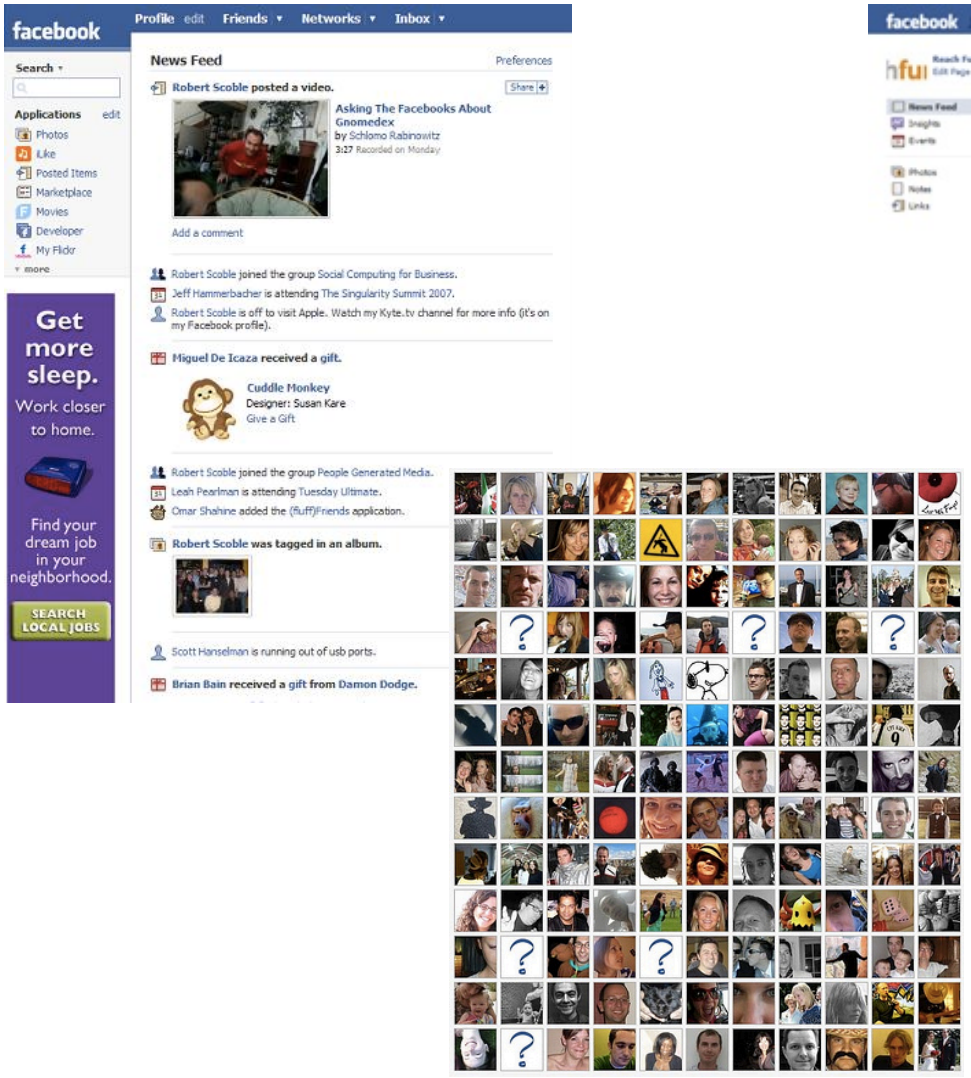


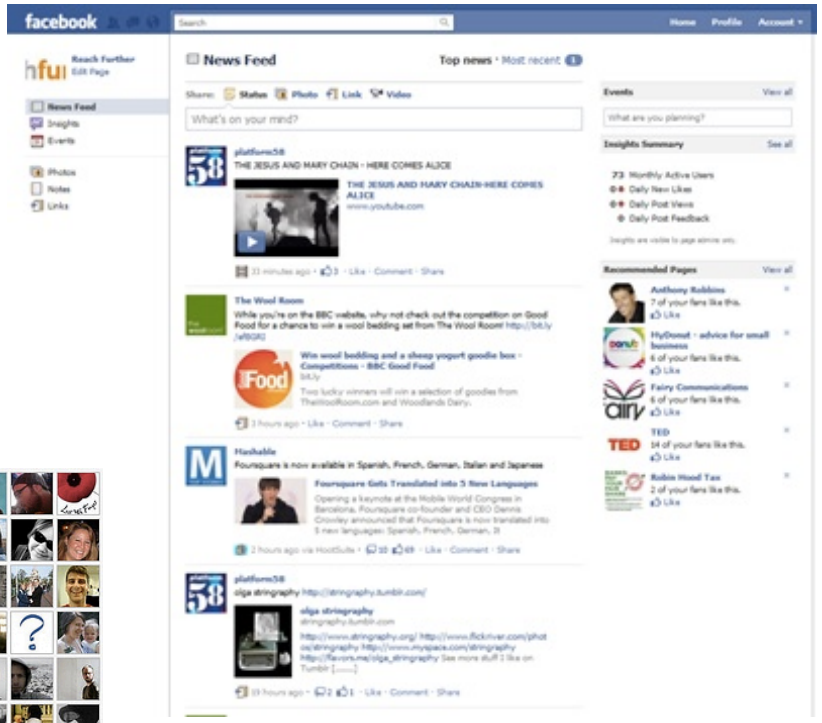


# Score Data Notification




# Social News Feed Update

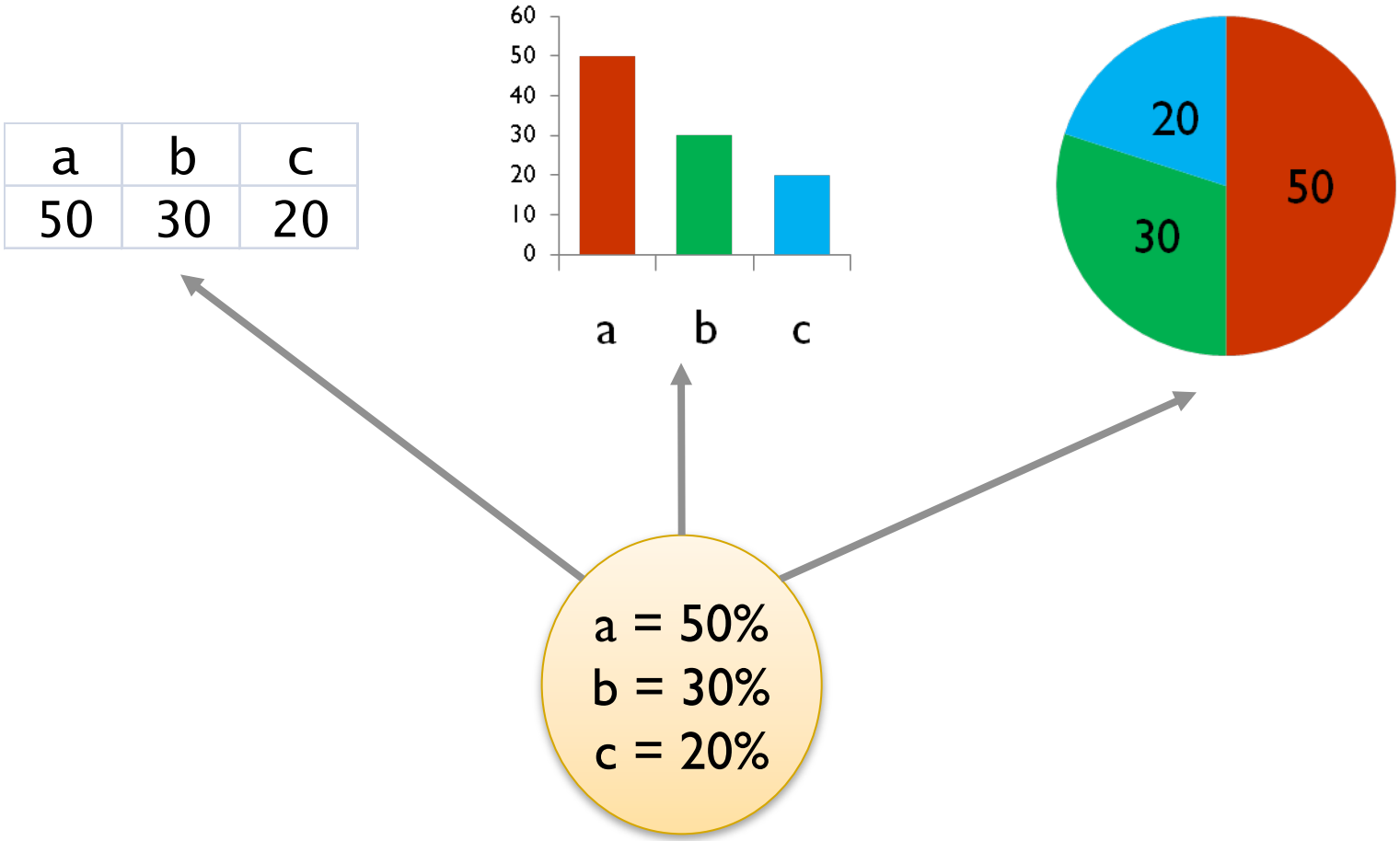


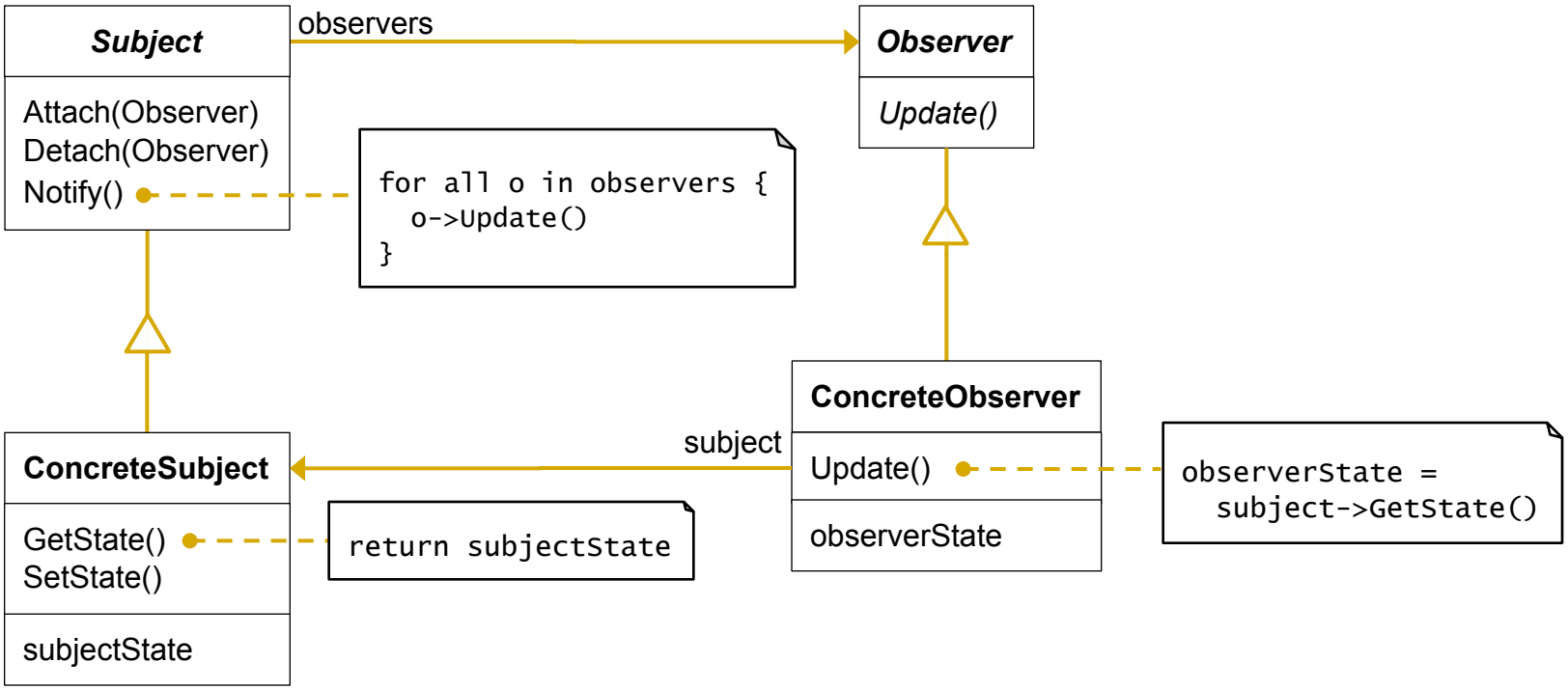
# Observer

- A *publish-subscribe* mechanism
  - A Subject (object being observed) maintains a list of observers
  - Observers get added to that list by subscribing to the subject
  - Observers implement a common interface (an `update()` method)
  - When a change occurs, the Subject iterates through the list of Observers and calls the `update()` method on them

# Model–View–Controller

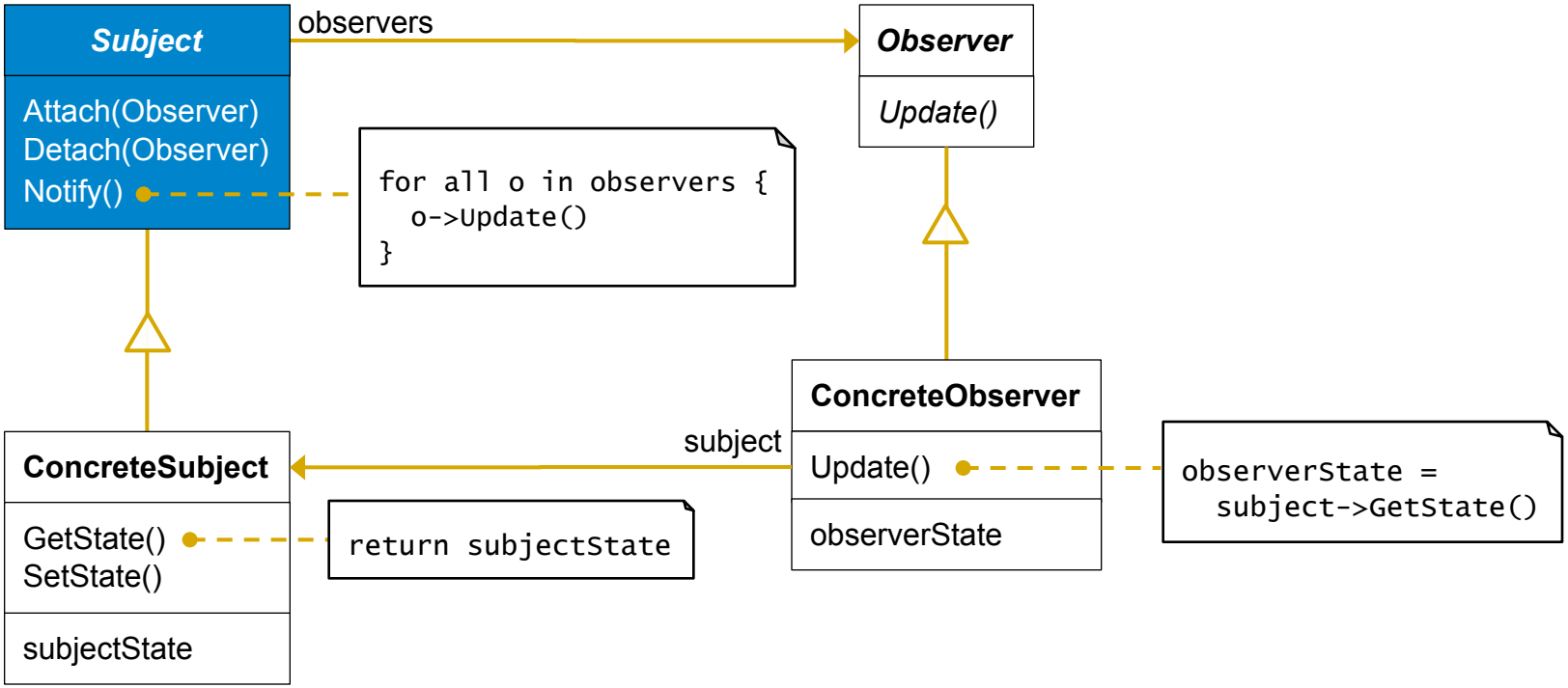


# Structure


Subject
observers
Observer
Attach(Observer)
Detach(Observer)
Notify()
Update()
for all o in observers {
o->Update()
}
ConcreteObserver
subject
ConcreteSubject
Update()
observerState =
subject->GetState()
GetState()
SetState()
return subjectState
observerState
subjectState

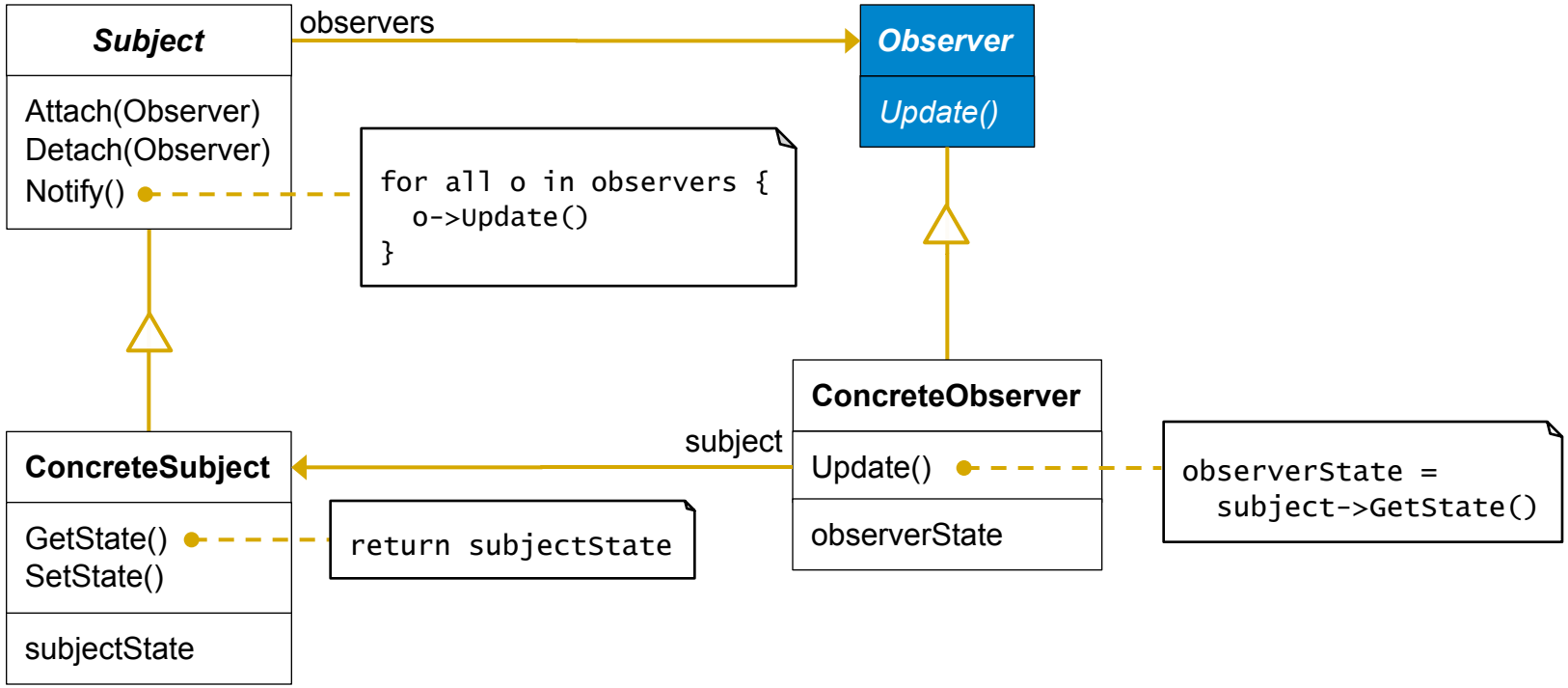
# Subject (similar to Model in MVC)

- Knows its observers. Any number of Observer objects may observe a Subject
- Provides an interface to add and remove Observer objects



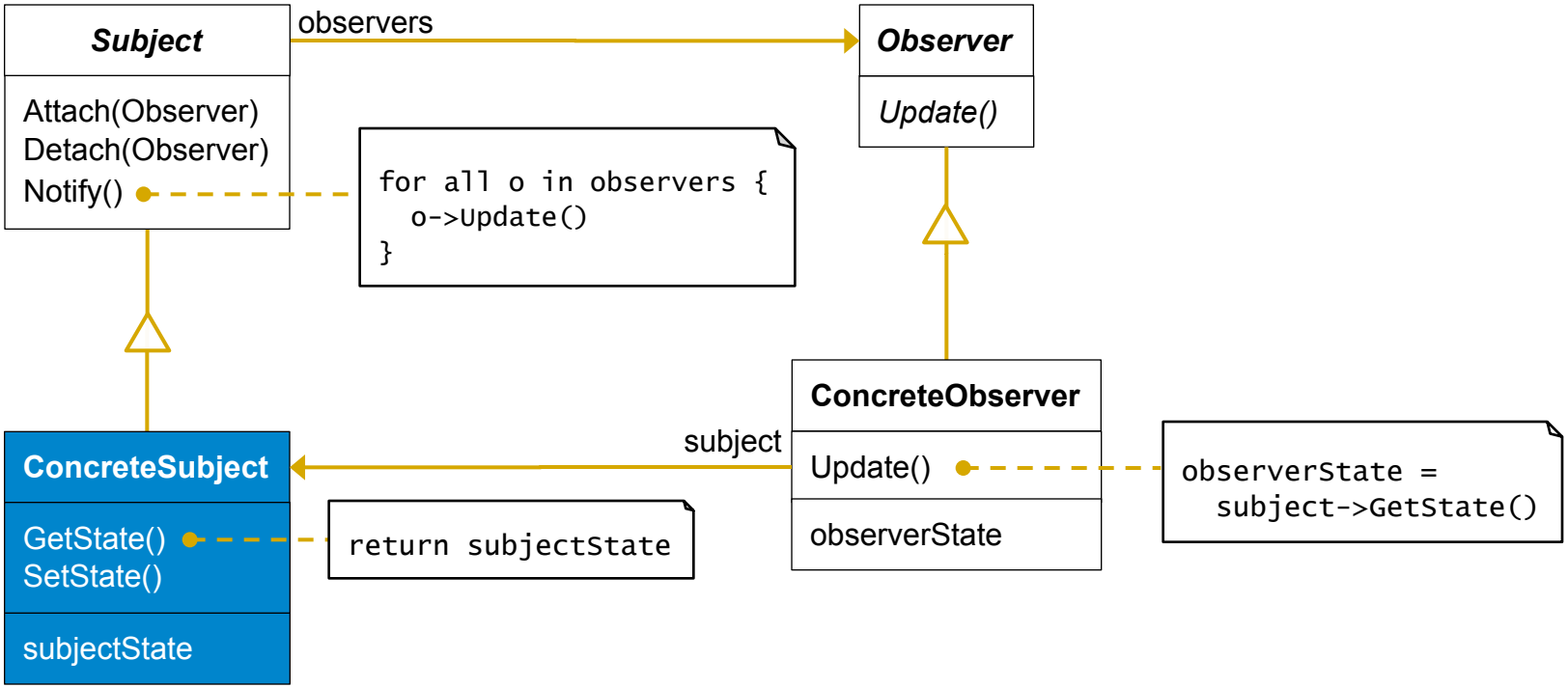
# Observer (similar to View in MVC)

- Defines an updating interface for objects that should be notified of changes in a Subject



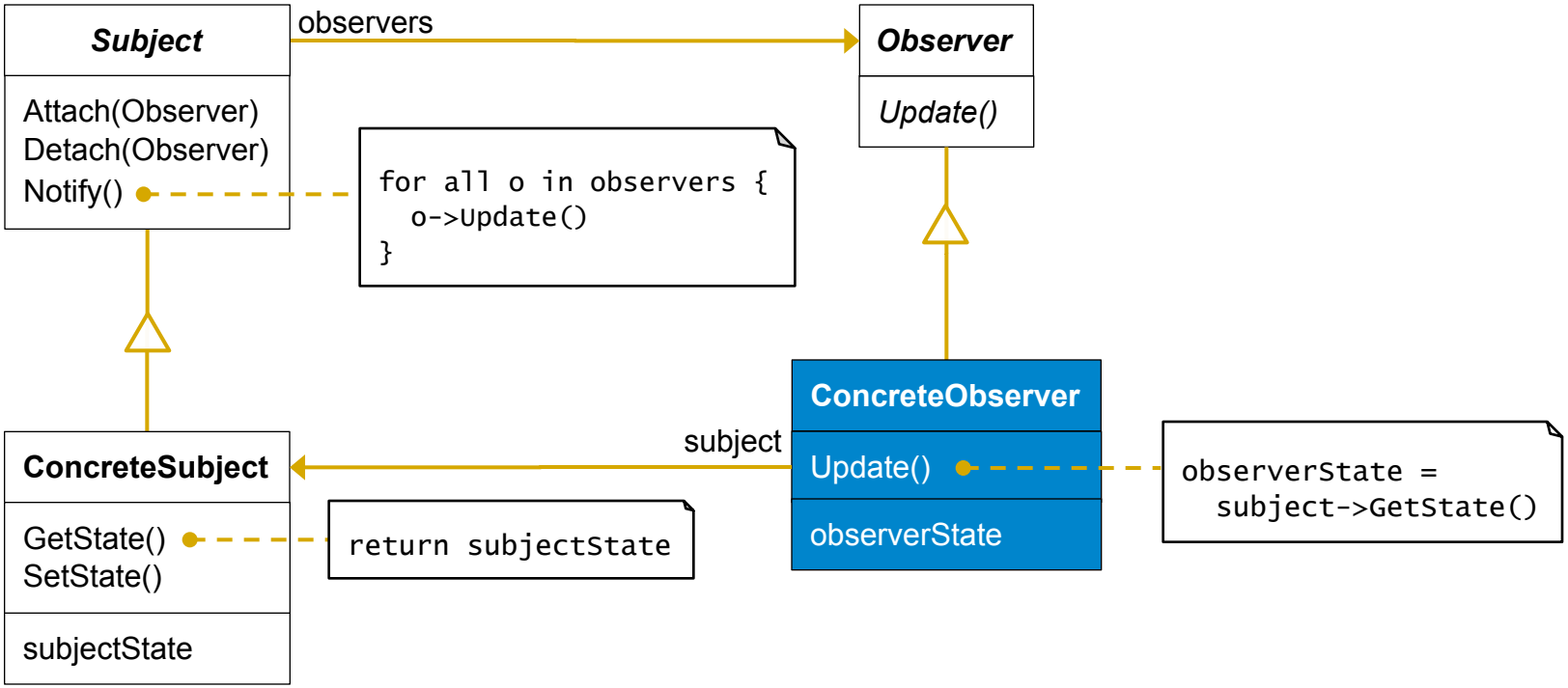
# ConcreteSubject

- Stores state of interest to ConcreteObserver objects
- Sends a notification to its observers when its state changes



# ConcreteObject

- Maintains a reference to a ConcreteSubject object
- Implements the Observer interface to keep its state consistent with the Subject



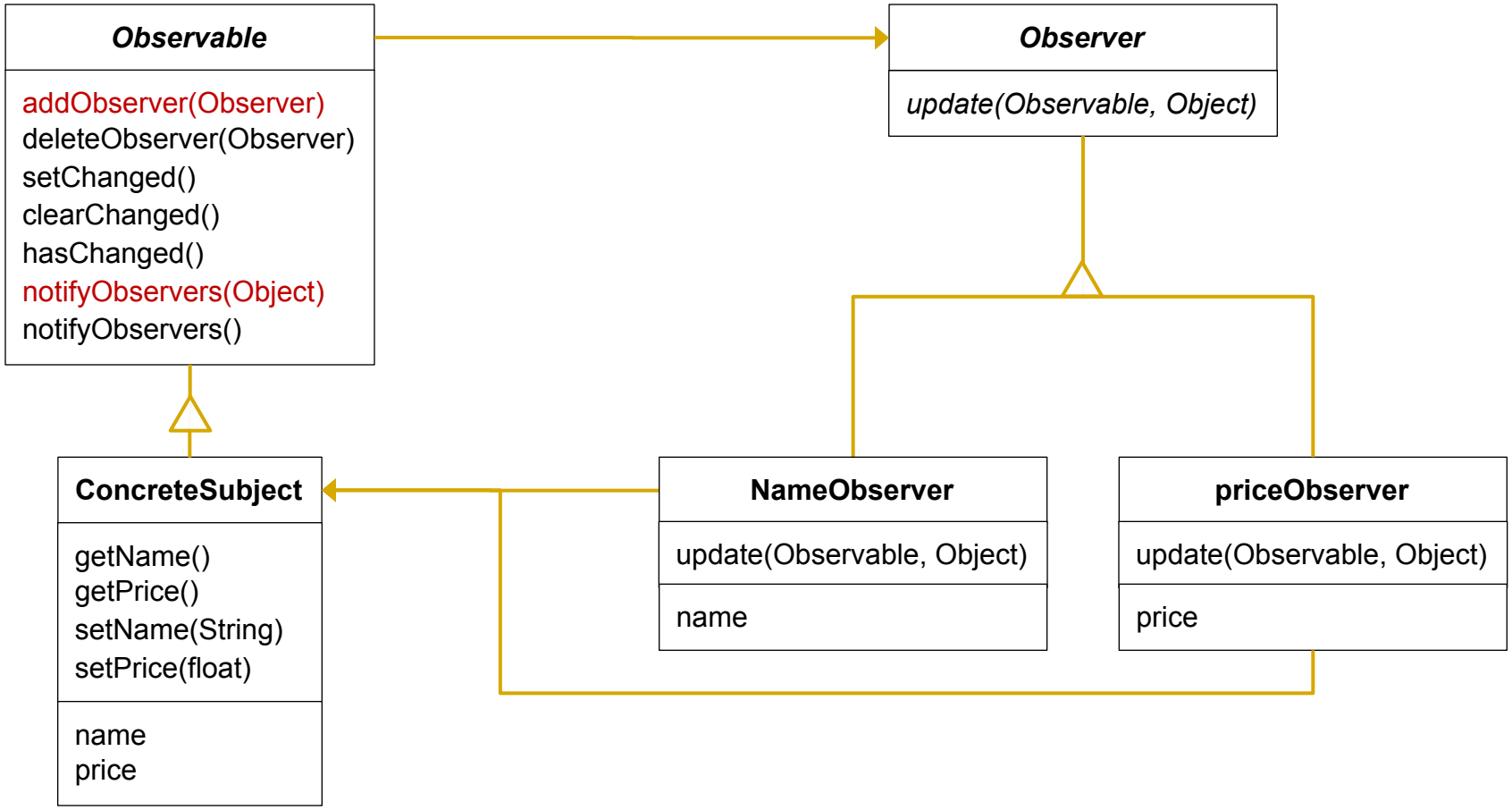
# Applicability

- When a change to one object requires changing others
- When an object should be able to notify other objects without making assumptions about those objects

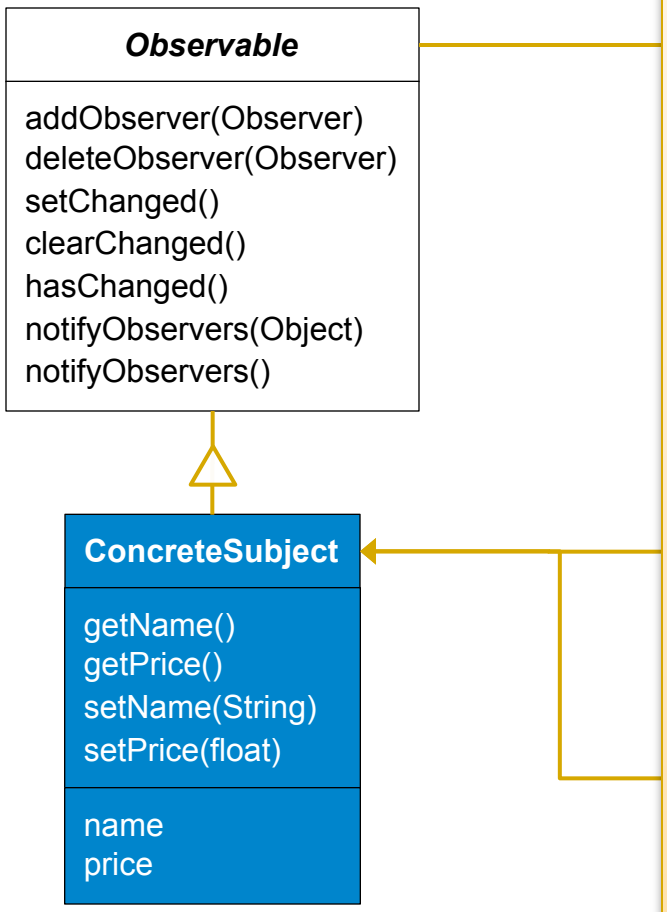
# Example with Java's Observable/Observer

- We could implement the pattern "from scratch" in Java
- But Java provides built-in Observable/Observer classes
- java.util.Observable class is the base Subject class
  - Any class that wants to be observed extends this class
  - Provides methods to add/delete observers
  - Provides methods to notify all observers
- java.util.Observer interface is the Observer interface
  - It must be implemented by any observer class

# Name and Price Observers

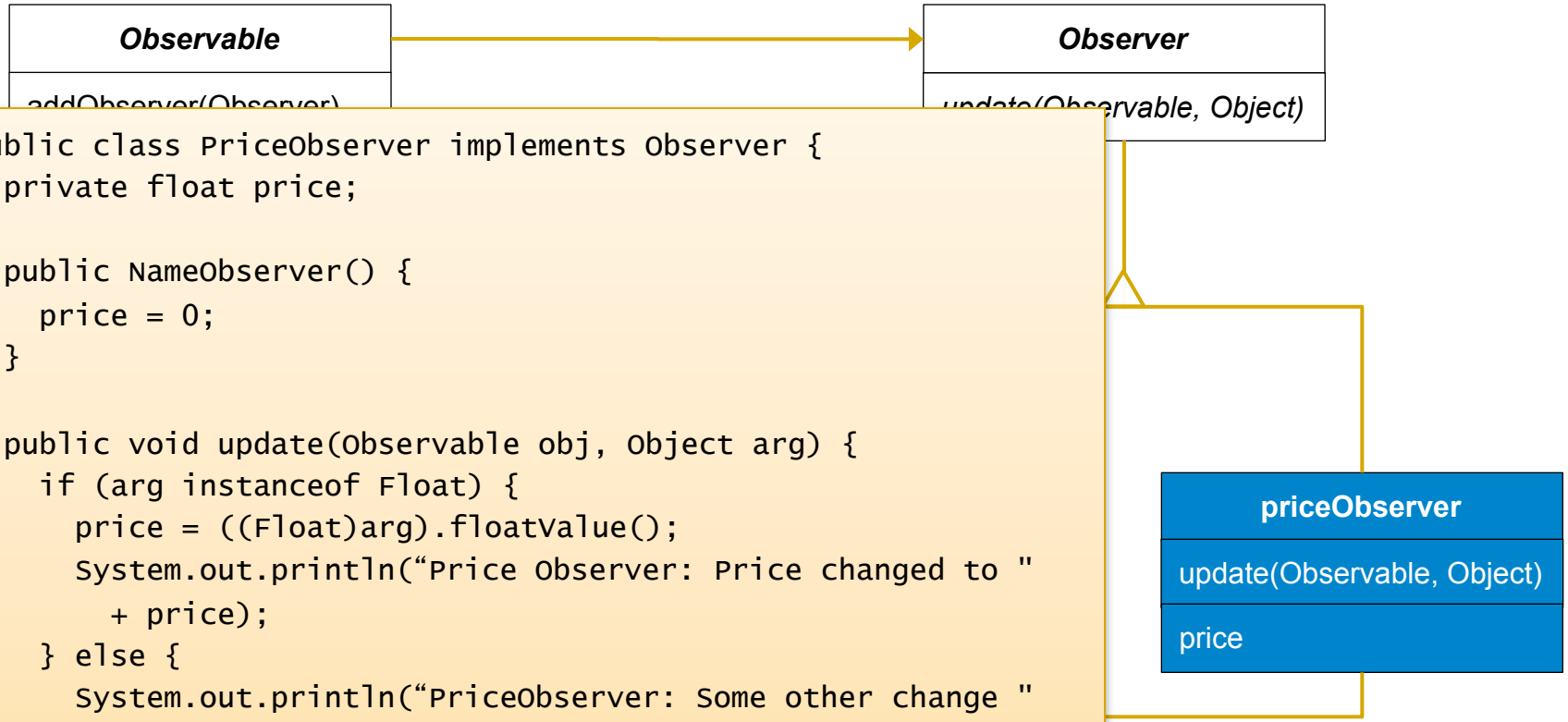


# ConcreteSubject




```
public class ConcreteSubject extends Observable {
  private String name;
  private float price;

  public ConcreteSubject(String name, float price) {
    this.name = name;
    this.price = price;
  }

  public String getName() {return name;}
  public float getPrice() {return price;}

  public void setName(String name) {
    this.name = name;
    setChanged();
    notifyObservers(name);
  }

  public void setPrice(float price) {
    this.price = price;
    setChanged();
    notifyObservers(new Float(price));
  }
}
```

# PriceObserver




```
public class PriceObserver implements Observer {
  private float price;

  public NameObserver() {
    price = 0;
  }

  public void update(Observable obj, Object arg) {
    if (arg instanceof Float) {
      price = ((Float)arg).floatValue();
      System.out.println("Price Observer: Price changed to "
        + price);
    } else {
      System.out.println("PriceObserver: Some other change "
        + " to subject!");
    }
  }
}
```

# TestObservers

```
public class TestObservers {
  public static void main(String args[]) {
    // Create the Subject and Observers.
    ConcreteSubject s = new ConcreteSubject("Corn Pops", 1.29f);
    NameObserver nameObs = new NameObserver();
    PriceObserver priceObs = new PriceObserver();

    // Add those Observers!
    s.addObserver(nameObs);
    s.addObserver(priceObs);

    // Make changes to the Subject.
    s.setName("Frosted Flakes");
    s.setPrice(4.57f);
    s.setPrice(9.22f);
    s.setName("Sugar Crispies");
  }
}
```

Output:

```
PriceObserver: Some other change to subject!
NameObserver: Name changed to Frosted Flakes
PriceObserver: Price changed to 4.57
NameObserver: Some other change to subject!
PriceObserver: Price changed to 9.22
NameObserver: Some other change to subject!
PriceObserver: Some other change to subject!
NameObserver: Name changed to Sugar Crispies
```

# Implementation Issues

- Dangling references to deleted subjects should be avoided
- Subject state should be self-consistent before notification
- Observer-specific update protocols
  - Push – subject sends observers detail at will
  - Pull – observers ask for detail after notification is sent
- Specify modifications of interest explicitly (filter events)
- Encapsulate complex update semantics

# Twitter


twitter
A global community of friends and strangers answering one simple question: What are you doing?
Biz Stone | Invite | Public | Codes | Setting
Characters available: 82
thing for her birthday
But who will get your updates? Invite some of your friends to Twitter!
Or make your account public and let everyone read them.
1 2 3
1 new friend request!
102 Friends
Recent Public Updates
TÇ DM: "The Things You Said" - perfect walking beat pace less than 10 seconds ago from im
Please Sign In!
Email or Mobile Number
Password Forgot?
Remember me
Sign In!
Want an account?
Join for Free!
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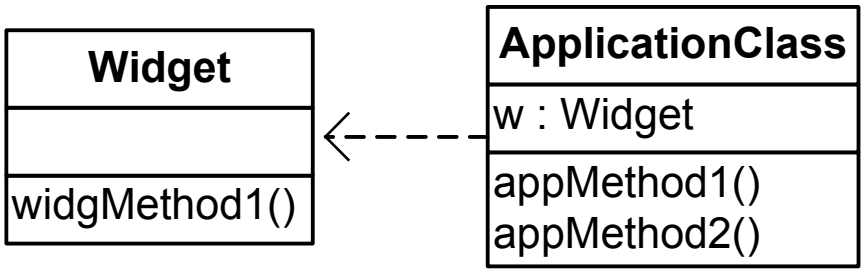
# Abstract Factory Pattern

# Motivation



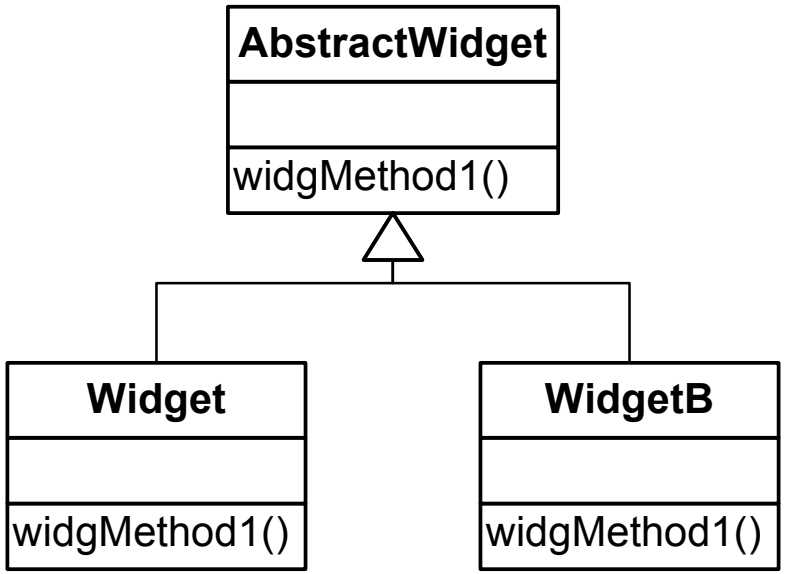

```
class ApplicationClass {
  Widget w;

  public appMethod1() {
    Widget w = new Widget();
    w.widgMethod1();
  }
  ...
```

- We can modify the internal `Widget` code without modifying the `ApplicationClass`
- What happens when we discover a new widget and would like to use it in the `ApplicationClass`?

# Problems with Changes

- `Multiple coupling between Widget and ApplicationClass`
- `ApplicationClass` knows the interface of `Widget`
- `ApplicationClass` explicitly uses the `Widget` type
  - Hard to change because `Widget` is a concrete class
- `ApplicationClass` explicitly creates new Widgets in many places
  - If we want to use the new `Widget` instead of the initial one, changes are spread all over the code

# Apply "Program to an Interface"



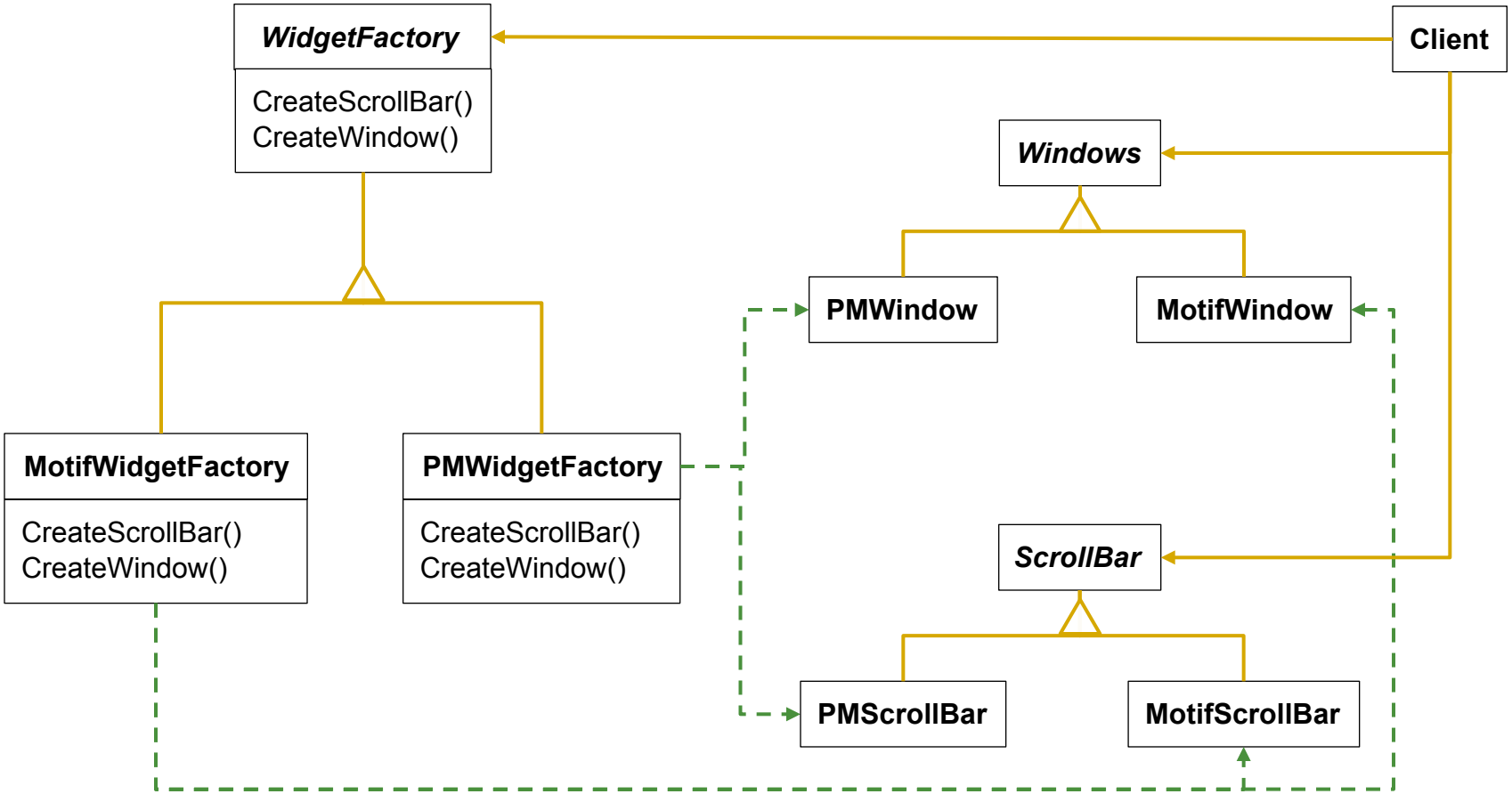

- `ApplicationClass` depends now on an (abstract) interface
  - Helps to solve the problem of explicit use
- But we still have to hard code which widget to create!
  - Problem of explicit creation not solved

# Apply "Program to an Interface"




- Different CD/Radio/MP3 players can be plugin to the car dashboard.
- …using polymorphic dependencies

# WidgetFactory



# Abstract Factory *aka* Kit

- Intent
  - Provide an interface for creating families of related or dependent objects without specifying their concrete classes

- Motivation
  - User interface toolkit supports multiple look-and-feel standards (Motif, Presentation Manager)
  - Different appearances and behaviors for UI widgets
  - Apps should not hard-code its widgets

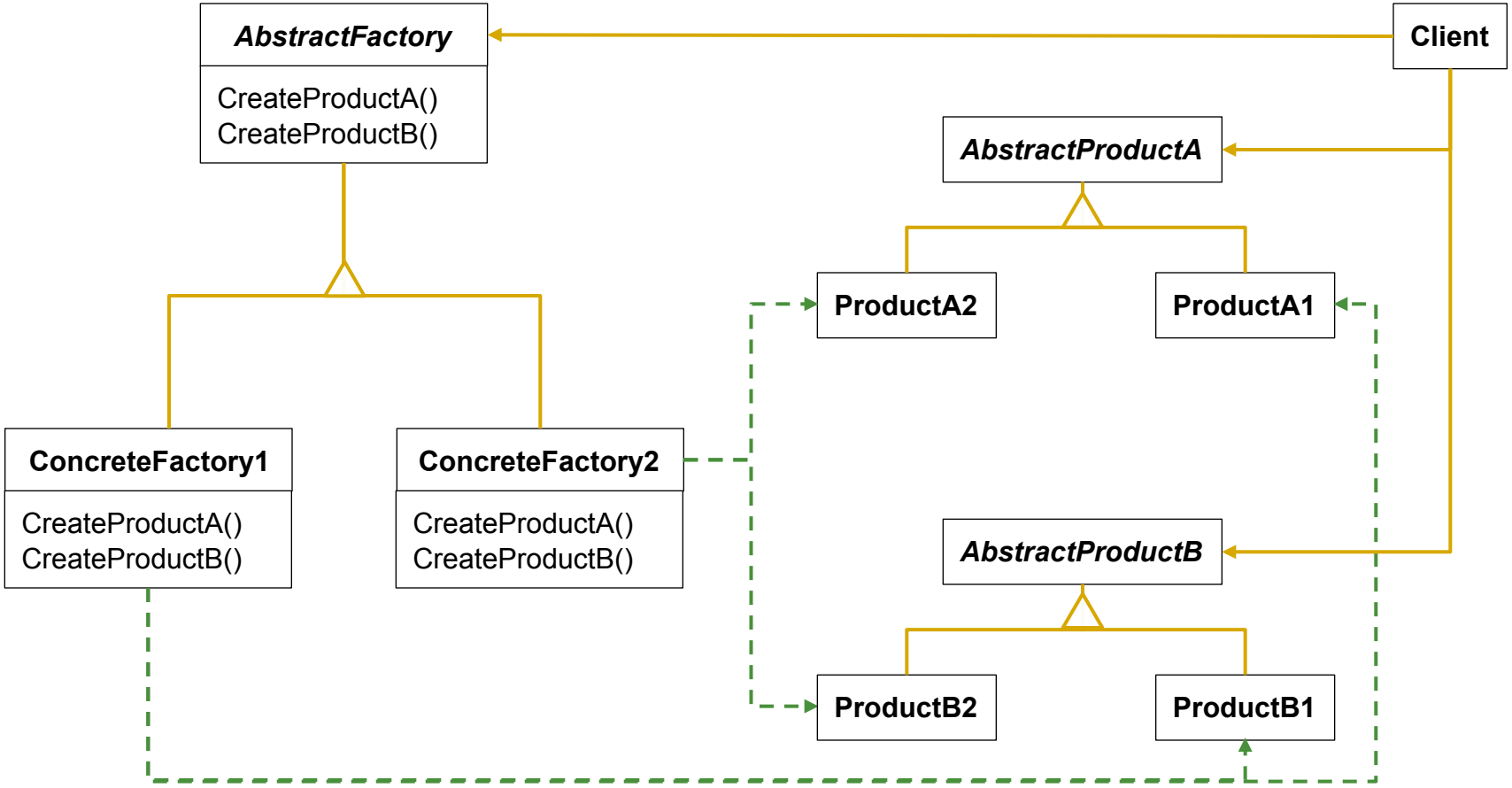
# Solution

- Place *Abstract Factory* Class between application layer and Concrete Factory Class(es)
  - Create an Abstract *WidgetFactory* class from a related set of Abstract Interfaces (Abstract Products)
    - e.g., Abstract Interfaces for creating each basic kind of widget
  - Create Concrete WidgetFactory for specific implementations
    - e.g., classes implement specific look-and-feel, and allow for different look-and-feel

# Applicability

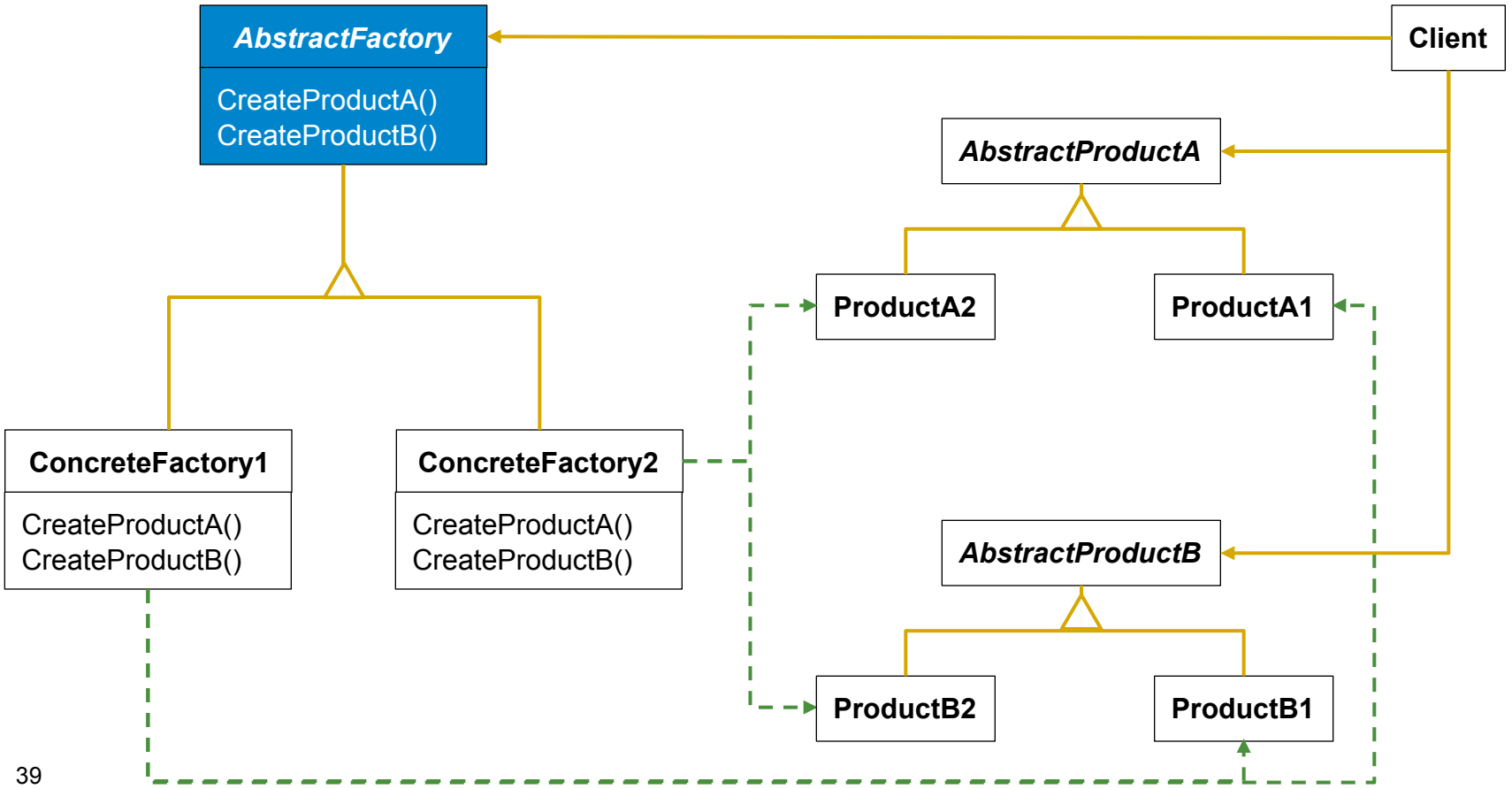
- Use the Abstract Factory pattern when
  - A system should be independent of how its products are created, composed, and represented
  - A system should be configured with one of multiple families of products
  - A family of related product objects is designed to be used together, and you need to enforce this constraint
  - You want to provide a class library of products, and you want to reveal just their interfaces, not their implementations

# Structure


AbstractFactory
CreateProductA()
CreateProductB()
Client
AbstractProductA
ProductA2
ProductA1
ConcreteFactory1
CreateProductA()
CreateProductB()
ConcreteFactory2
CreateProductA()
CreateProductB()
AbstractProductB
ProductB2
ProductB1

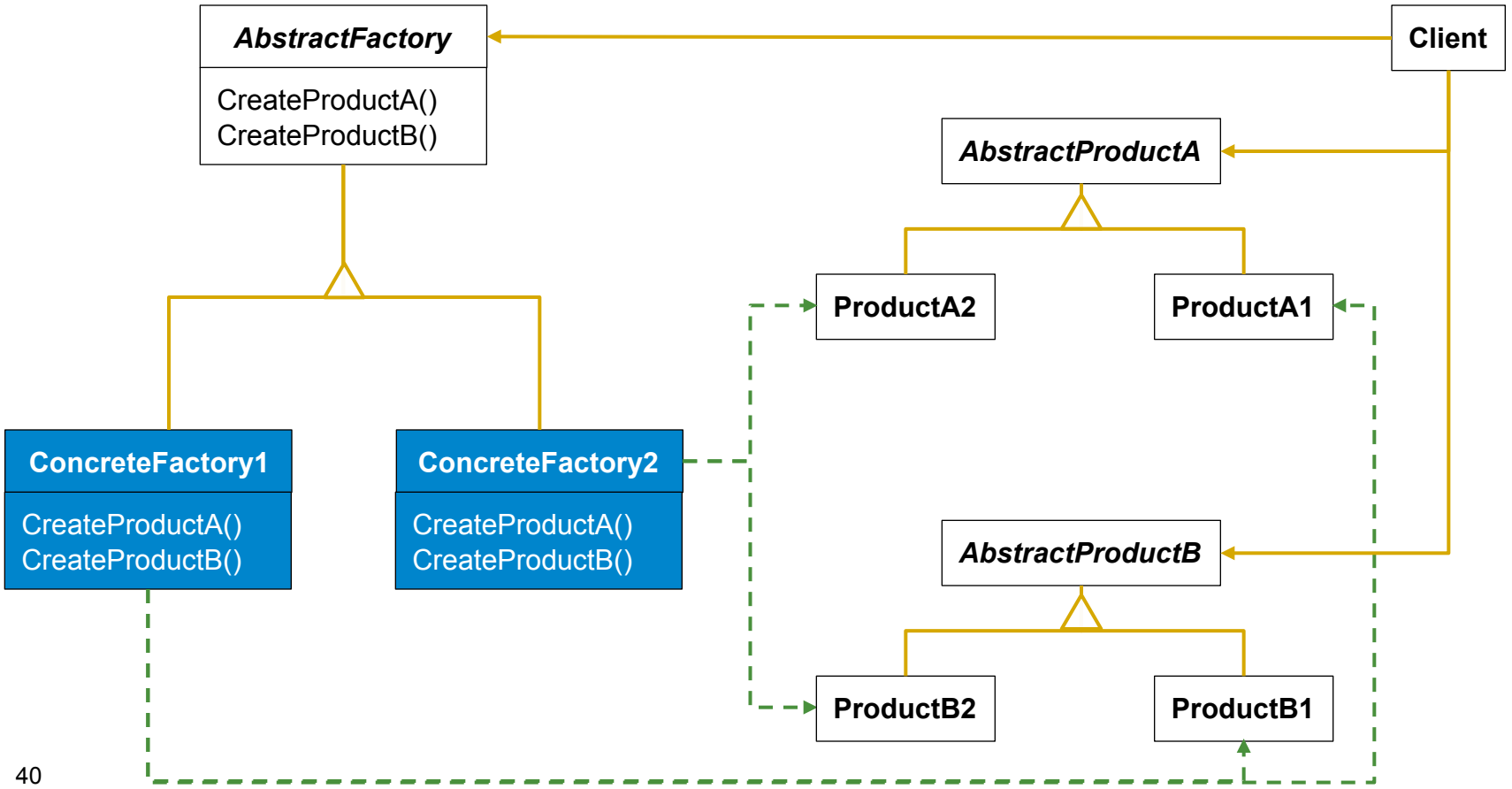
# AbstractFactory

- Declares interface for operations that create abstract product objects



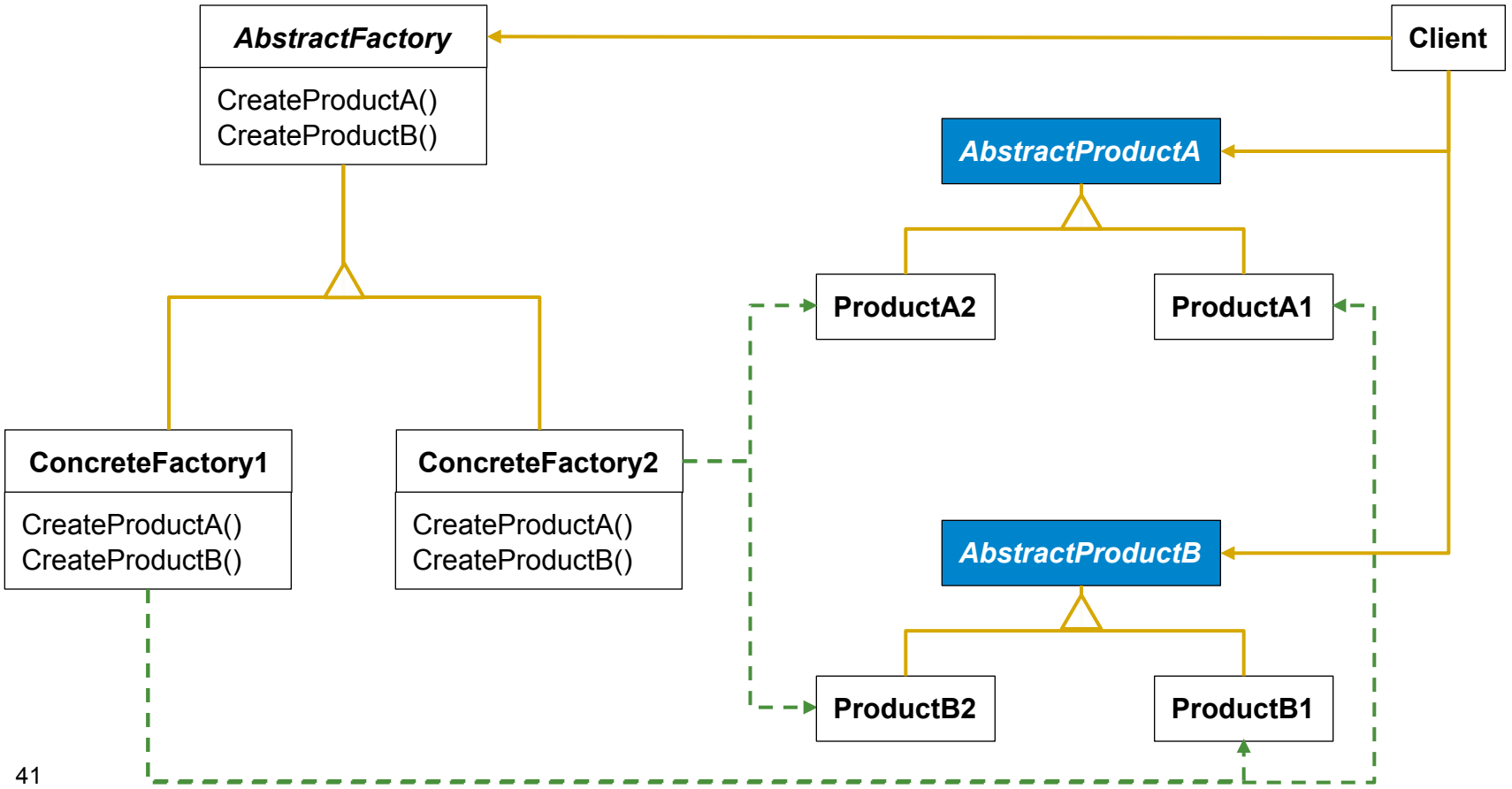
# ConreteFactory

- Implements operations to create concrete product object



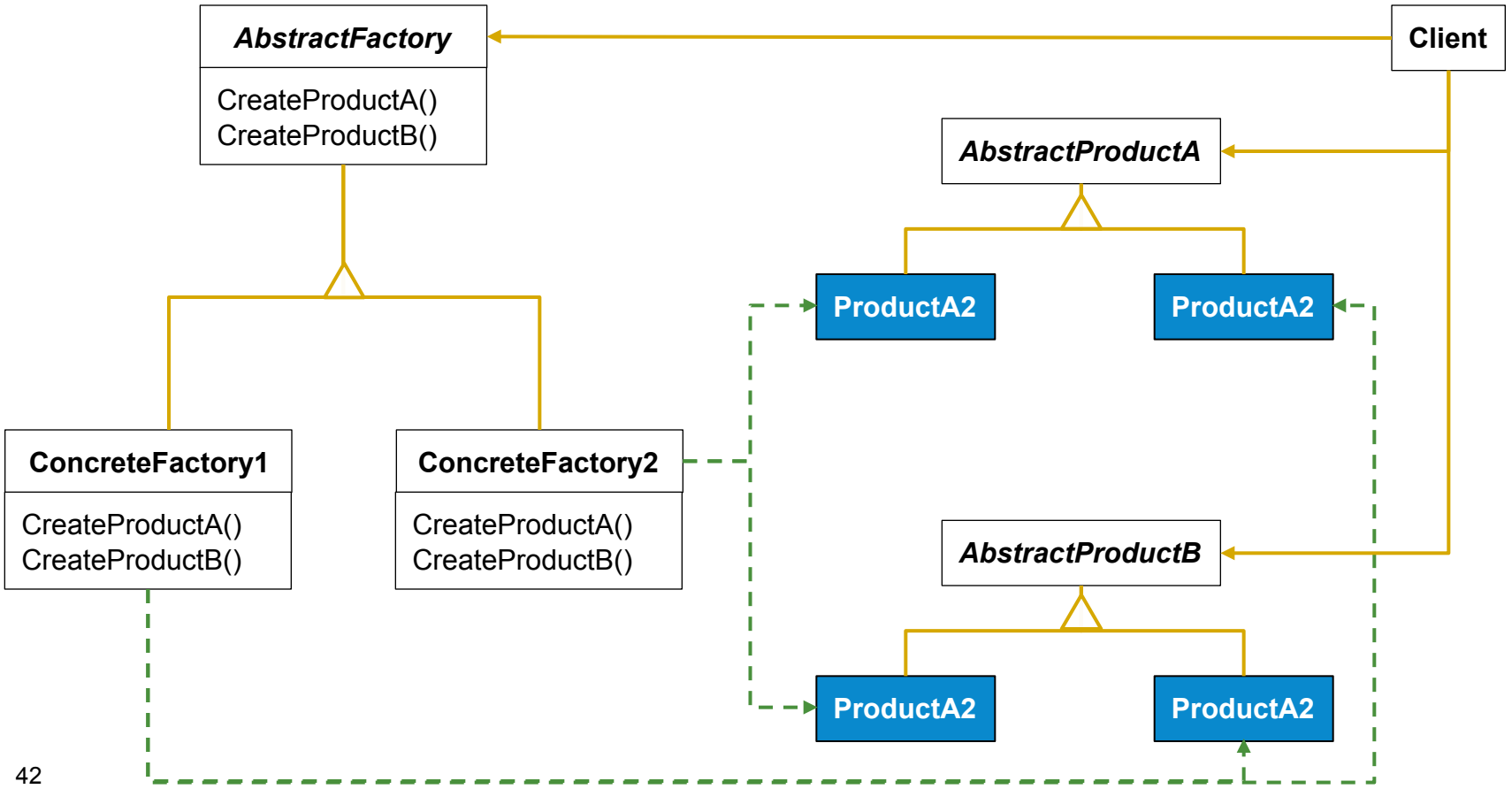
# AbstractProduct

- Declares an interface for a type of product object



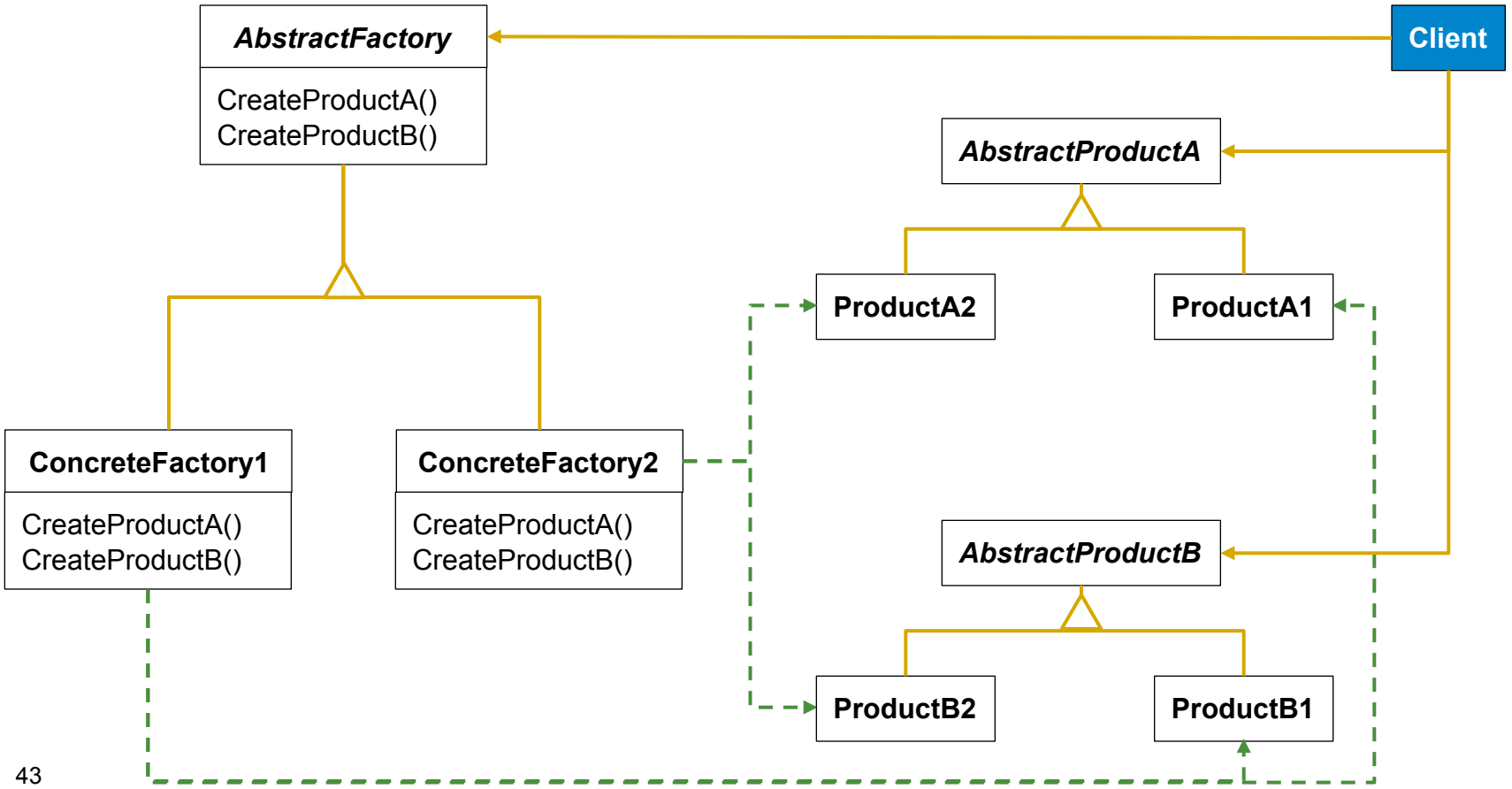
# ConcreteProduct

- Defines a product object to be created by concrete factory
- Implements the abstract product interface



# Client

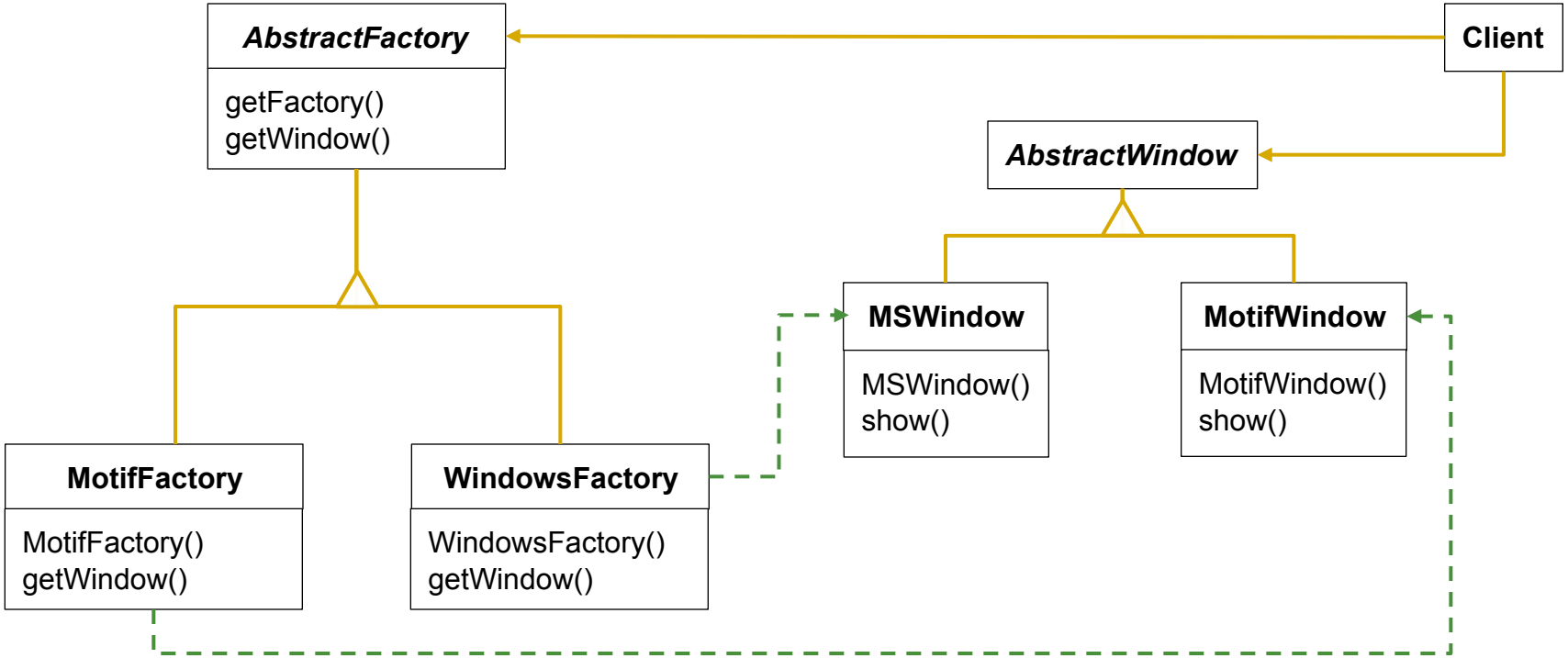
- Uses only interfaces declared by AbstractFactory and AbstractProduct classes



# Consequences

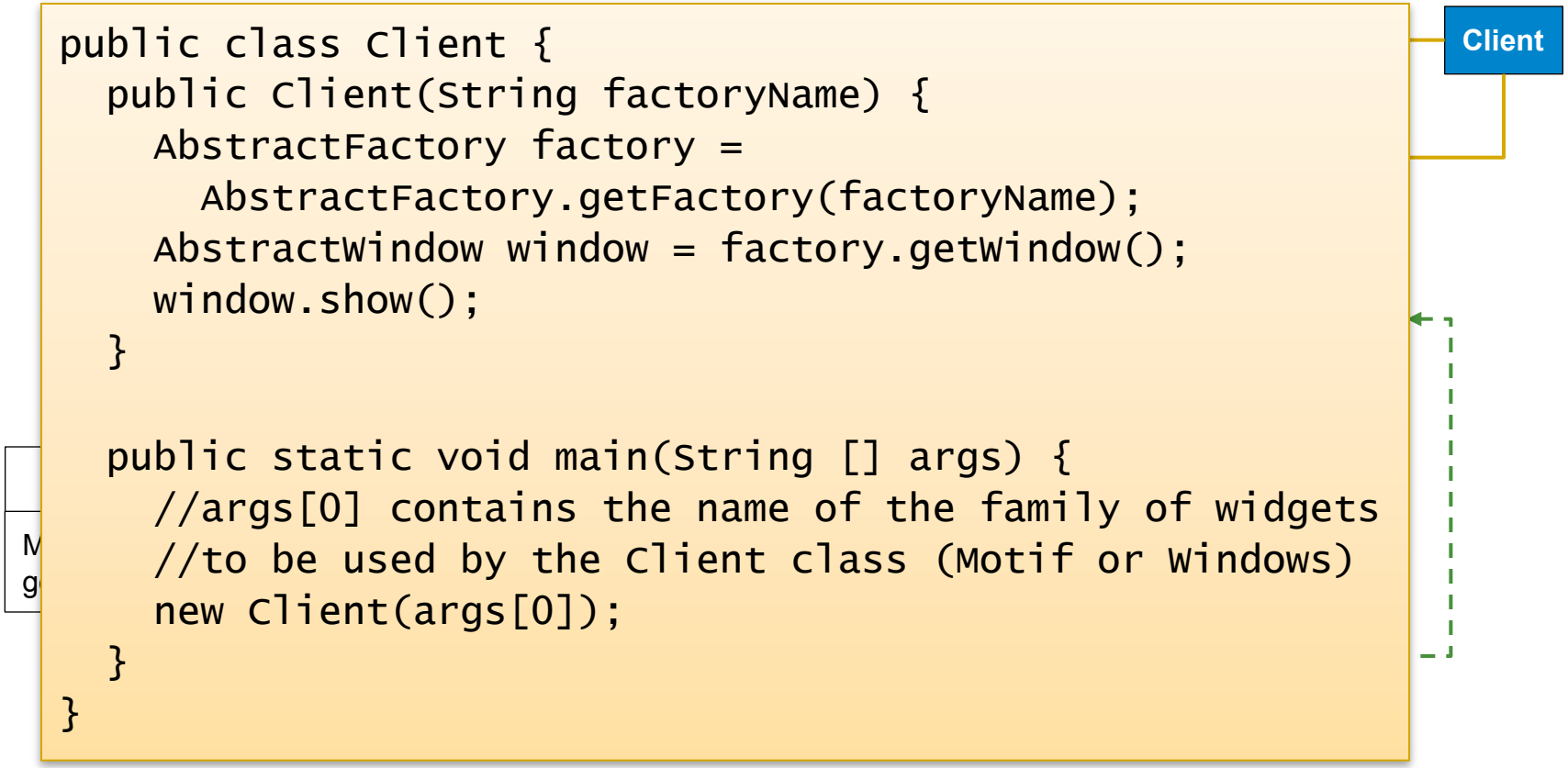
- Explicit creation of `Widget` objects is not anymore dispersed; hence, is easier to change
- `Functional methods in ApplicationClass` are decoupled from various concrete implementations of widgets
  - Product class names do not appear in client code
- Use of Factories forces adherence to interfaces and `encapsulates both interface definitions and` implementations
- Supporting new kinds of products is difficult
  - AbstractFactory and all its subclasses need to be changed

# Example – Windows

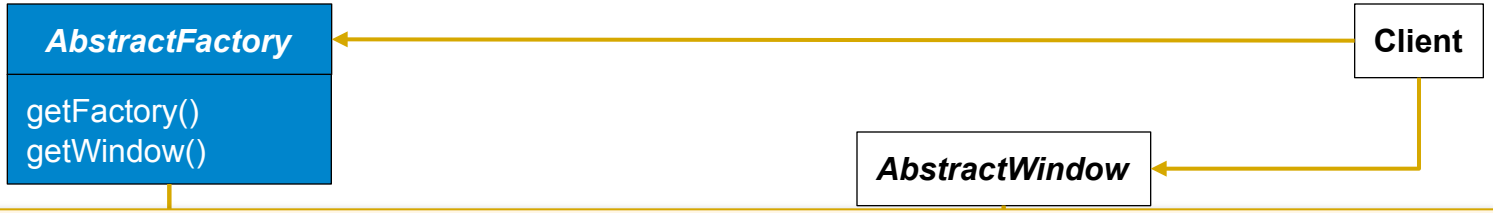


# Code for Class Client

```
public class Client {
  public Client(String factoryName) {
    AbstractFactory factory =
      AbstractFactory.getFactory(factoryName);
    AbstractWindow window = factory.getWindow();
    window.show();
  }

  public static void main(String [] args) {
    //args[0] contains the name of the family of widgets
    //to be used by the Client class (Motif or Windows)
    new Client(args[0]);
  }
}
```



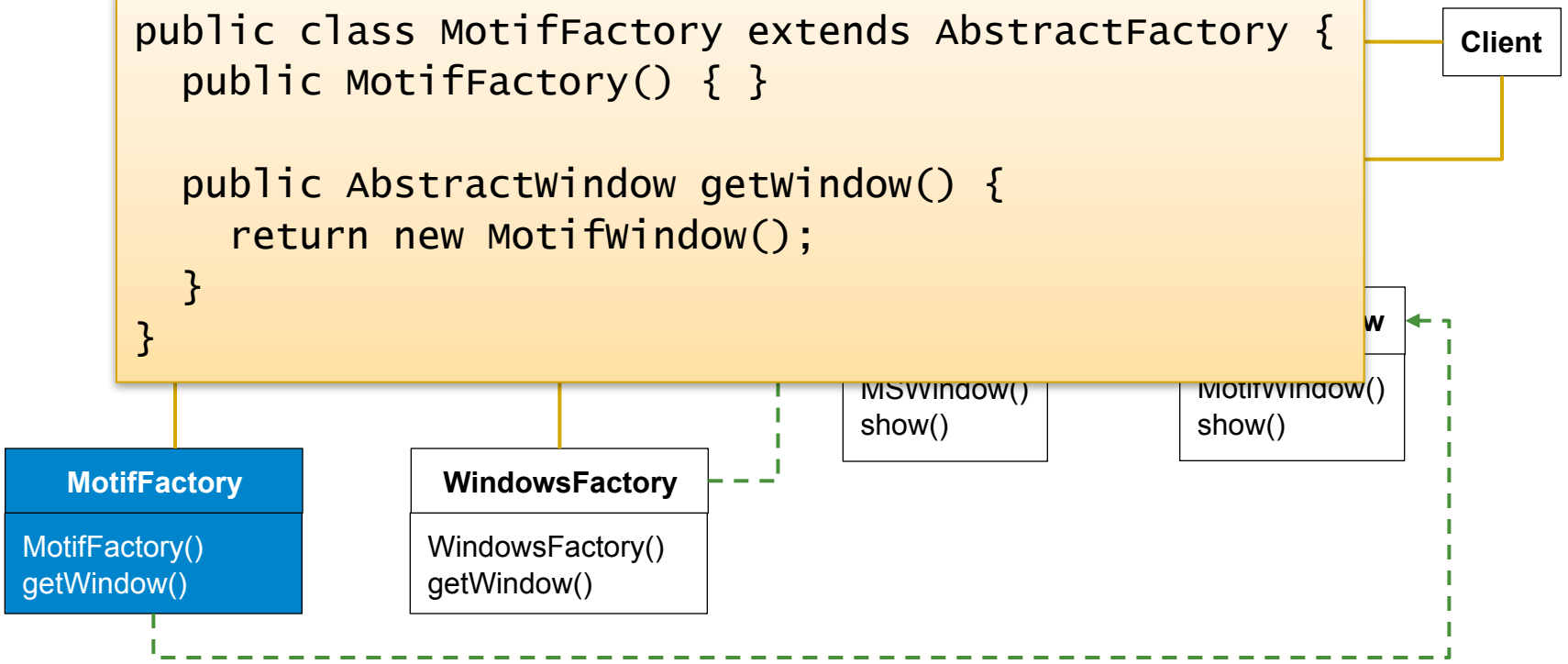
# Code for Class AbstractFactory




```
public abstract class AbstractFactory {
  public static final String MOTIF_WIDGET_NAME = "Motif";
  public static final String WINDOWS_WIDGET_NAME = MSWindows";

  public static AbstractFactory getFactory(String name) {
    if (name.equals(MOTIF_WIDGET_NAME))
      return new MotifFactory( );
    else if (name.equals(WINDOWS_WIDGET_NAME))
      return new WindowsFactory( );
    return null;
  }

  public abstract AbstractWindow getWindow();
}
```

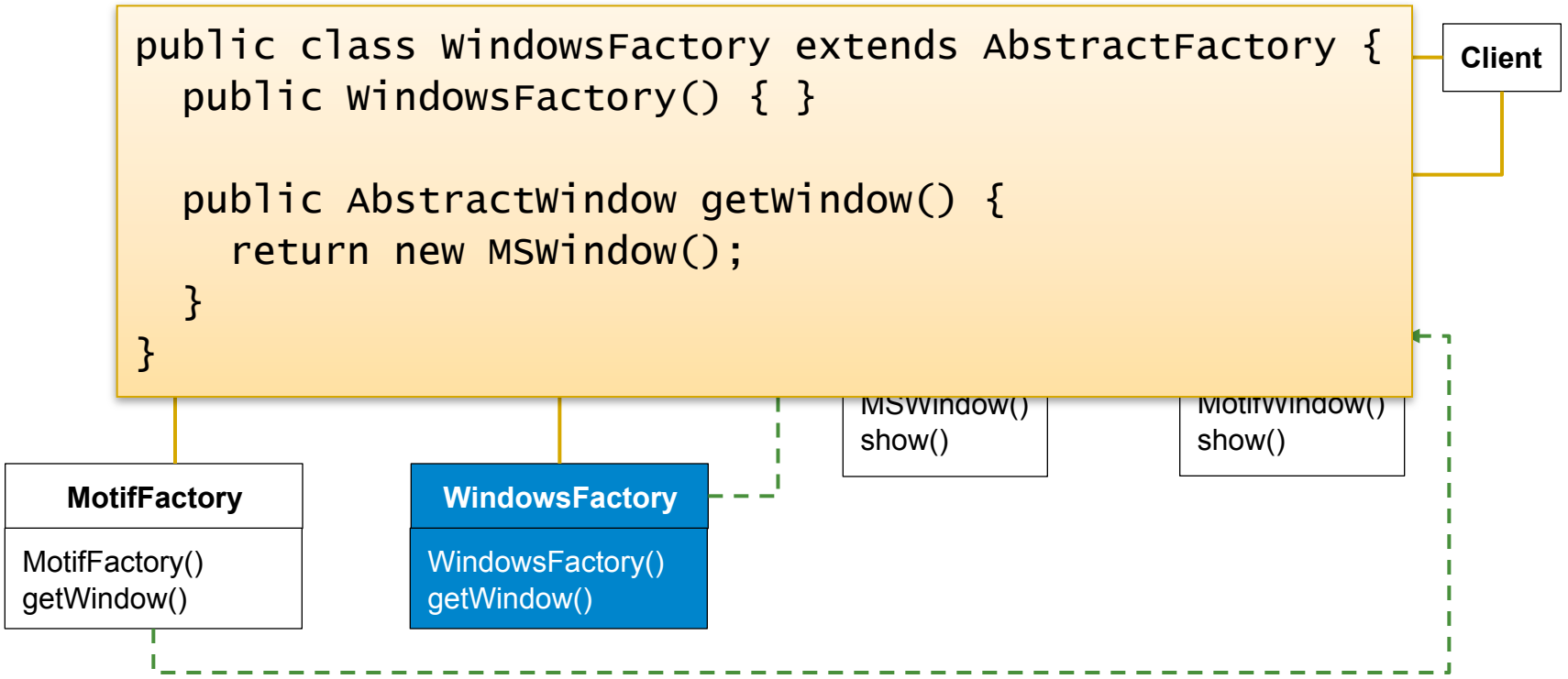
# Code for Class MotifFactory

```
public class MotifFactory extends AbstractFactory {
  public MotifFactory() { }

  public AbstractWindow getWindow() {
    return new MotifWindow();
  }
}
```

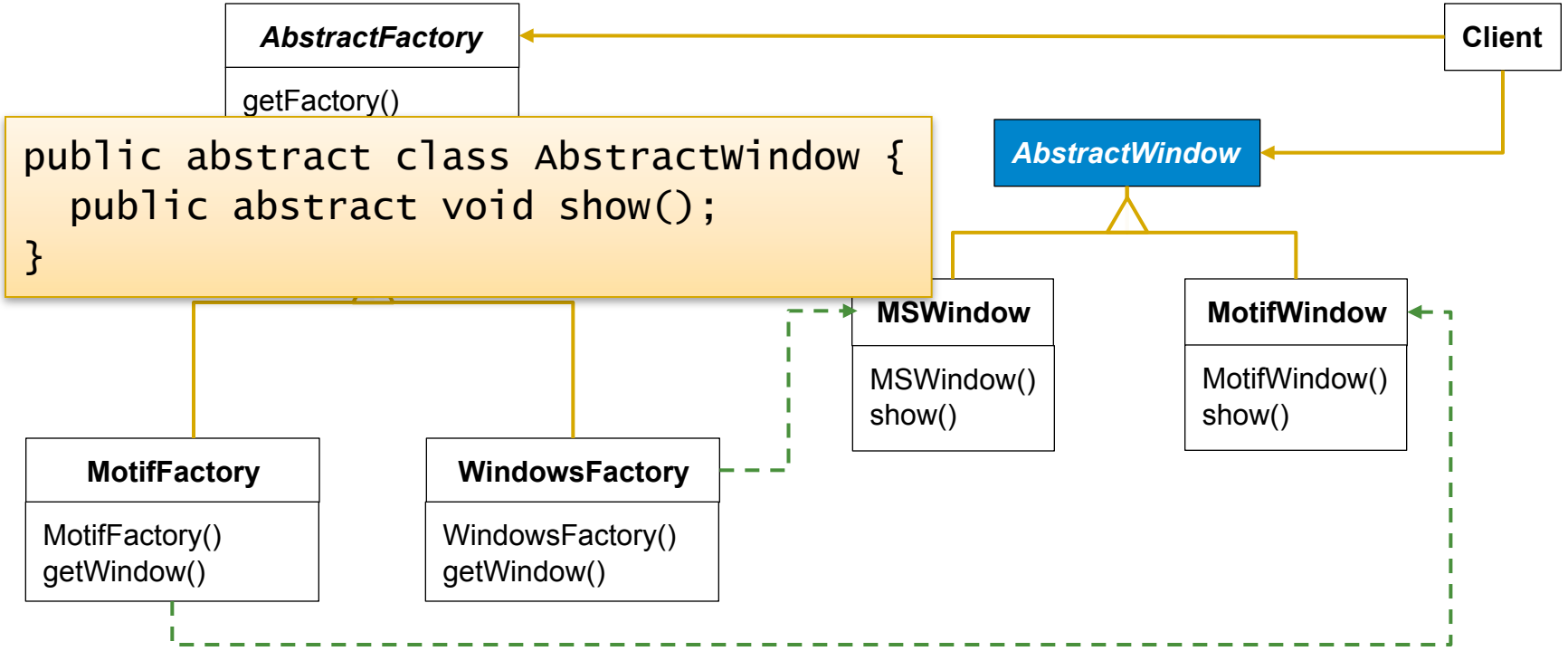


# Code for Class WindowsFactory

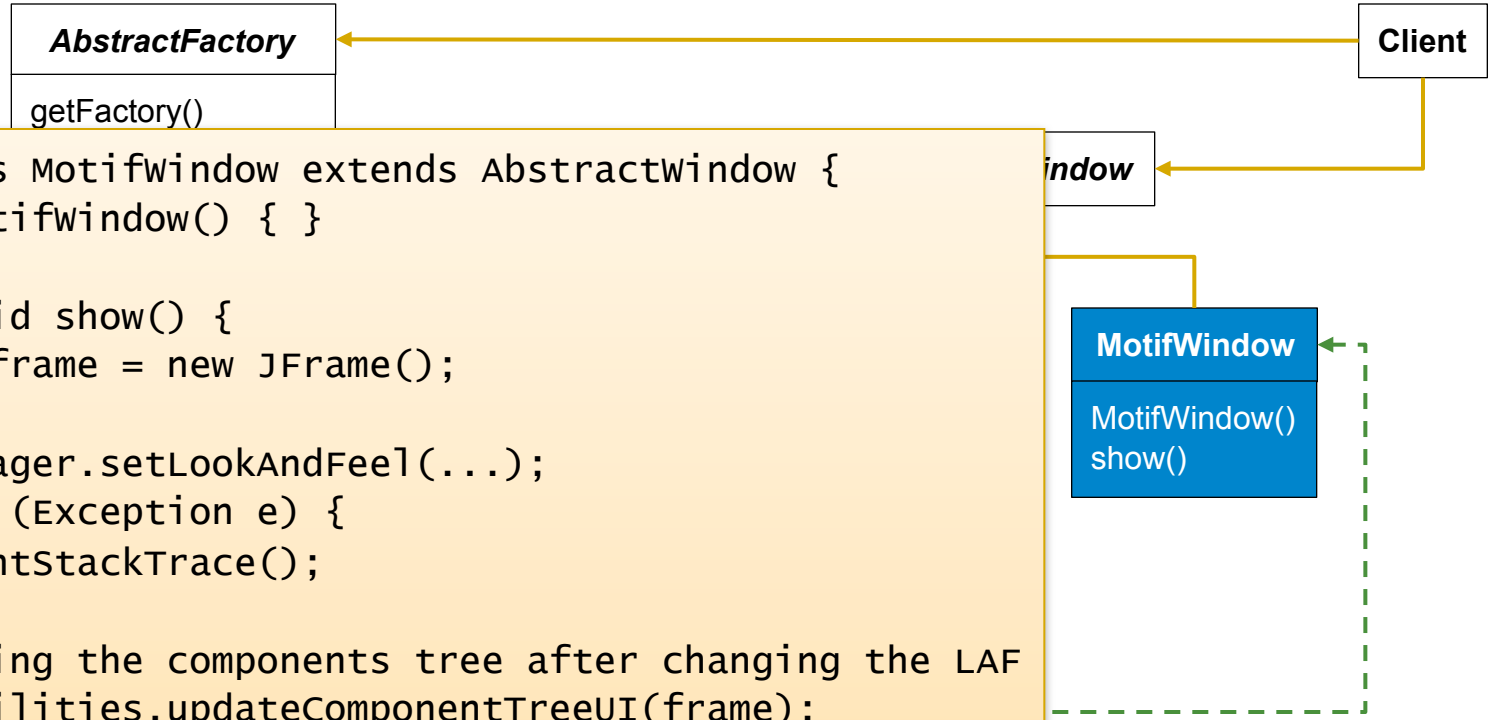
```
public class WindowsFactory extends AbstractFactory {
  public WindowsFactory() { }

  public AbstractWindow getWindow() {
    return new MSWindow();
  }
}
```



# Code for Class AbstractWindow

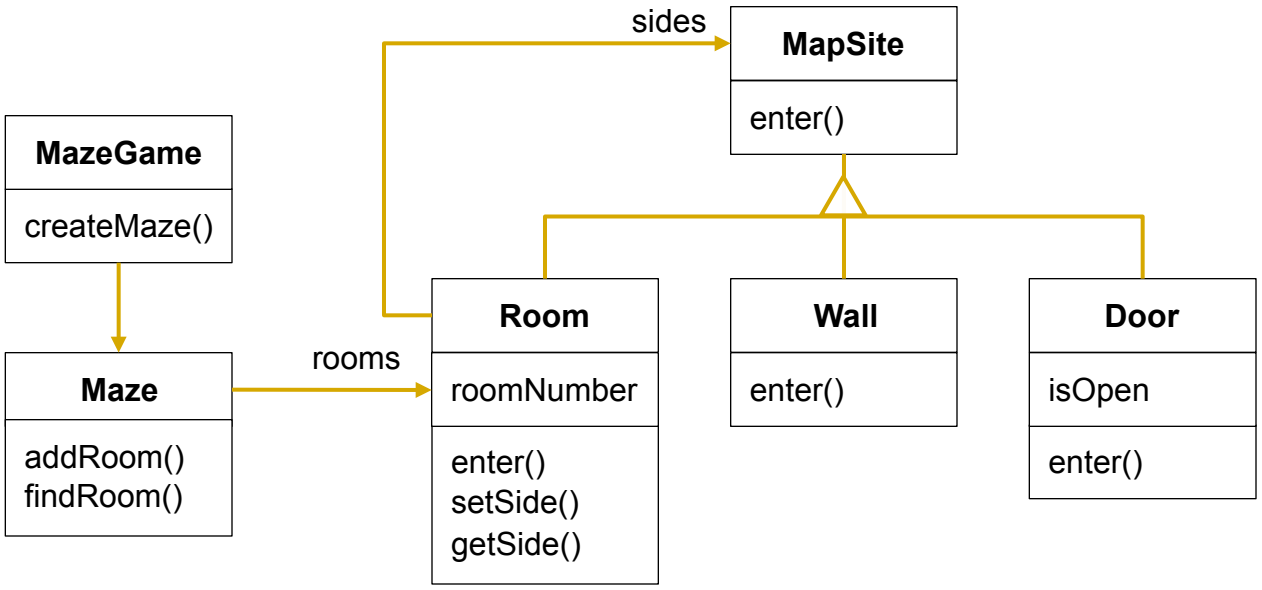


# Code for Class MotifWindow




```
public class MotifWindow extends AbstractWindow {
  public MotifWindow() { }

  public void show() {
    JFrame frame = new JFrame();
    try {
      UIManager.setLookAndFeel(...);
    } catch (Exception e) {
      e.printStackTrace();
    }
    //updating the components tree after changing the LAF
    SwingUtilities.updateComponentTreeUI(frame);
    frame.setSize(300, 300);
    frame.setVisible(true);
  }
}
```

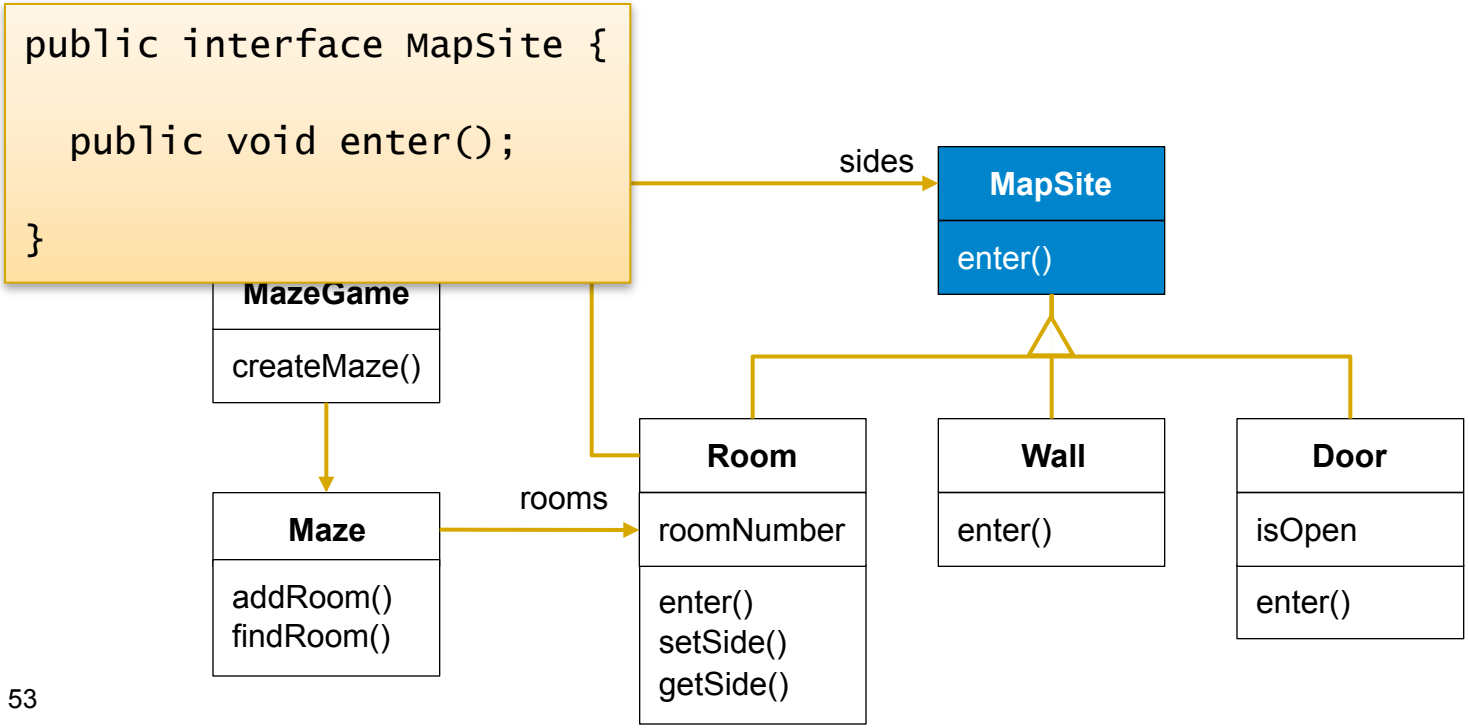
# Example – Maze Game

# Class Mapsite

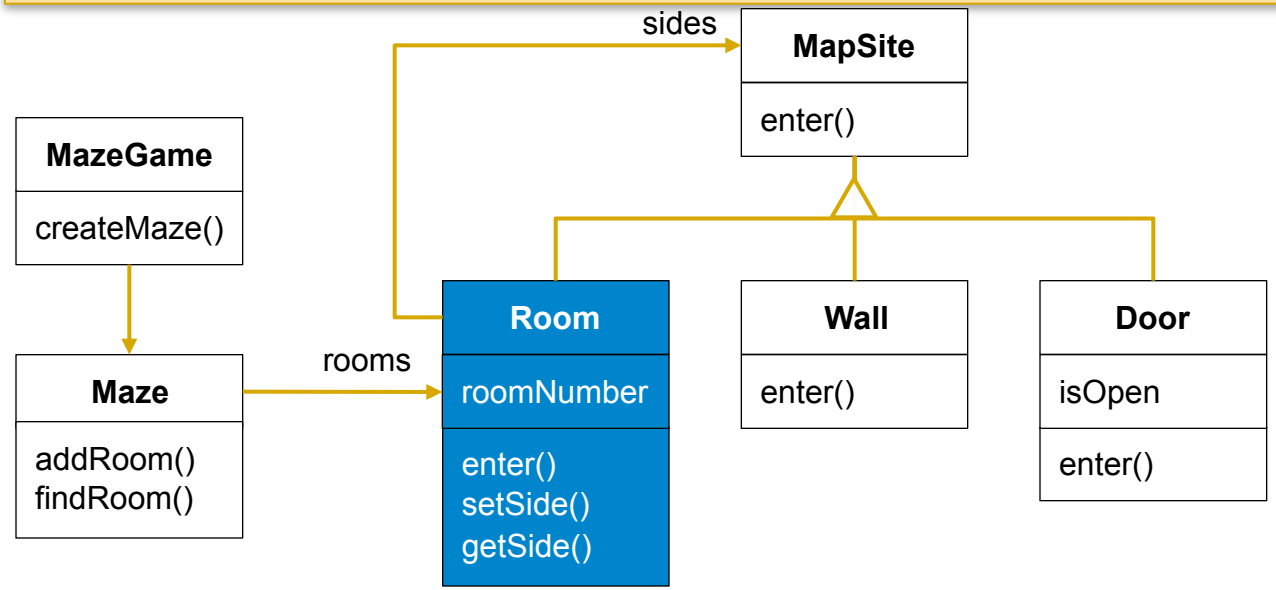
- Meaning of enter() depends on what you are entering
- room → location changes
- door → if door is open go in; else hurt your nose ;)
- wall → ouch

```
public interface MapSite {

  public void enter();

}
```



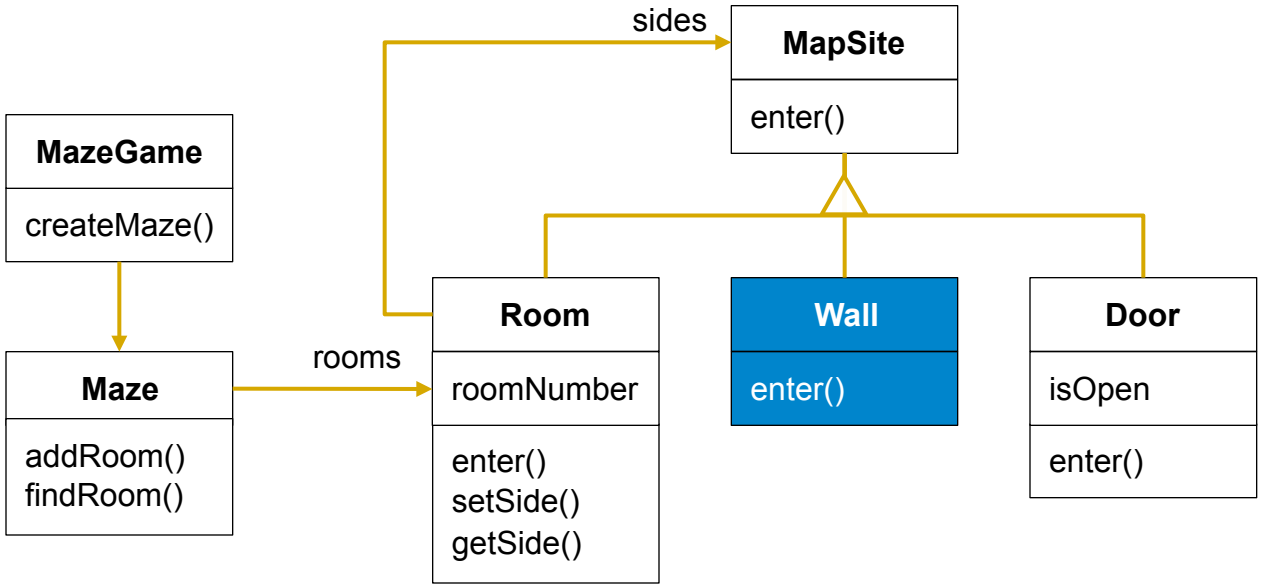
# Class Room

```
public class Room implements MapSite {

  public Room(int roomNumber) {...}

  public MapSite getSide(Direction dir) {...}

  public void setSide(Direction dir, MapSite site) {...}

  public void enter() {...}

  protected int roomNumber = 0;
  protected MapSite[] sides = new MapSite[4];
}
```



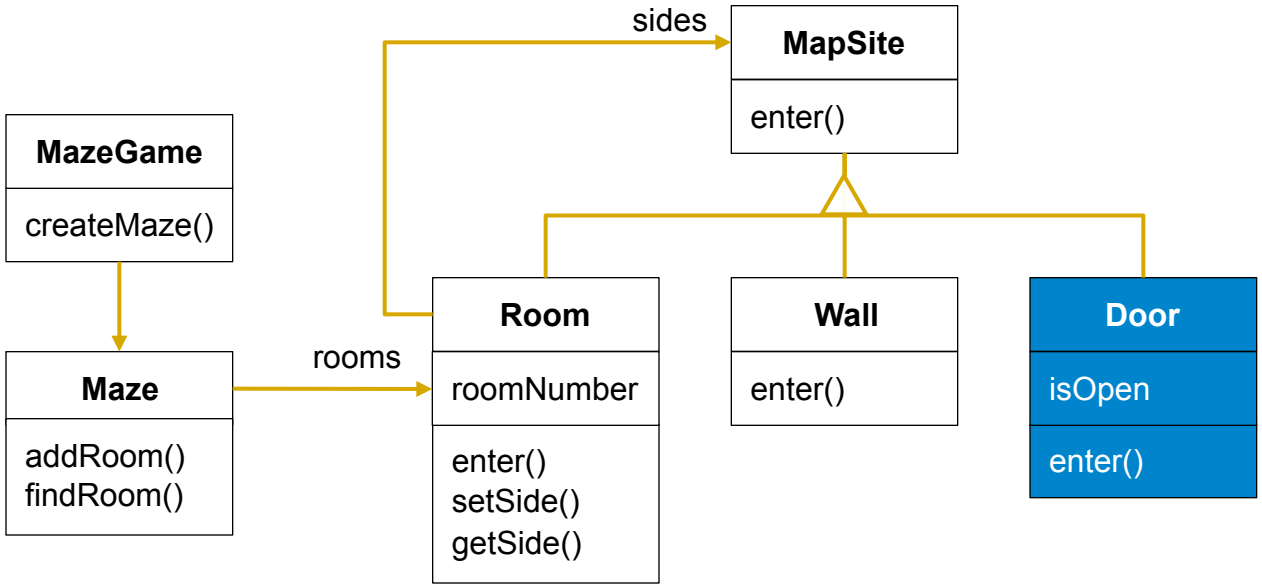
# Class Wall

```
public class Wall implements MapSite {

  public void enter() {...}
}
```



# Class Door

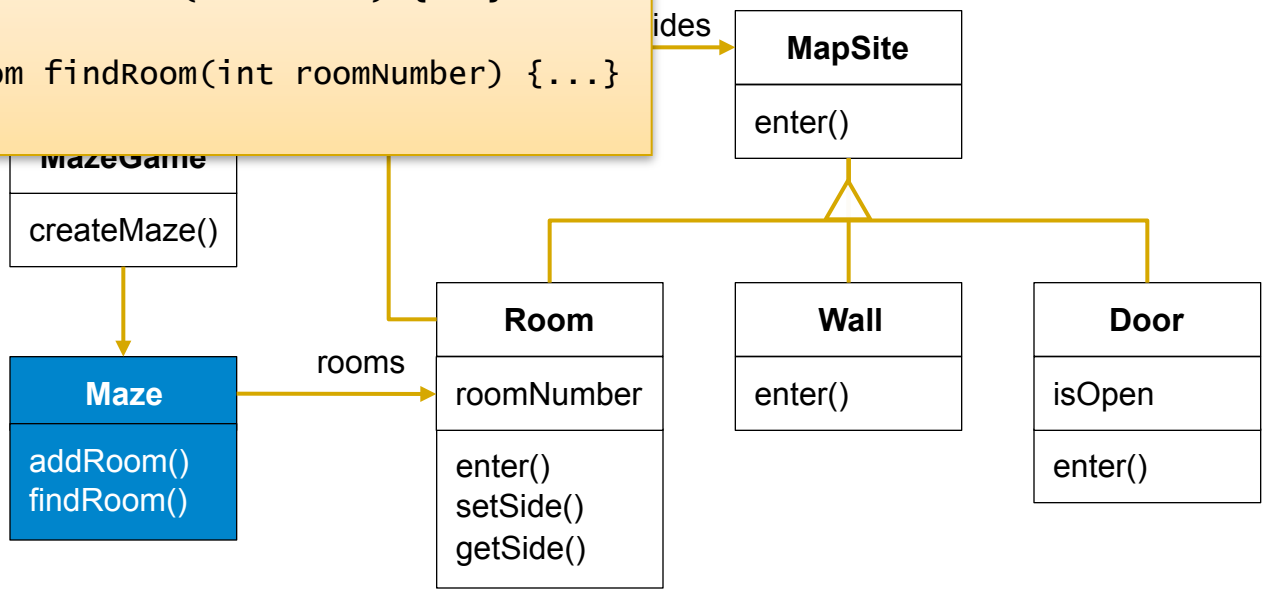
```
public class Door implements MapSite {

  public Door(Room room1, Room room2) {...}

  public Room otherSideFrom(Room room) {...}

  public void enter() {...}

  protected Room room1;
  protected Room room2;
  protected boolean open;
}
```



# Class Maze

- A maze is a collection of rooms
- Maze can find a particular room given the room number
- `findRoom()` could do a lookup using a linear search or a hash table or a simple array

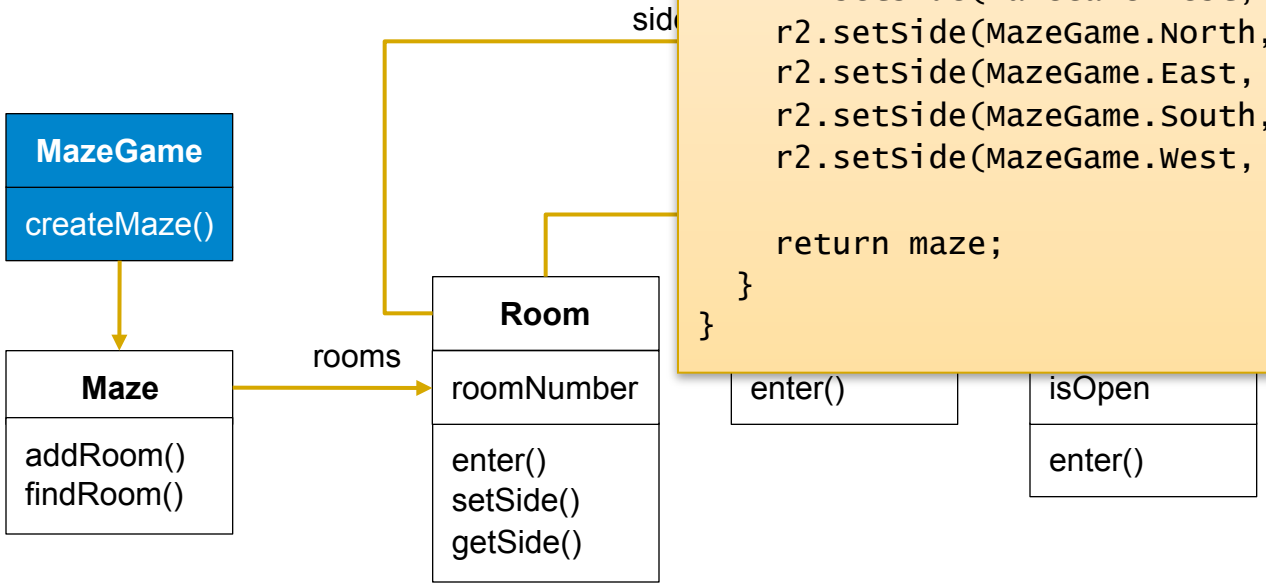
```
public class Maze {

  public void addRoom(Room room) {...}

  public Room findRoom(int roomNumber) {...}
}
```



# Creating the Maze

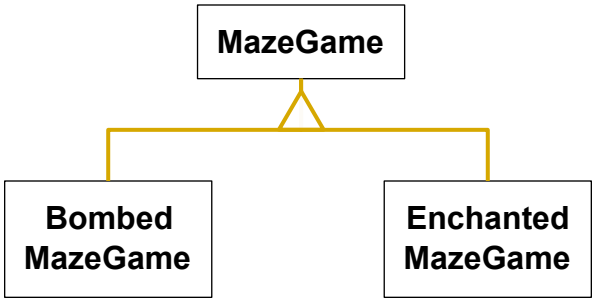
- The problem is inflexibility
  - Hard-coding of maze layout

```
public class MazeGame {
  public Maze createMaze() {
    Maze maze = new Maze();

    Room r1 = new Room(1);
    Room r2 = new Room(2);
    Door door = new Door(r1, r2);
    maze.addRoom(r1); maze.addRoom(r2);

    r1.setSide(MazeGame.North, new Wall());
    r1.setSide(MazeGame.East, door);
    r1.setSide(MazeGame.South, new Wall());
    r1.setSide(MazeGame.West, new Wall());
    r2.setSide(MazeGame.North, new Wall());
    r2.setSide(MazeGame.East, new Wall());
    r2.setSide(MazeGame.South, new Wall());
    r2.setSide(MazeGame.West, door);

    return maze;
  }
}
```



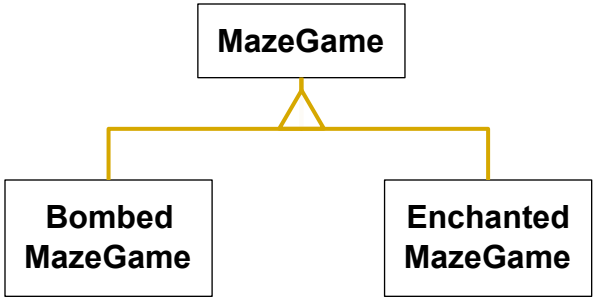
# We Want Flexibility in Maze Creation

- Be able to vary the kinds of mazes
  - Rooms with bombs
  - Walls that have been bombed
  - Enchanted rooms
    - Need a password to enter the door!



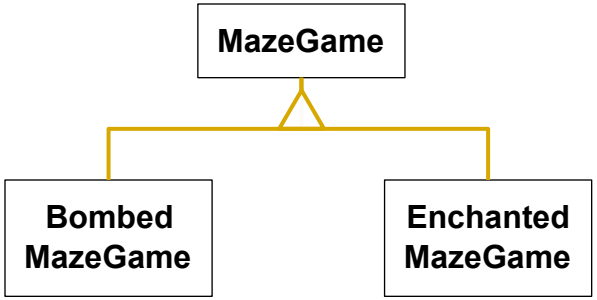
# Idea 1: Subclass BombedMazeGame

```
public class BombedMazeGame extends MazeGame {
  public Maze createMaze() {
    Maze maze = new Maze();

    Room r1 = new RoomWithABomb(1);
    Room r2 = new RoomWithABomb(2);
    Door door = new Door(r1, r2);

    maze.addRoom(r1); maze.addRoom(r2);

    r1.setSide(MazeGame.North, new BombedWall());
    r1.setSide(MazeGame.East, door);
    r1.setSide(MazeGame.South, new BombedWall());
    r1.setSide(MazeGame.West, new BombedWall());
    ...
```



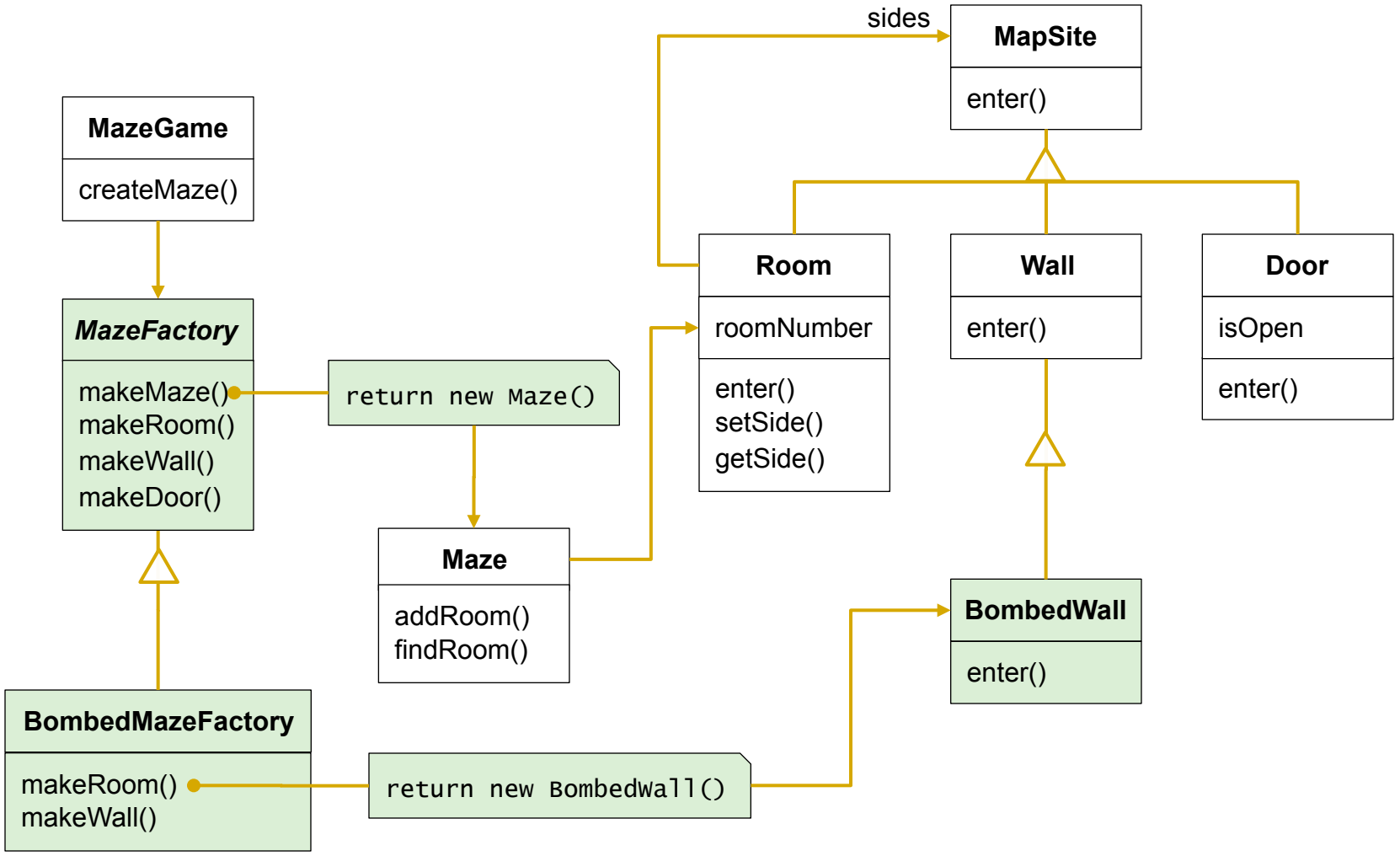
# Subclass EnchantedMazeGame

```
public class EnchantedMazeGame extends MazeGame {
  public Maze createMaze() {
    Maze maze = new Maze();

    Room r1 = new EnchantedRoom(1);
    Room r2 = new EnchantedRoom(2);
    Door door = new DoorNeedingSpell(r1, r2);

    maze.addRoom(r1); maze.addRoom(r2);

    r1.setSide(MazeGame.North, new Wall());
    r1.setSide(MazeGame.East, door);
    r1.setSide(MazeGame.South, new Wall());
    r1.setSide(MazeGame.West, new Wall());
    ...
```

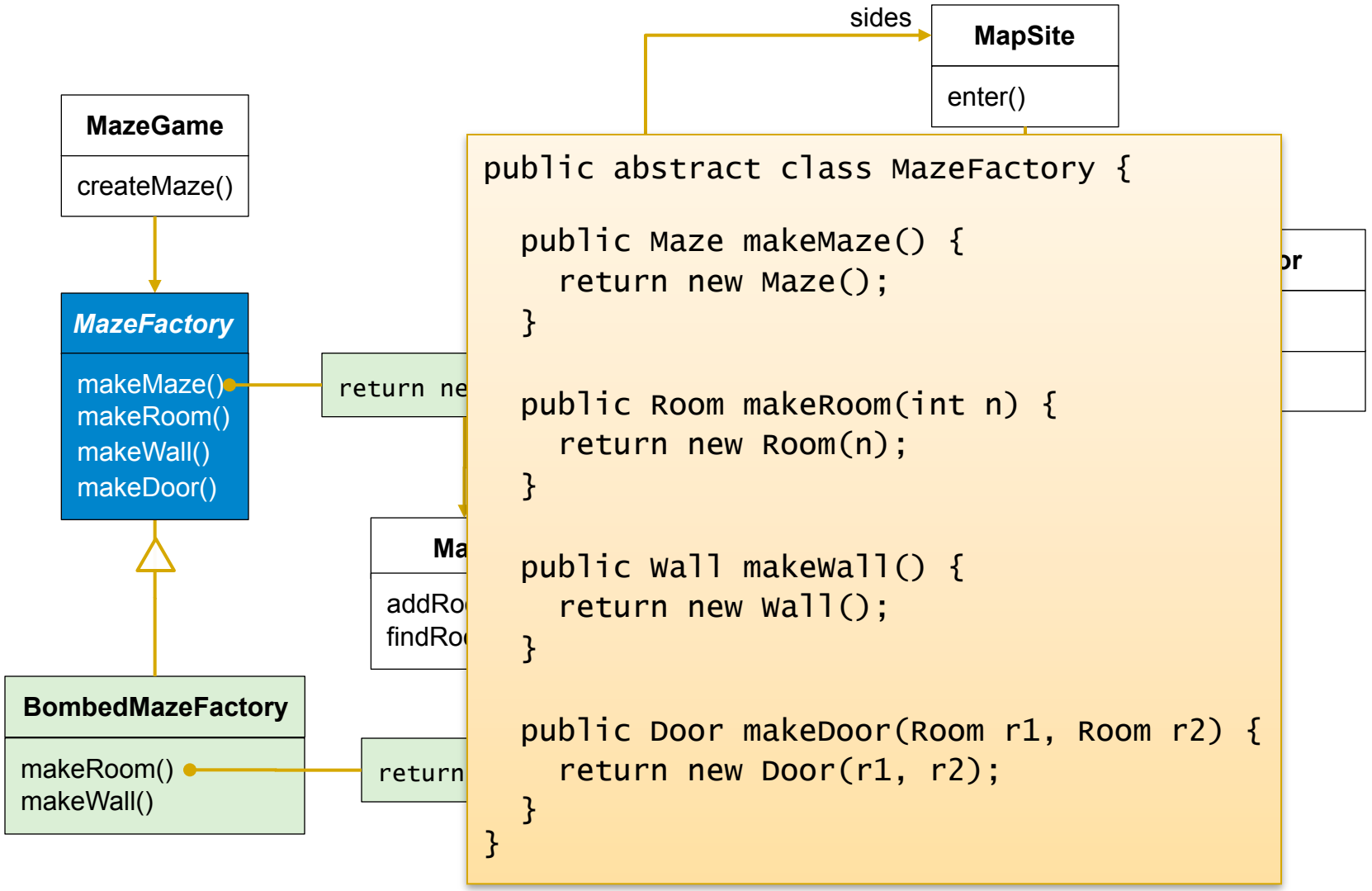



- Lots of code duplication for each type of maze... :((

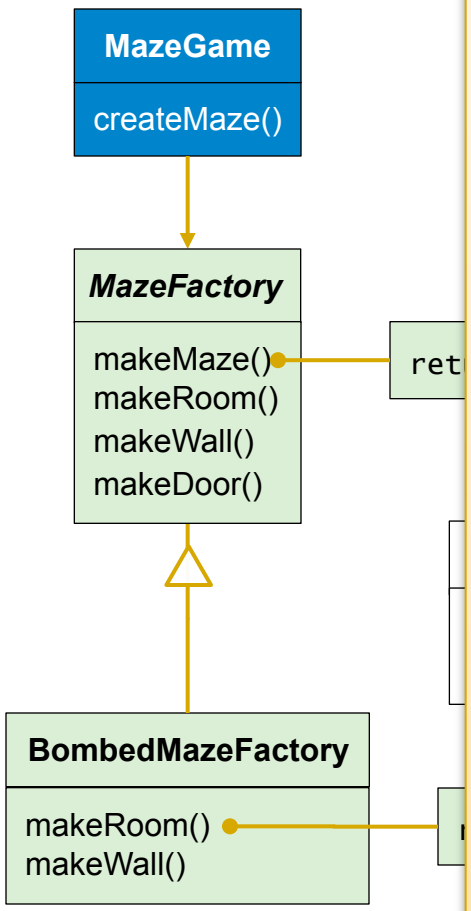
# Idea 2: Use Abstract Factory



# MazeFactory Abstract Class

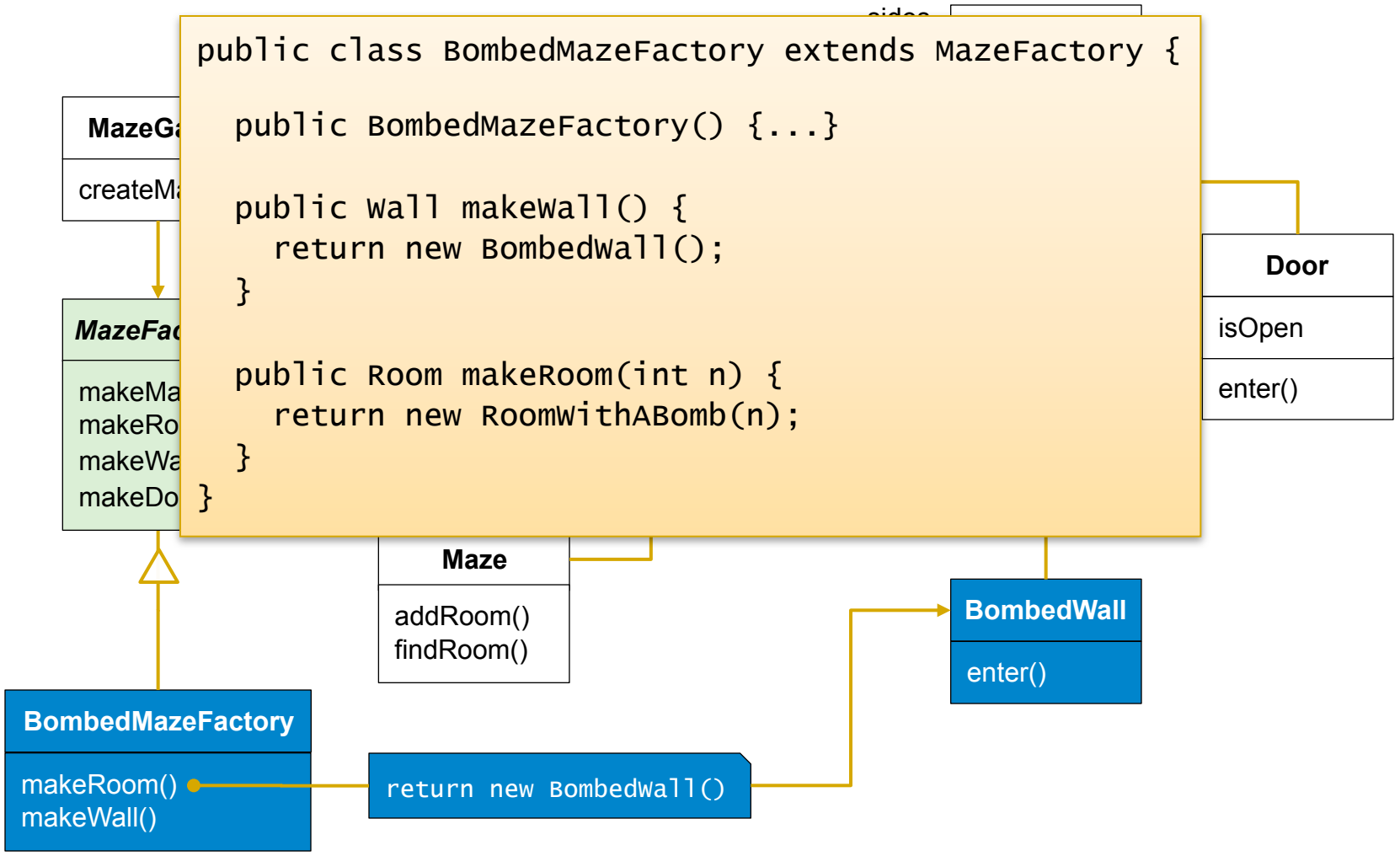


# Modified Method createMaze




```
public class MazeGame {
  public Maze createMaze(MazeFactory factory) {
    Maze maze = factory.makeMaze();

    Room r1 = factory.makeRoom(1);
    Room r2 = factory.makeRoom(2);
    Door door = factory.makeDoor(r1, r2);
    maze.addRoom(r1); maze.addRoom(r2);

    r1.setSide(MazeGame.North, factory.makeWall());
    r1.setSide(MazeGame.East, door);
    r1.setSide(MazeGame.South, factory.makeWall());
    r1.setSide(MazeGame.West, factory.makeWall());
    r2.setSide(MazeGame.North, factory.makeWall());
    r2.setSide(MazeGame.East, factory.makeWall());
    r2.setSide(MazeGame.South, factory.makeWall());
    r2.setSide(MazeGame.West, door);

    return maze;
  }
}
```

# Subclass BombedMazeFactory



# Subclass Enchanted Factory

```
public class EnchantedMazeFactory extends MazeFactory {

  public EnchantedMazeFactory() {...}

  public Room makeRoom(int n) {
    return new EnchantedRoom(n, new Spell());
  }

  public Door makeDoor(Room r1, Room r2) {
    return new DoorNeedingSpell(r1, r2);
  }
}
```

# Localizing Change in One Place: the Instantiation

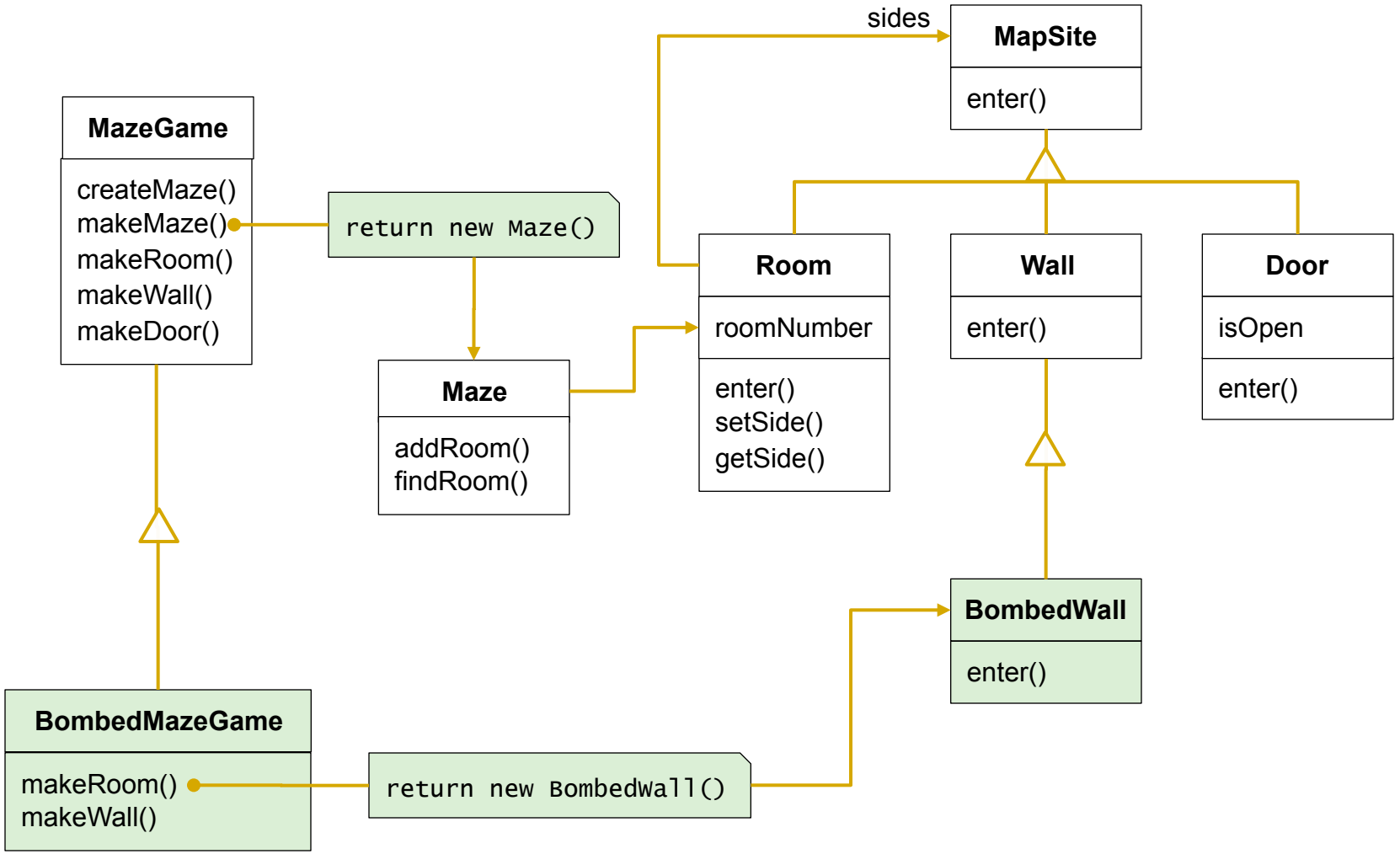
- To build an Enchanted Maze

```
MazeFactory factory = new EnchantedMazeFactory();
aMaze = game.createMaze(factory);
```

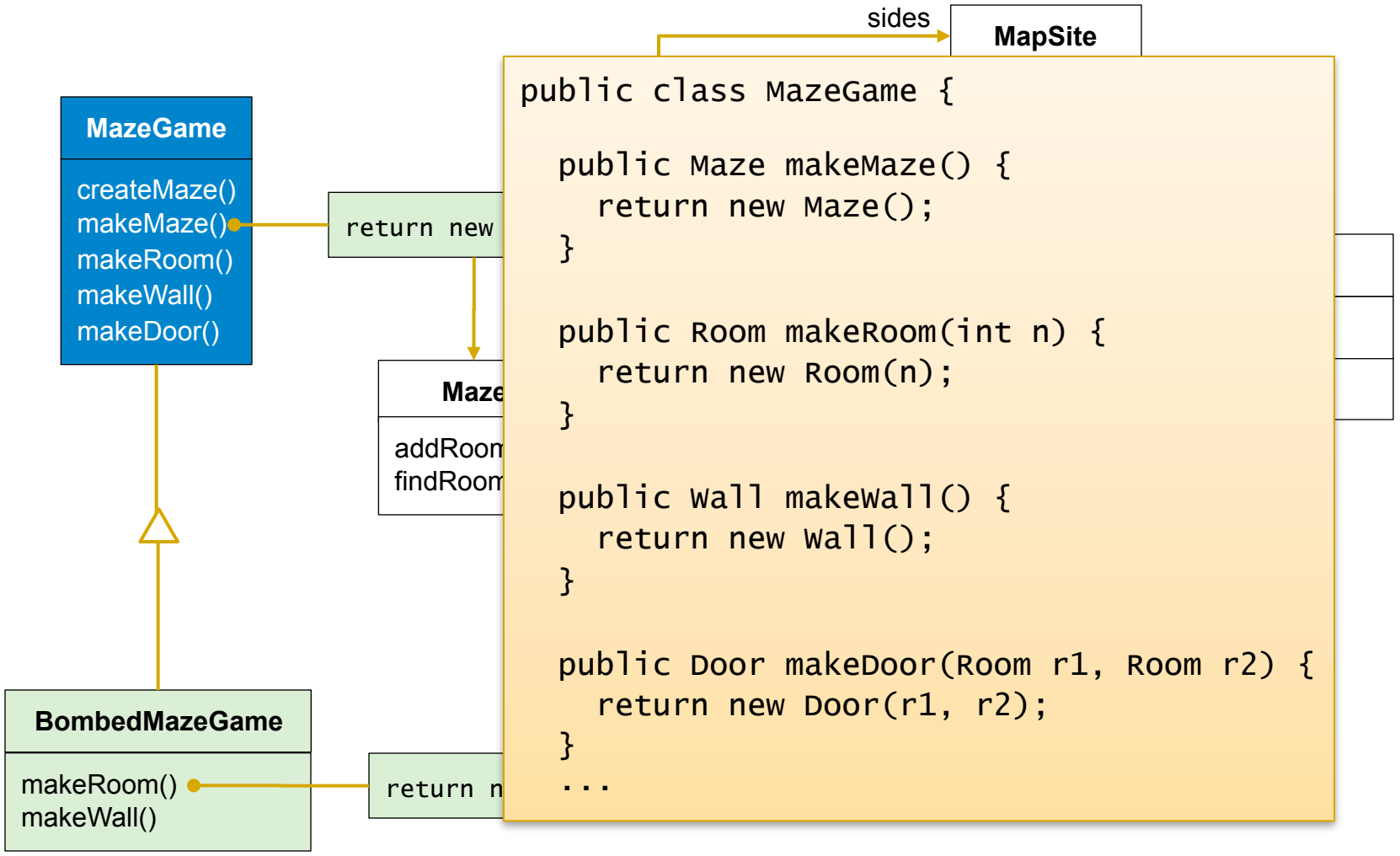
- To build a Bombed Maze

```
MazeFactory factory = new BombedMazeFactory();
maze = game.createMaze(factory);
```

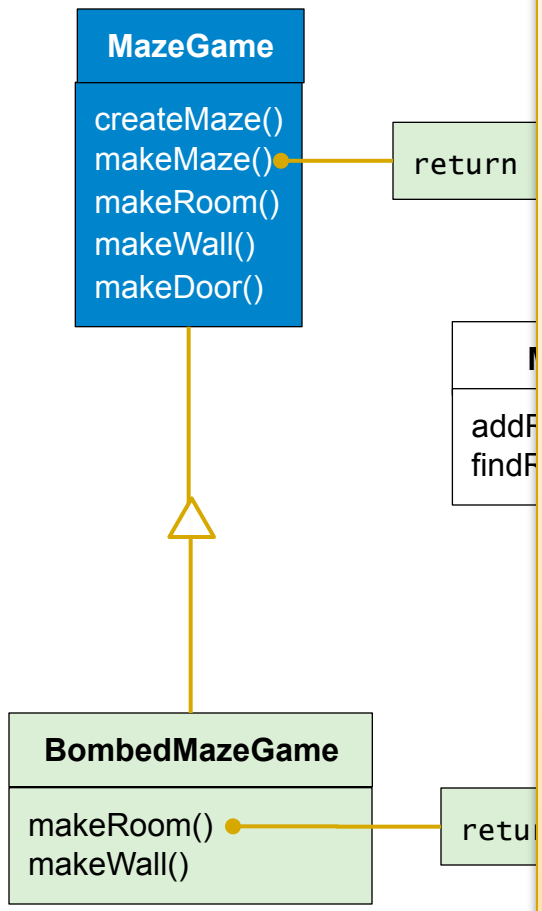
# Idea 3: Use Factory Method



# Factory Methods in MazeGame



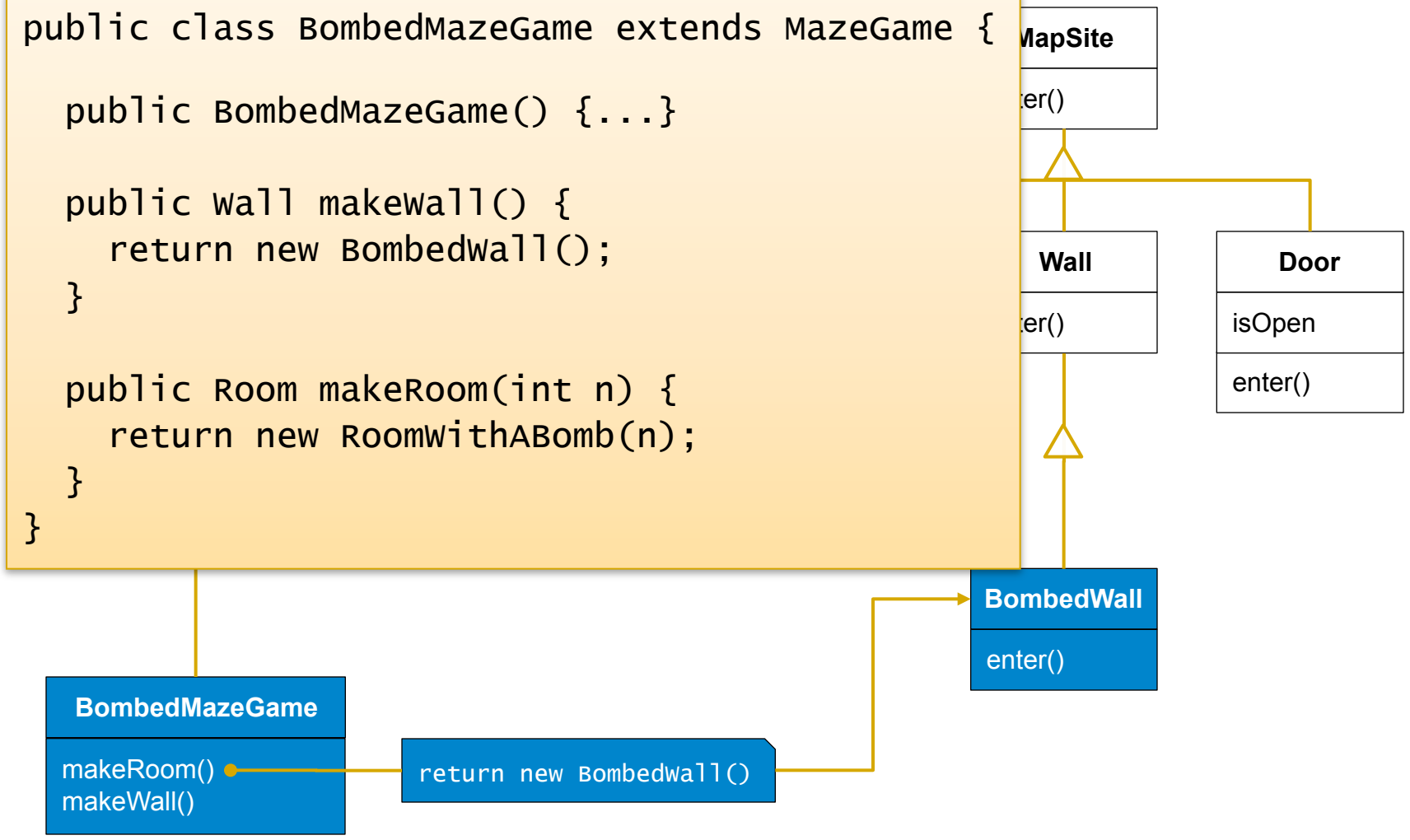
# Modified Method createMaze




```
public class MazeGame {
  public Maze createMaze() {
    Maze maze = makeMaze();

    Room r1 = makeRoom(1);
    Room r2 = makeRoom(2);
    Door door = makeDoor(r1, r2);
    maze.addRoom(r1); maze.addRoom(r2);

    r1.setSide(MazeGame.North, makeWall());
    r1.setSide(MazeGame.East, door);
    r1.setSide(MazeGame.South, makeWall());
    r1.setSide(MazeGame.West, makeWall());
    r2.setSide(MazeGame.North, makeWall());
    r2.setSide(MazeGame.East, makeWall());
    r2.setSide(MazeGame.South, makeWall());
    r2.setSide(MazeGame.West, door);

    return maze;
  }
}
```

# Subclass BombedMazeGame

```
public class BombedMazeGame extends MazeGame {

  public BombedMazeGame() {...}

  public Wall makeWall() {
    return new BombedWall();
  }

  public Room makeRoom(int n) {
    return new RoomWithABomb(n);
  }
}
```



# Abstract Factory vs. Factory Method

- In Abstract Factory, a class delegates the responsibility of object instantiation to another one via composition
- The Factory Method pattern uses inheritance to handle the desired object instantiation