Lecture 7: Design Patterns for Variable and Evolving Systems

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Today’s Goals

• Using design patterns to implement variability.
  • Strategy Pattern
  • Factory Pattern
  • Decorator Pattern
  • Adapter Pattern
  • Facade Pattern
  • Template Method Pattern
OO Design Exercise: Building a Better Duck

Duck

- quack()
- swim()
- fly()
- display()
// Other Methods

MallardDuck

display() { .. }
Adding new ducks

Duck
- quack()
- swim()
- fly()
- display()
// Other Methods

MallardDuck
- display() { .. }

RedheadDuck
- display() { .. }

RubberDuck
- display() { .. }
Why not override?

Duck
- quack()
- swim()
- fly()
- display()
// Other Methods

WoodenDuck
- display() { .. }
- @Override quack() { .. }
- @Override fly() { .. }

MallardDuck
- display() { .. }

RedheadDuck
- display() { .. }

RubberDuck
- display() { .. }
- @Override fly() { .. }
Why not interfaces?

```java
<<interface>> Flyable
fly()

<<interface>> Quackable
quack()

Duck
swim()
display()
// Other Methods

MallardDuck
display() { .. }
fly() { .. }
quack() { .. }

RedheadDuck
display() { .. }
fly() { .. }
quack() { .. }

RubberDuck
display() { .. }
quack() {... }

WoodenDuck
display() { .. }
```
How do we fix this mess?

Apply good OO design principles!

Step 1: Identify the aspects that vary and encapsulate them.
Step 2: Implement behaviors as classes

Principle - Program to interface, not implementation.

Programming to an implementation:

```java
MallardDuck d = new MallardDuck();
d.flyWithWings();
```
Requires knowing duck type and methods.

Programming to an interface:

```java
Duck d = new MallardDuck();
d.performFly();
```
Behavior called in same way for all ducks. Only implement behavior once.

(GOOD)
HAS-A can be better than IS-A
Principle: Favor composition over inheritance.
Enter... Design patterns

Don’t just describe classes, describe problems.

Patterns prescribe design guidelines for common problem types.
Guidelines, not solutions

“Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem in such a way that you can use this solution a million times over, without ever doing it the same way twice.”

- Christopher Alexander
You already applied one pattern

Strategy Pattern

Defines family of algorithms, encapsulates them, makes them interchangeable.
Factory Pattern - Motivation
Factory Pattern - Motivation

Pizza orderPizza(){
    Pizza pizza = new Pizza();
    pizza.prepare();
    pizza.bake();
    pizza.cut();
    pizza.box();
    return pizza;
}
Pizza orderPizza(String type) {
    Pizza pizza;
    if (type.equals("cheese")) {
        pizza = new CheesePizza();
    } else if (type.equals("pepperoni")) {
        pizza = new PepperoniPizza();
    }
    // Prep methods
}

Factory Pattern - Motivation

Pizza orderPizza(String type) {
    Pizza pizza;
    if (type.equals("cheese")) {
        pizza = new CheesePizza();
    } else if (type.equals("pepperoni")) {
        pizza = new PepperoniPizza();
    } else if (type.equals("kebab")) {
        pizza = new KebabPizza();
    }

    // Prep methods
}

Factory Pattern - Motivation

Pizza orderPizza(String type){

Pizza pizza;

pizza.prepare();
pizza.bake();
pizza.cut();
pizza.box();
return pizza;
}
The Simple Factory

```java
Pizza createPizza(String s) {
    if (s.equals(“Pepperoni”))
        return new PepperoniPizza();
    // Other pizza types
}
```
Franchising the Factory

PizzaStore
- PizzaFactory factory
- orderPizza(String)

NewYorkPizzaFactory
- createPizza(String)

ChicagoPizzaFactory
- createPizza(String)

<<interface>> Pizza
- prepare()
- bake()
- cut()
- box()

NYPepperoniPizza
- prepare()
- bake()
- cut()
- box()

NYCheesePizza
- prepare()
- bake()
- cut()
- box()

ChicagoPepperoniPizza
- prepare()
- bake()
- cut()
- box()

ChicagoCheesePizza
- prepare()
- bake()
- cut()
- box()
Factory Pattern - Definition

Defines interface for creating an object, lets subclasses decide which object to instantiate. Allows reasoning about creators and products.
Each factory manages a subset of the products.

Factory Pattern - In Practice

Each type of product has a defined interface.
Benefits of Factory Pattern

1. Loose coupling.
2. Creation code is centralized.
3. Easy to add new products.
4. Lowered class dependency (depend on abstractions, not concrete classes).
Let’s take a break!
The Coffee Shop Ordering System

Beverage
  description
  getDescription()
  cost()

HouseBlend
cost()

DarkRoast
cost()

Decaf
cost()

Espresso
cost()

HouseBlendWithSoy
cost()

HouseBlendWithMilk
cost()

HouseBlendWithSoyAndMocha
cost()

HouseBlendWithWhippedCream
cost()
Ordering System - Take 2

Boolean for condiment.

double cost()
{
    double total = super.cost();
    total+=29;
    return total;
}

Beverage

description
milk
soy
mocha
whip
getDescription()
cost()

// Getters/Setters for the condiments

Cost for condiments calculated in the parent, then specifics of drink added in child.

HouseBlend

cost()

DarkRoast

cost()

Decaf

cost()

Espresso

cost()
How Code Reuse is Achieved

- Inheritance allows writing code once and reusing in the children.
  - Good - changes only made once (in theory).
  - Bad - maintenance issues and inflexible design.
    - Inherit all behaviors of the parent. Might have to work around inherited features in child.

- Code can also be reused through composition.
Composition

• “Attach” an object to another object to add behaviors and attributes.
  • All Ducks have some form of flying behavior.
  • Implement behavior as a class, attach at object creation.

• Behavior extension done at runtime.
  • Dynamically change abilities of objects as system runs.

• Change a class without changing code of the class.
The Open-Closed Principle

• Classes should be open for extension, closed for modification.
  • Add new behavior without changing existing code.
  • Create class with new data and operators, attach class it is intended to extend.
  • Allow extension without direct modification.

• Do not try to apply this everywhere.
  • Focus on areas likely to change.
The Decorator Pattern

Mocha is a **decorator**. Type mirrors object it decorates.

DarkRoast inherits from Beverage, has cost() method.

Whip is a **decorator**. Type mirrors object it decorates (and anything that object decorates).

DarkRoast wrapped in Mocha and Whip is a Beverage, and can perform any Beverage function.

Through polymorphism, a Beverage wrapped in Mocha is still a Beverage.
The Decorator Pattern Defined

• Attaches responsibilities to an object dynamically.
• Flexible alternative to subclassing.
  • Decorators have same supertype as decorated object.
  • One or more decorators can wrap an object.
  • Can pass decorated object in place of the original.
  • Decorator adds its own behavior before or after calling wrapped object.
The Decorator Pattern

Decorators add new behaviors to Components

Each concrete Decorator has instance variable to store wrapped component.

Decorators add behavior by adding operations and attributes.

Component
behavior() // Other methods

ConcreteComponent
behavior() // Other methods

Decorator
behavior() // Other methods

ConcreteDecoratorA
Component wrapped
behavior() newBehavior() // Other methods

ConcreteDecoratorB
Component wrapped
Object newAttribute
behavior() // Other methods

Each Decorator offers same methods the Component offers.
double cost(){
    double total = beverage.cost();
    total+=10;
    return total;
}
The Decorator Pattern

• Uses inheritance to achieve *type matching*, but not to inherit behavior.

• By composing decorator with a component, we add new behavior to component.
  • Adds flexibility to how we mix and match behaviors.
  • Can reassign decorators at runtime.
  • Can add new behavior by writing new decorator.
Decorator Pattern Negatives

- Often results in explosion of small classes.
  - Results in hard to understand design.

- Potential type issues.
  - If code does not need specific type, decorators can be used transparently.
    - Everything is a Beverage.
  - Problems if we need to know type.
    - DarkRoast gets a discount.
Working With Other Systems

• We want to incorporate services or code from another system.
  • Their interface may be compatible with your interface.
Adapters

Your Existing System

Adapter

External System

Adapter implements the interface your class expects.

And talks to the external class to service requests.
Adapter Example

<<interface>>
Duck
quack()
fly()

MallardDuck
quack()
fly()

<<interface>>
Turkey
gobble()
fly()

TurkeyAdapter
Turkey adaptee
quack()
fly()

WildTurkey

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The Adapter Pattern Defined

• Converts an interface into interface client expects.
  • **Adapter**’s methods call corresponding methods from adaptee.
  • If adaptee changes, only the adapter needs to change.
    • No changes needed to classes that call adapter.
The Adapter Pattern

Client

<<interface>>

Target

request()

Adapter

Adaptee adaptee

request()

Adapter implements target interface.

Requests get delegated to Adaptee.

The client sees only the target interface.

Adapter composed with Adaptee.
Let’s take a break!
Watching a Movie

To watch a movie, we need to perform a few tasks:

1. Turn on the popcorn popper.
2. Start the popper.
3. Dim the lights.
4. Put the screen down.
5. Turn the projector on.
6. Set the projector input to blu-ray.
7. Put the projector on widescreen mode.
8. Turn the sound amplifier on.
9. Set the amplifier to DVD input.
10. Set the amplifier to surround sound.
11. Set the amplifier volume to medium.
12. Turn the blu-ray player on.
13. Start the blu-ray.
Wrapping Classes

- The Adapter Pattern converts the interface of a class into one the client is expecting.
- The Decorator Pattern doesn’t alter an interface, but wraps classes in new functionality.
- The Facade Pattern simplifies interactions by hiding complexity behind a clean, easy-to-understand interface.
  - Wrapping classes into a shared interface.
The Facade Pattern

- Create a new class that exposes simple methods (the *facade*).
- Facade calls on classes to implement high-level methods.
- Client calls facade instead of classes.
- Classes still accessible.
The Facade Pattern Defined

• Provides a unified interface to a set of classes.
• Facade defines a high-level interface that makes a subsystem easier to use.
  • Provides an additional method of access.
  • Multiple facades may provide situational functions.
  • Decouples client from any one subsystem.
The Facade Pattern

Client

Facade
// Methods

Subsystem Classes
The Principle of Least Knowledge

• Talk only to your immediate friends.

• Be careful of the number of classes your class interacts with and how it interacts with them.

• Only invoke methods that belong to the object, objects passed as parameters, objects created or instantiated, and attached objects.
Coffee and Tea

Starbucks Coffee Barista Training Manual

Baristas! Please follow these recipes precisely when preparing Starbucks beverages.

**Starbucks Coffee Recipe**

1. Boil some water
2. Brew coffee in boiling water
3. Pour coffee in cup
4. Add sugar and milk

**Starbucks Tea Recipe**

1. Boil some water
2. Steep tea in boiling water
3. Pour tea in cup
4. Add lemon

All recipes are Starbucks Coffee trade secrets and should be kept strictly confidential.

The recipe for coffee looks a lot like the recipe for tea, doesn't it?
Coffee and Tea (In Code)

**Coffee**
- prepareRecipe()
- boilWater()
- brewCoffeeGrinds()
- pourInCup()
- addSugarAndMilk()

```java
void prepareRecipe(){
    boilWater();
    brewCoffeeGrinds();
    pourInCup();
    addSugarAndMilk();
}
```

**Tea**
- prepareRecipe()
- boilWater()
- steepTeaBag()
- pourInCup()
- addLemon()

```java
void prepareRecipe(){
    boilWater();
    steepTeaBag();
    pourInCup();
    addLemon();
}
```
Coffee and Tea (In Code) - Take 2

Coffee
- prepareRecipe()
- brewCoffeeGrinds()
- addSugarAndMilk()

Tea
- prepareRecipe()
- steepTeaBag()
- addLemon()

CaffeineBeverage
- prepareRecipe()
- boilWater()
- pourInCup()
Back to the Recipes

Algorithm
1) Boil some water.
2) Use hot water to extract the beverage from a solid form.
3) Pour the beverage into a cup.
4) Add appropriate condiments to the beverage.

- Steps 1 and 3 already abstracted into base class.
- Steps 2 and 4 not abstracted, but are the same concept applied to different beverages.
Abstracting `prepareRecipe()`

- **Coffee**: `brewCoffeeGrinds()`, `addSugarAndMilk()`
- **Tea**: `steepTeaBag()`, `addLemon()`.
  - Steeping and brewing aren’t all that different (`brew()`).
  - Adding sugar is like adding lemon (`addCondiments()`).

```java
void prepareRecipe() {
    boilWater();
    brew();
    pourInCup();
    addCondiments();
}
```
Our Redesigned Code

public abstract class CaffeineBeverage {
    final void prepareRecipe() {
        boilWater();
        brew();
        pourInCup();
        addCondiments();
    }

    abstract void brew();
    abstract void addCondiments();

    void boilWater() {
        System.out.println("Boiling water");
    }

    void pourInCup() {
        System.out.println("Pouring into cup");
    }
}

Now, the same prepareRecipe() method will be used to make both Tea and Coffee. prepareRecipe() is declared final because we don’t want our subclasses to be able to override this method and change the recipe! We’ve generalized steps 2 and 4 to brew() the beverage and addCondiments().

Because Coffee and Tea handle these methods in different ways, they’re going to have to be declared as abstract. Let the subclasses worry about that stuff!

Remember, we moved these into the CaffeineBeverage class (back in our class diagram).

CaffeineBeverage
- prepareRecipe()
- brew()
- addCondiments()
- boilWater()
- pourInCup()

Tea
- brew()
- addCondiments()

Coffee
- brew()
- addCondiments()
What Have We Done?

• Two recipes are the same, although some steps require *different implementations*.

• Generalized recipe into a base class.
  • CaffeineBeverage controls the steps of the recipe. It performs common steps itself.
    • (*encapsulating what does not change...*)
  • It relies on subclasses to implement unique steps.
    • (*... from what does change*)
The Template Method Pattern

• `prepareRecipe()` is our **template method**.
  • Serves as a template for an algorithm.
• Each step is represented by a method.
• Some methods handled by the base class, others by the subclasses.
  • The supplied methods are declared abstract.
What Does the Template Method Get Us?

Original Implementation

- Coffee and Tea control algorithm.
- Code duplicated in Coffee and Tea.
- Changes to algorithm require changes to the subclasses.
- Classes are organized in a structure that requires more work to add a new beverage.
- Knowledge of algorithm and how to implement it distributed over multiple classes.

Template Method:

- CaffeineBeverage controls and protects the algorithm, implements common code.
- Algorithm lives in one place and changes only made there.
- Template Method allows new beverages to be added. They implement specialized methods.
- CaffeineBeverage class contains all knowledge about algorithm, relies on subclasses to provide implementations.
The Template Method Pattern

• Defines skeleton of an algorithm in a method, deferring some steps to subclasses.

• Lets subclasses redefine steps of an algorithm without changing the algorithm’s structure.

• A template defines an algorithm as a set of steps.
  • Abstract steps are implemented by subclasses.
  • Ensures algorithm’s structure stays unchanged.
Template Method Pattern

The AbstractClass contains the template method.
...and abstract versions of the operations used in the template method.

The template method makes use of the primitiveOperations to implement an algorithm. It is decoupled from the actual implementation of these operations.

There may be many ConcreteClasses, each implementing the full set of operations required by the template method.

The ConcreteClass implements the abstract operations, which are called when the templateMethod() needs them.
Looking Inside the Code

Here we have our abstract class; it is declared abstract and meant to be subclassed by classes that provide implementations of the operations.

```java
abstract class AbstractClass {
    final void templateMethod() {
        primitiveOperation1();
        primitiveOperation2();
        concreteOperation();
    }

    abstract void primitiveOperation1();
    abstract void primitiveOperation2();

    void concreteOperation() {
        // implementation here
    }
}
```

Here’s the template method. It’s declared final to prevent subclasses from reworking the sequence of steps in the algorithm.

The template method defines the sequence of steps, each represented by a method.

In this example, two of the primitive operations must be implemented by concrete subclasses.

We also have a concrete operation defined in the abstract class. More about these kinds of methods in a bit...
Adding Hooks

- Parent defines concrete default implementations (hooks).
  - Subclasses can override, but do not have to.
  - Gives subclasses ability to “hook into” the algorithm.

```java
class CaffeineBeverage {
    void prepareRecipe() {
        boilWater();
        brew();
        pourInCup();
        if (wantsCondiments()) {
            addCondiments();
        }
    }
}

boolean wantsCondiments() {
    return true;
}
```
The Hollywood Principle

• Don’t call us, we’ll call you.
• Prevents “dependency rot”.
  • High-level components depend on low-level components, low-level depend on high level.
• Allows low-level components to hook into a system, but high-level components decide when and how they are needed.
Principles of Design

1. Identify aspects that vary and encapsulate them away from what doesn’t.
2. Program to interface rather than implementation.
3. Favor composition over inheritance.
4. Open for extension, but closed for modification.
5. Talk only to your immediate friends.
6. Don’t call us, we’ll call you.
Why not use a design pattern?

What are the drawbacks to using patterns?

• Potentially over-engineered solution.
• Increased system complexity.
• Design inefficiency.

How can we avoid these pitfalls?
We Have Learned

• Design patterns allow implementation and management of variability in code.
  • Strategy Pattern encapsulates interchangeable behaviors and uses delegation to decide which to use.
  • Factory Pattern encapsulates object creation so system doesn’t need to know what type of object was created.
  • Decorator Pattern wraps an object in another to provide new behavior without code changes.
We Have Learned

- Design patterns allow implementation and management of variability in code.
  - Adapter Pattern wraps object in a new interface.
  - Facade Pattern wraps a set of classes in simplified interfaces.
  - Template Method Pattern encapsulates pieces of algorithms so that subclasses can hook into a computation.
Next Time

• Modularity

• Assignment 2 due Sunday. Any questions?