04834580 Software Engineering (Honor Track) 2024-25

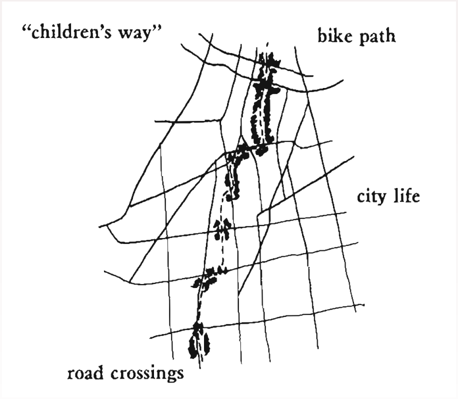
Creational & Structural Design Patterns

Sergey Mechtaev
mechtaev@pku.edu.cn
School of Computer Science, Peking University

Patterns In Architecture

In “A Pattern Language” [1], Christopher Alexander wrote

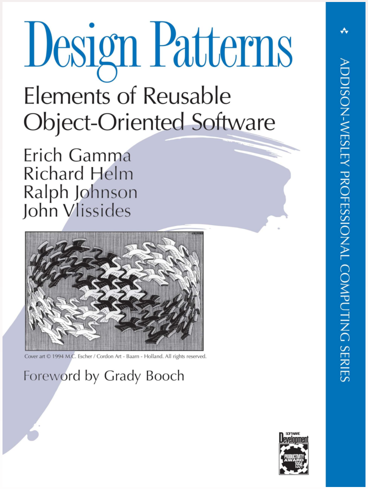
> *Each patterns describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over...*



Patterns In Software Engineering

The "Gang of Four" [2] introduced patterns for software design:

- Creational:
  - Singleton
  - Factory
  - Builder
  - ...
- Structural:
  - Adapter
  - Decorator
  - ...
- Behavioral:
  - Template Method
  - Iterator
  - Visitor
  - Observer
  - ...


Design Patterns
Elements of Reusable Object-Oriented Software
Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides
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Foreword by Grady Booch
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Singleton

Definition ([2])

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

Erich Gamma:

> "I'am in favor of dropping Singleton. Its use is almost always a design smell".

Singleton: Simple Implementation

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```
public final class Singleton {
    private static final Singleton INSTANCE = new Singleton();

    private Singleton() {}

    public static Singleton getInstance(){
      return INSTANCE;
    }
}
```

Singleton: Thread-Safe Lazy Initialization

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```java
public final class Singleton {
    private static volatile Singleton instance = null;

    private Singleton() {}

    public static synchronized Singleton getInstance() {
        if (instance == null) {
            instance = new Singleton();
        }
        return instance;
    }
}
```

Singleton: Double-Checked Locking

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```
public final class Singleton {
    private static volatile Singleton instance = null;

    private Singleton() {}

    public static Singleton getInstance() {
        if (instance == null) {
            synchronized(Singleton.class) {
                if (instance == null) {
                    instance = new Singleton();
                }
            }
        }
        return instance;
    }
}
```

Singleton: Rust Implementation

Rust does not allow directly using global mutable variables.

```rust
use std::sync::Mutex;

static ARRAY: Mutex<Vec<i32>> = Mutex::new(Vec::new());

fn do_a_call() {
    ARRAY.lock().unwrap().push(1);
}

fn main() {
    do_a_call();
    do_a_call();
    do_a_call();

    let array = ARRAY.lock().unwrap();
    println!("Called {} times: {:?}", array.len(), array);
    drop(array);

    *ARRAY.lock().unwrap() = vec![3, 4, 5];

    println!("New singleton object: {:?}", ARRAY.lock().unwrap());
}
```

Factory Method

Definition ([2])

Define an interface for creating an object, but let subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.

Factory Method: Base Creator

Example: different types of dialogs (Windows, Mac, HTML, etc) require their own types of elements. That's why we create a subclass for each dialog type and override their factory methods.

```java
public abstract class Dialog {

    public void renderWindow() {
        // ... other code ...

        Button okButton = createButton();
        okButton.render();
    }

    public abstract Button createButton();
}
```

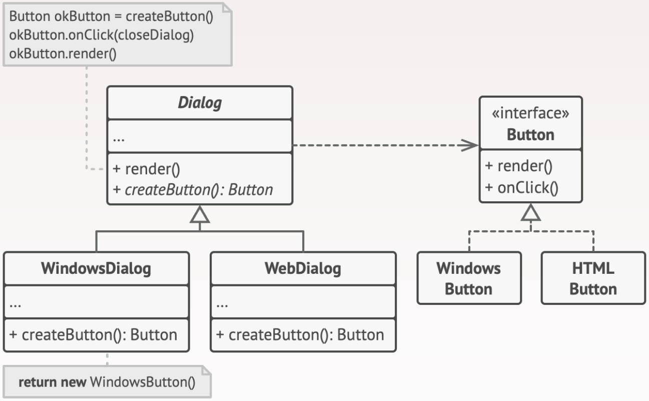
Factory Method: Concrete Creator

Now, each dialog type will instantiate proper button classes. Base dialog works with products using their common interface, that's why its code remains functional after all changes.

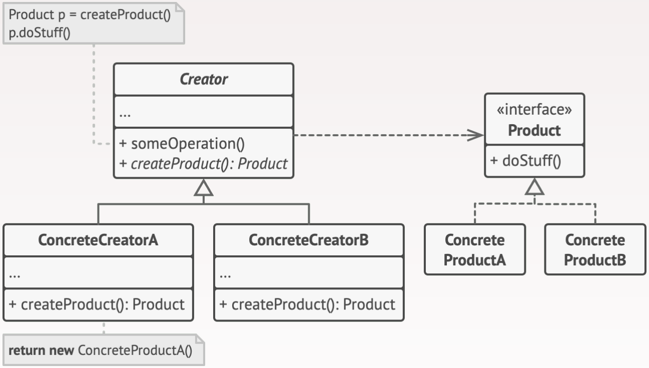
```
public class HtmlDialog extends Dialog {

    @Override
    public Button createButton() {
        return new HtmlButton();
    }
}
```

Factory: Example Structure



Factory: General Structure



Builder

Definition ([2])

Separate the construction of a complex object from its representations so that the same construction process can create different representations.

Builder: Interface

In this example, the Builder pattern allows step by step construction of different car models.

```
public interface Builder {
    void setCarType(CarType type);
    void setSeats(int seats);
    void setEngine(Engine engine);
    void setTransmission(Transmission transmission);
    void setTripComputer(TripComputer tripComputer);
    void setGPSNavigator(GPSNavigator gpsNavigator);
}
```

Builder: Implementation

```java
public class CarBuilder implements Builder {
    private CarType type;
    private int seats;
    private Engine engine;
    private Transmission transmission;
    private TripComputer tripComputer;
    private GPSNavigator gpsNavigator;

    @Override
    public void setSeats(int seats) {
        this.seats = seats;
    }

    @Override
    public void setEngine(Engine engine) {
        this.engine = engine;
    }

    ...
}
```

Builder: Implementation Continued

```
public class CarBuilder implements Builder {

    ...

    public Car getResult() {
        return new Car(type, seats, engine, transmission, tripComputer, gpsNavigator);
    }
}
```

Builder: Rust's Clap Library

```
Command::new("git")
    ...
    .subcommand(
        Command::new("diff")
            .about("Compare two commits")
            .arg(arg!(base: [COMMIT]))
            .arg(arg!(head: [COMMIT]))
            .arg(arg!(path: [PATH]).last(true))
            .arg(
                arg!(--color <WHEN>)
                    .value_parser(["always", "auto", "never"])
                    .num_args(0..=1)
                    .require_equals(true)
                    .default_value("auto")
                    .default_missing_value("always"),
            ),
    )
```

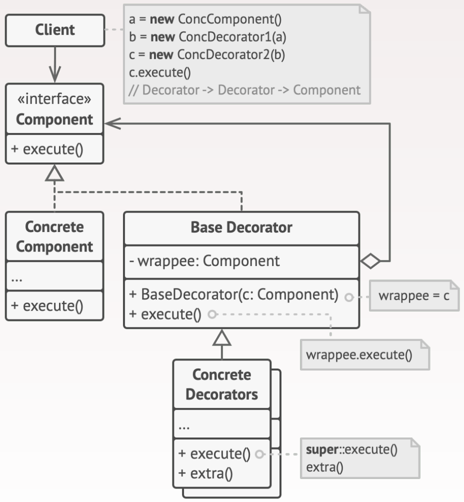
Check examples: `https://github.com/clap-rs/clap/tree/master/examples`

Decorator

Definition ([2])

Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.

Decorator: General Structure

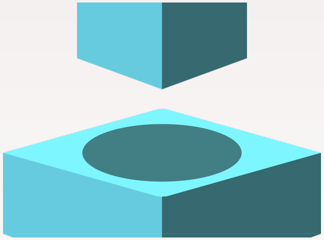


Adapter

Definition ([2])

Convert the interface of a class into another interface clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.

Adapter: Example



```
public class RoundHole {
    private double radius;

    public RoundHole(double radius) {
        this.radius = radius;
    }

    public double getRadius() {
        return radius;
    }

    public boolean fits(RoundPeg peg) {
        boolean result;
        result = (this.getRadius() >= peg.getRadius());
        return result;
    }
}
```

Adapter: Example

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RoundPegs are compatible with RoundHoles:

```java
public class RoundPeg {
    private double radius;

    public RoundPeg() {}

    public RoundPeg(double radius) {
        this.radius = radius;
    }

    public double getRadius() {
        return radius;
    }
}
```

Adapter: Example

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SquarePegs are **incompatible** with RoundHoles:

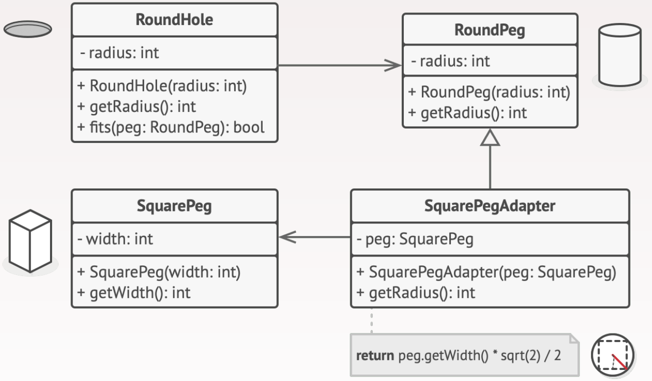
```java
public class SquarePeg {
    private double width;

    public SquarePeg(double width) {
        this.width = width;
    }

    public double getWidth() {
        return width;
    }

    public double getSquare() {
        double result;
        result = Math.pow(this.width, 2);
        return result;
    }
}
```

Adapter: Example

This adapter allows fitting square pegs into round holes:

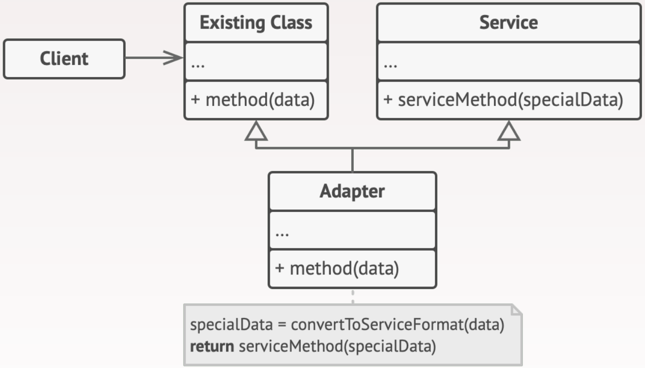
```java
public class SquarePegAdapter extends RoundPeg {
    private SquarePeg peg;

    public SquarePegAdapter(SquarePeg peg) {
        this.peg = peg;
    }

    @Override
    public double getRadius() {
        double result;
        // Calculate a minimum circle radius, which can fit this peg.
        result = (Math.sqrt(Math.pow((peg.getWidth() / 2), 2) * 2));
        return result;
    }
}
```

Adapter: Example Structure



```
return peg.getWidth() * sqrt(2) / 2
```

Adapter: General Structure



```
specialData = convertToServiceFormat(data)
return serviceMethod(specialData)
```

References I

[1] Christopher Alexander.
A pattern language: towns, buildings, construction.
Oxford university press, 1977.

[2] Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides.
Design patterns: elements of reusable object-oriented software.
Pearson Deutschland GmbH, 1995.