Object-Oriented Programming and Design with Java

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1 Introduction to Design Patterns

1.1 What's a design pattern?

Design patterns are typical solutions to commonly occurring problems in software design. They are like pre-made blueprints that you can customize to solve a recurring design problem in your code.

You can't just find a pattern and copy it into your program, the way you can with off-the-shelf functions or libraries. The pattern is not a specific piece of code, but a general concept for solving a particular problem. You can follow the pattern details and implement a solution that suits the realities of your own program.

Patterns are often confused with algorithms, because both concepts describe typical solutions to some known problems. While an algorithm always defines a clear set of actions that can achieve some goal, a pattern is a more high-level description of a solution. The code of the same pattern applied to two different programs may be different.

An analogy to an algorithm is a cooking recipe: both have clear steps to achieve a goal. On the other hand, a pattern is more like a blueprint: you can see what the result and its features are, but the exact order of implementation is up to you.

1.1.1 What does the pattern consist of?

Most patterns are described very formally so people can reproduce them in many contexts. Here are the sections that are usually present in a pattern description:

- **Intent** of the pattern briefly describes both the problem and the solution.
- **Motivation** further explains the problem and the solution the pattern makes possible.
- **Structure** of classes shows each part of the pattern and how they are related.
- **Code example** in one of the popular programming languages makes it easier to grasp the idea behind the pattern.

Some pattern catalogs list other useful details, such as applicability of the pattern, implementation steps and relations with other patterns.

1.2 History of patterns

Who invented patterns? That's a good, but not a very accurate, question. Design patterns aren't obscure, sophisticated concepts—quite the opposite. Patterns are typical solutions to common problems in object-oriented design. When a solution gets repeated over and over in various projects, someone eventually puts a name to it and describes the solution in detail. That's basically how a pattern gets discovered.

The concept of patterns was first described by Christopher Alexander in A Pattern Language: Towns, Buildings, Construction. The book describes a "language" for designing the urban environment. The units of this language are patterns. They may describe how high windows should be, how many levels a building should have, how large green areas in a neighborhood are supposed to be, and so on.

The idea was picked up by four authors: Erich Gamma, John Vlissides, Ralph Johnson, and Richard Helm. In 1994, they published Design Patterns: Elements of Reusable Object-Oriented Software, in which they applied the concept of design patterns to programming. The book featured 23 patterns solving various problems of object-oriented design and became a best-seller very quickly. Due to its lengthy name, people started to call it "the book by the gang of four" which was soon shortened to simply "the GoF book".

Since then, dozens of other object-oriented patterns have been discovered. The "pattern approach" became very popular in other programming fields, so lots of other patterns now exist outside of object-oriented design as well.

1.3 Why should I learn patterns?

The truth is that you might manage to work as a programmer for many years without knowing about a single pattern. A lot of people do just that. Even in that case, though, you might be implementing some patterns without even knowing it. So why would you spend time learning them?

- Design patterns are a toolkit of tried and tested solutions to common problems in software design. Even if you never encounter these problems, knowing patterns is still useful because it teaches you how to solve all sorts of problems using principles of object-oriented design.

- Design patterns define a common language that you and your teammates can use to communicate more efficiently. You can say, "Oh, just use a Singleton for that," and everyone will understand the idea behind your suggestion. No need to explain what a singleton is if you know the pattern and its name.

1.4 Classification of patterns

Design patterns differ by their complexity, level of detail and scale of applicability to the entire system being designed. I like the analogy to road construction: you can make an intersection safer by either installing some traffic lights or building an entire multi-level interchange with underground passages for pedestrians.

The most basic and low-level patterns are often called idioms. They usually apply only to a single programming language.

The most universal and high-level patterns are architectural patterns. Developers can implement these patterns in virtually any language. Unlike other patterns, they can be used to design the architecture of an entire application.

In addition, all patterns can be categorized by their intent, or purpose. This book covers three main groups of patterns:

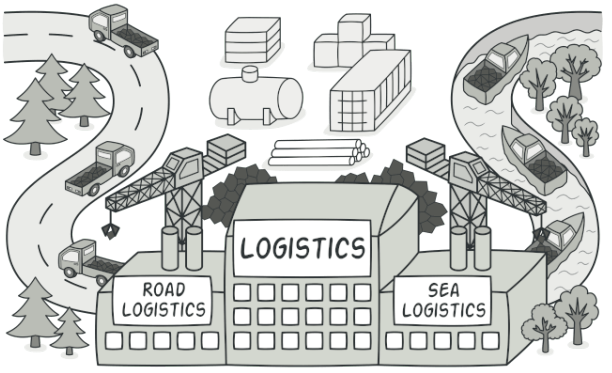
- **Creational patterns** provide object creation mechanisms that increase flexibility and reuse of existing code.
- **Structural patterns** explain how to assemble objects and classes into larger structures, while keeping these structures flexible and efficient.
- **Behavioral patterns** take care of effective communication and the assignment of responsibilities between objects.

2 Creational Design Patterns

2.1 Factory Method

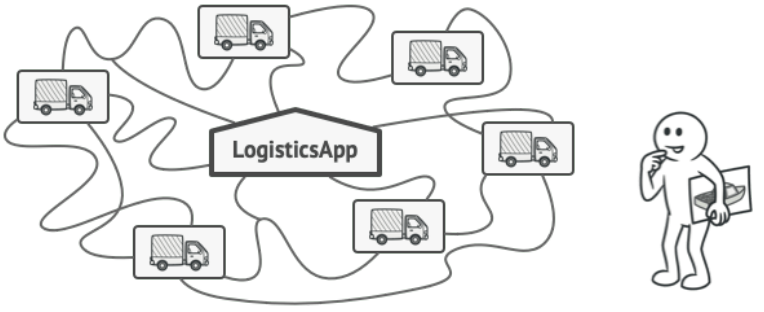
2.1.1 Intent

Factory Method is a creational design pattern that provides an interface for creating objects in a superclass, but allows subclasses to alter the type of objects that will be created.



2.1.2 Problem

Imagine that you're creating a logistics management application. The first version of your app can only handle transportation by trucks, so the bulk of your code lives inside the Truck class.



Adding a new class to the program isn't that simple if the rest of the code is already coupled to existing classes.

After a while, your app becomes pretty popular. Each day you receive dozens of requests from sea transportation companies to incorporate sea logistics into the app.

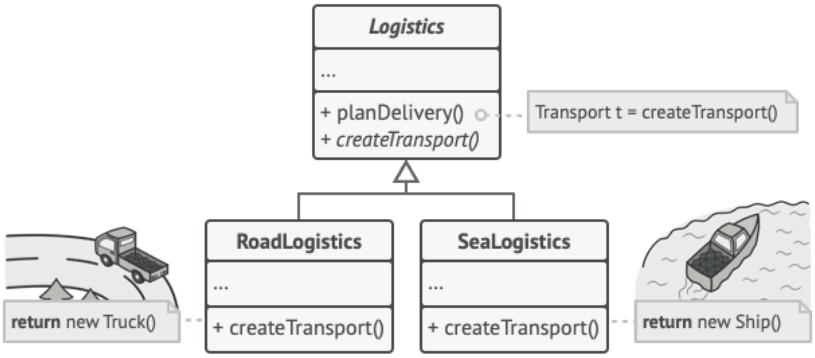
Great news, right? But how about the code? At present, most of your code is coupled to the Truck class. Adding Ships into the app would require making changes to the entire codebase. Moreover, if later you decide to add another type of transportation to the app, you will probably need to make all of these changes again.

As a result, you will end up with pretty nasty code, riddled with conditionals that switch the app's behavior depending on the class of transportation objects.

2.1.3 Solution

The **Factory Method** pattern suggests that:

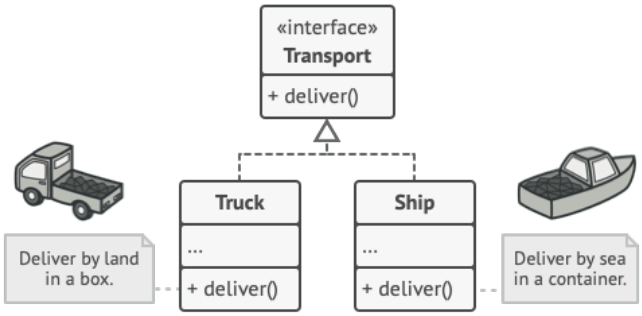
- You replace direct object construction calls (using the new operator) with calls to a special factory method.
- Don't worry: the objects are still created via the new operator, but it's being called from within the factory method.
- Objects returned by a factory method are often referred to as *products*.



Subclasses can alter the class of objects being returned by the factory method.

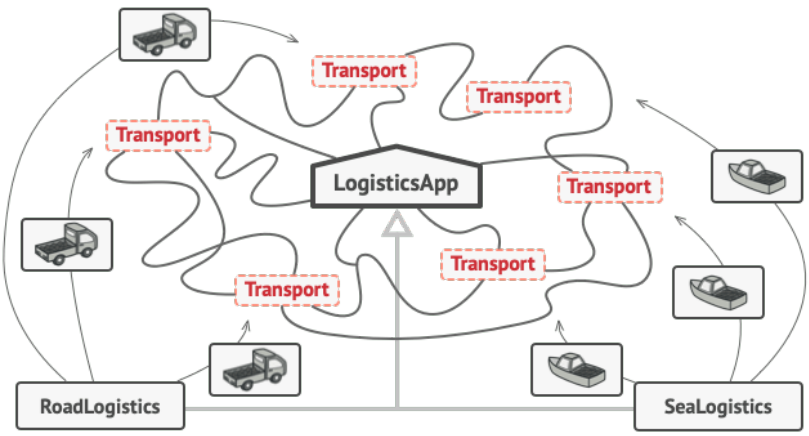
At first glance, this change may look pointless: we just moved the constructor call from one part of the program to another. However, consider this: now you can override the factory method in a subclass and change the class of products being created by the method.

There's a slight limitation though: *subclasses may return different types of products only if these products have a common base class or interface.* Also, the factory method in the base class should have its return type declared as this interface.



All products must follow the same interface.

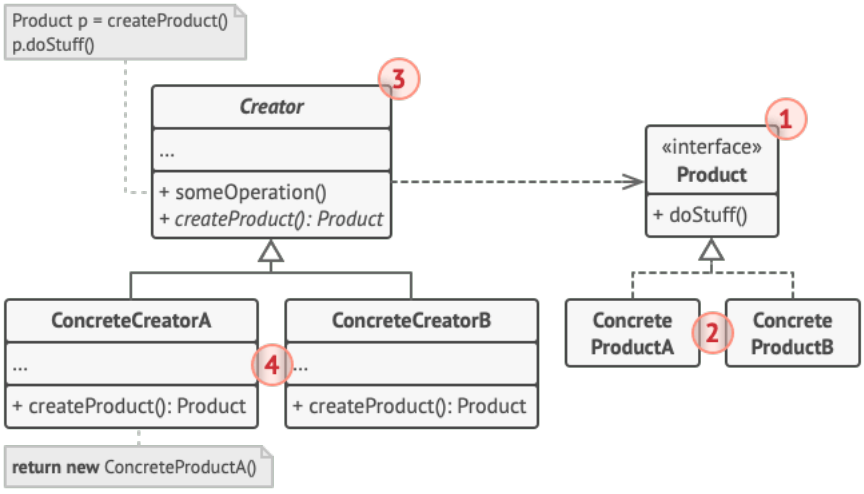
For example, both Truck and Ship classes should implement the Transport interface, which declares a method called *deliver*. Each class implements this method differently: trucks deliver cargo by land, ships deliver cargo by sea. The factory method in the RoadLogistics class returns truck objects, whereas the factory method in the SeaLogistics class returns ships.



As long as all product classes implement a common interface, you can pass their objects to the client code without breaking it.

The code that uses the factory method (often called the client code) doesn't see a difference between the actual products returned by various subclasses. The client treats all the products as abstract Transport. The client knows that all transport objects are supposed to have the *deliver method*, but exactly how it works isn't important to the client.

2.1.4 Structure



1. The Product declares the interface, which is common to all objects that can be produced by the creator and its subclasses.

2. Concrete Products are different implementations of the product interface.

3. The Creator class declares the factory method that returns new product objects. It's important that the return type of this method matches the product interface.

   You can declare the factory method as abstract to force all subclasses to implement their own versions of the method. As an alternative, the base factory method can return some default product type.

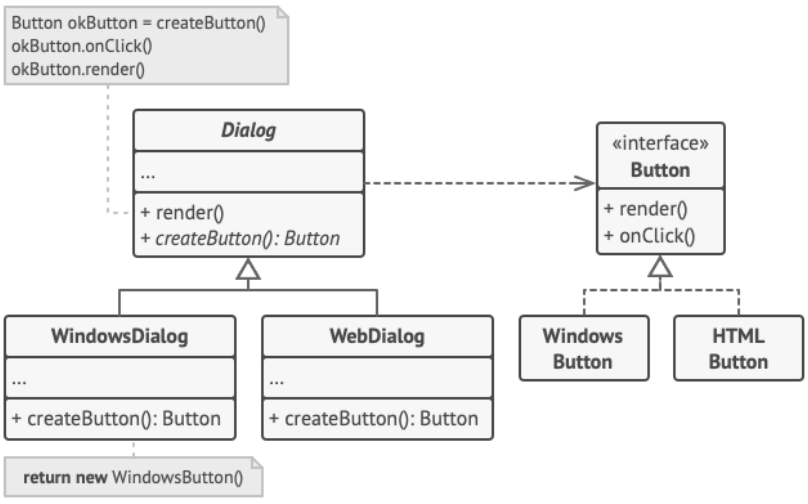
   Note, despite its name, product creation is NOT the primary responsibility of the creator. Usually, the creator class already has some core business logic related to products. The factory method helps to decouple this logic from the concrete product classes. Here is an analogy: a large software development company can have a training department for programmers. However, the primary function of the company as a whole is still writing code, not producing programmers.

4. Concrete Creators override the base factory method so it returns a different type of product.

   Note that the factory method doesn't have to create new instances all the time. It can also return existing objects from a cache, an object pool, or another source.

2.1.5 Pseudocode

This example illustrates how the Factory Method can be used for creating cross-platform UI elements without coupling the client code to concrete UI classes.



The cross-platform dialog example.

The base Dialog class uses different UI elements to render its window. Under various operating systems, these elements may look a little bit different, but they should still behave consistently. A button in Windows is still a button in Linux.

When the factory method comes into play, you don't need to rewrite the logic of the Dialog class for each operating system. If we declare a factory method that produces buttons inside the base Dialog class, we can later create a subclass that returns Windows-styled buttons from the factory method. The subclass then inherits most of the code from the base class, but, thanks to the factory method, can render Windows-looking buttons on the screen.

For this pattern to work, the base Dialog class must work with abstract buttons: a base class or an interface that all concrete buttons follow. This way the code within Dialog remains functional, whichever type of buttons it works with.

Of course, you can apply this approach to other UI elements as well. However, with each new factory method you add to the Dialog, you get closer to the Abstract Factory pattern. Fear not, we'll talk about this pattern later.

PSEUDO CODE

```
// The creator class declares the factory method that must return an object
//   of a product class. The creator's subclasses usually provide the
//   implementation of this method.
class Dialog is
  // The creator may also provide some default implementation
  //   of the factory method.
  abstract method createButton():Button

  // Note that, despite its name, the creator's primary responsibility isn't
  //   creating products. It usually contains some core business logic that
  //   relies on product objects returned by the factory method. Subclasses can
  //   indirectly change that business logic by overriding the factory method
  //   and returning a different type of product from it.
  method render() is
    // Call the factory method to create a product object.
    Button okButton = createButton()
    // Now use the product.
    okButton.onClick()
    okButton.render()


// Concrete creators override the factory method to change the
//   resulting product's type.
class WindowsDialog extends Dialog is
  method createButton():Button is
    return new WindowsButton()


class WebDialog extends Dialog is
  method createButton():Button is
    return new HTMLButton()


// The product interface declares the operations that all
//   concrete products must implement.
interface Button is
  method render()
  method onClick()


// Concrete products provide various implementations of the product interface.
class WindowsButton implements Button is
  method render() is
    // Render a button in Windows style.
  method onClick() is
    // Bind a native OS click event.


class HTMLButton implements Button is
  method render() is
```

```
    // Return an HTML representation of a button.
  method onClick() is
    // Bind a web browser click event.


class Application is
  field dialog: Dialog

  // The application picks a creator's type depending on the
  //   current configuration or environment settings.
  method initialize() is
    config = readApplicationConfigFile()

    if (config.OS == "Windows") then
      dialog = new WindowsDialog()
    else if (config.OS == "Web") then
      dialog = new WebDialog()
    else
      throw new Exception("Error! Unknown operating system.")

  // The client code works with an instance of a concrete creator, albeit through
  //   its base interface. As long as the client keeps working with the creator
  //   via the base interface, you can pass it any creator's subclass.
  method main() is
    this.initialize()
    dialog.render()
```

2.1.6 Applicability

- Use the Factory Method when you don't know beforehand the exact types and dependencies of the objects your code should work with.

▷ The Factory Method separates product construction code from the code that actually uses the product. Therefore it's easier to extend the product construction code independently from the rest of the code.

For example, to add a new product type to the app, you'll only need to create a new creator subclass and override the factory method in it.

- Use the Factory Method when you want to provide users of your library or framework with a way to extend its internal components.

▷ Inheritance is probably the easiest way to extend the default behavior of a library or framework. But how would the framework recognize that your subclass should be used instead of a standard component?

The solution is to reduce the code that constructs components across the framework into a single factory method and let anyone override this method in addition to extending the component itself.

Let's see how that would work. Imagine that you write an app using an open source UI framework. Your app should have round buttons, but the framework only provides square ones. You extend the standard Button class with a glorious RoundButton subclass. But now you need to tell the main UIFramework class to use the new button subclass instead of a default one.

To achieve this, you create a subclass UIWithRoundButtons from a base framework class and override its createButton method. While this method returns Button objects in the base class, you make your subclass return RoundButton objects. Now use the UIWithRoundButtons class instead of UIFramework. And that's about it!

- Use the Factory Method when you want to save system resources by reusing existing objects instead of rebuilding them each time.

▷ You often experience this need when dealing with large, resource-intensive objects such as database connections, file systems, and network resources.

Let's think about what has to be done to reuse an existing object:

1. First, you need to create some storage to keep track of all of the created objects.
2. When someone requests an object, the program should look for a free object inside that pool.
3. … and then return it to the client code.
4. If there are no free objects, the program should create a new one (and add it to the pool).

That's a lot of code! And it must all be put into a single place so that you don't pollute the program with duplicate code.

Probably the most obvious and convenient place where this code could be placed is the constructor of the class whose objects we're trying to reuse. However, a constructor must always return new objects by definition. It can't return existing instances.

Therefore, you need to have a regular method capable of creating new objects as well as reusing existing ones. That sounds very much like a factory method.

2.1.7 How to Implement

1. Make all products follow the same interface. This interface should declare methods that make sense in every product.

2. Add an empty factory method inside the creator class. The return type of the method should match the common product interface.

3. In the creator's code find all references to product constructors. One by one, replace them with calls to the factory method, while extracting the product creation code into the factory method.

   You might need to add a temporary parameter to the factory method to control the type of returned product.

   At this point, the code of the factory method may look pretty ugly. It may have a large switch statement that picks which product class to instantiate. But don't worry, we'll fix it soon enough.

4. Now, create a set of creator subclasses for each type of product listed in the factory method. Override the factory method in the subclasses and extract the appropriate bits of construction code from the base method.

5. If there are too many product types and it doesn't make sense to create subclasses for all of them, you can reuse the control parameter from the base class in subclasses.

   For instance, imagine that you have the following hierarchy of classes: the base Mail class with a couple of subclasses: AirMail and GroundMail; the Transport classes are Plane, Truck and Train. While the AirMail class only uses Plane objects, GroundMail may work with both Truck and Train objects. You can create a new subclass (say TrainMail) to handle both cases, but there's another option. The client code can pass an argument to the factory method of the GroundMail class to control which product it wants to receive.

6. If, after all of the extractions, the base factory method has become empty, you can make it abstract. If there's something left, you can make it a default behavior of the method.

2.1.8 Pros and Cons

+ You avoid tight coupling between the creator and the concrete products.

+ Single Responsibility Principle. You can move the product creation code into one place in the program, making the code easier to support.

+ Open/Closed Principle. You can introduce new types of products into the program without breaking existing client code.

- The code may become more complicated since you need to introduce a lot of new subclasses to implement the pattern. The best case scenario is when you're introducing the pattern into an existing hierarchy of creator classes.

2.1.9 Relations with Other Patterns

- Many designs start by using Factory Method (less complicated and more customizable via subclasses) and evolve toward Abstract Factory, Prototype, or Builder (more flexible, but more complicated).
- Abstract Factory classes are often based on a set of Factory Methods, but you can also use Prototype to compose the methods on these classes.
- You can use Factory Method along with Iterator to let collection subclasses return different types of iterators that are compatible with the collections.
- Prototype isn't based on inheritance, so it doesn't have its drawbacks. On the other hand, Prototype requires a complicated initialization of the cloned object. Factory Method is based on inheritance but doesn't require an initialization step.
- Factory Method is a specialization of Template Method. At the same time, a Factory Method may serve as a step in a large Template Method.

2.1.10 Examples

```
public abstract class Pizza {
  public abstract void addIngredients();

  public void bakePizza() {
    System.out.println("Pizza baked at 400 for 20 minutes.");
  }
}
```

```
public class CheesePizza extends Pizza {
  @Override
  public void addIngredients() {
    System.out.println("Preparing ingredients for cheese pizza.");
  }
}
```

```
public class PepperoniPizza extends Pizza {
  @Override
  public void addIngredients() {
    System.out.println("Preparing ingredients for pepperoni pizza.");
  }
}
```

```
public class VeggiePizza extends Pizza {
  @Override
  public void addIngredients() {
    System.out.println("Preparing ingredients for veggie pizza.");
  }
}
```

```
public abstract class BasePizzaFactory {

  public abstract Pizza createPizza(String type);
}
```

```
public class PizzaFactory extends BasePizzaFactory {
  @Override
  public Pizza createPizza(String type) {
    Pizza pizza;

    switch (type.toLowerCase()) {
      case "cheese":
        pizza = new CheesePizza();
        break;
      case "pepperoni":
        pizza = new PepperoniPizza();
        break;
      case "veggie":
        pizza = new VeggiePizza();
        break;
      default:
        throw new IllegalArgumentException("No such pizza.");
```

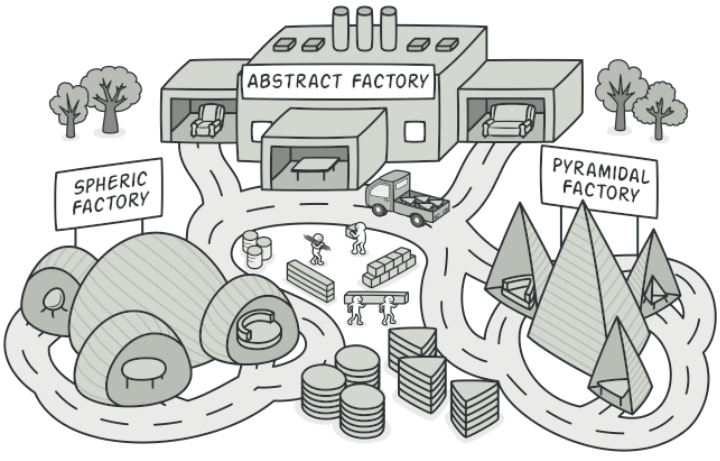
```
18      }

20      pizza.addIngredients();
        pizza.bakePizza();
22
        return pizza;
24    }
  }
```

```
1  public class TestPizzaFactory {
     public static void main(String[] args) {
3      testMakePizzas();
     }
5
     public void testMakePizzas() {
7      BasePizzaFactory pizzaFactory = new PizzaFactory();
       Pizza cheesePizza = pizzaFactory.createPizza("cheese");
9      Pizza veggiePizza = pizzaFactory.createPizza("veggie");
     }
11 }
```

2.2 Abstract Factory

2.2.1 Intent

Abstract Factory is a creational design pattern that lets you produce families of related objects without specifying their concrete classes.



2.2.2 Problem

Imagine that you're creating a furniture shop simulator.

Product families and their variants.

Your code consists of classes that represent:

1. A family of related products, say: Chair + Sofa + CoffeeTable.
2. Several variants of this family. For example, products Chair + Sofa + CoffeeTable are available in these variants: Modern, Victorian, ArtDeco.

You need a way to create individual furniture objects so that they match other objects of the same family. Customers get quite mad when they receive non-matching furniture.

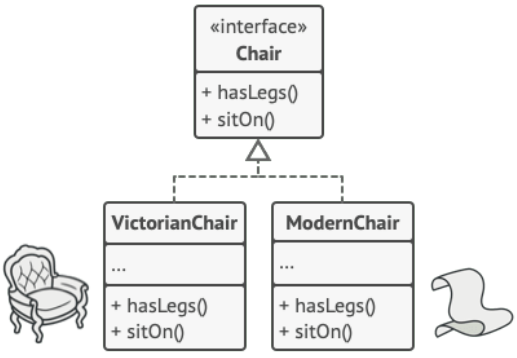
A Modern-style sofa doesn't match Victorian-style chairs.

Also, you don't want to change existing code when adding new products or families of products to the program. Furniture vendors update their catalogs very often, and you wouldn't want to change the core code each time it happens.

2.2.3 Solution

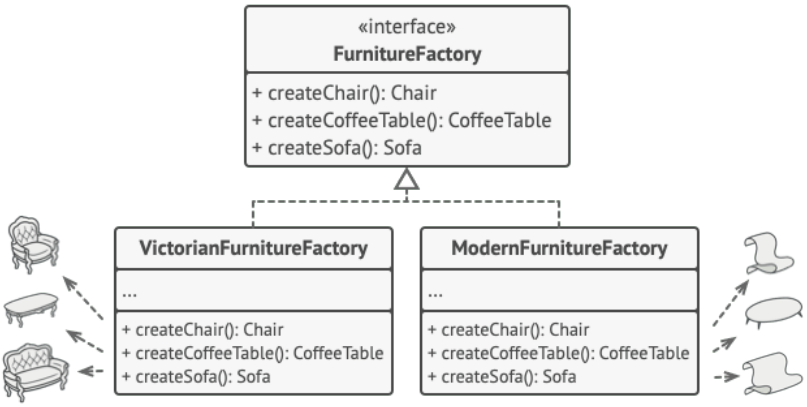
The Abstract Factory pattern suggests that:

- The first thing is to explicitly declare interfaces for each distinct product of the product family (e.g., chair, sofa or coffee table).
- Then you can make all variants of products follow those interfaces. For example, all chair variants can implement the Chair interface; all coffee table variants can implement the CoffeeTable interface, and so on.



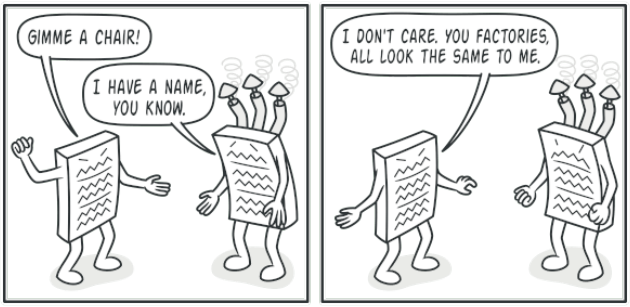
All variants of the same object must be moved to a single class hierarchy.

- The next move is to declare the Abstract Factory—an interface with a list of creation methods for all products that are part of the product family (for example, *createChair*, *createSofa* and *createCoffeeTable*). These methods must return **abstract** product types represented by the interfaces we extracted previously: Chair, Sofa, CoffeeTable and so on.
- Now, how about the product variants? For each variant of a product family, we create a separate factory class based on the AbstractFactory interface. A factory is a class that returns products of a particular kind. For example, the ModernFurnitureFactory can only create ModernChair, ModernSofa and ModernCoffeeTable objects.



Each concrete factory corresponds to a specific product variant.

The client code has to work with both factories and products via their respective abstract interfaces. This lets you change the type of a factory that you pass to the client code, as well as the product variant that the client code receives, without breaking the actual client code.

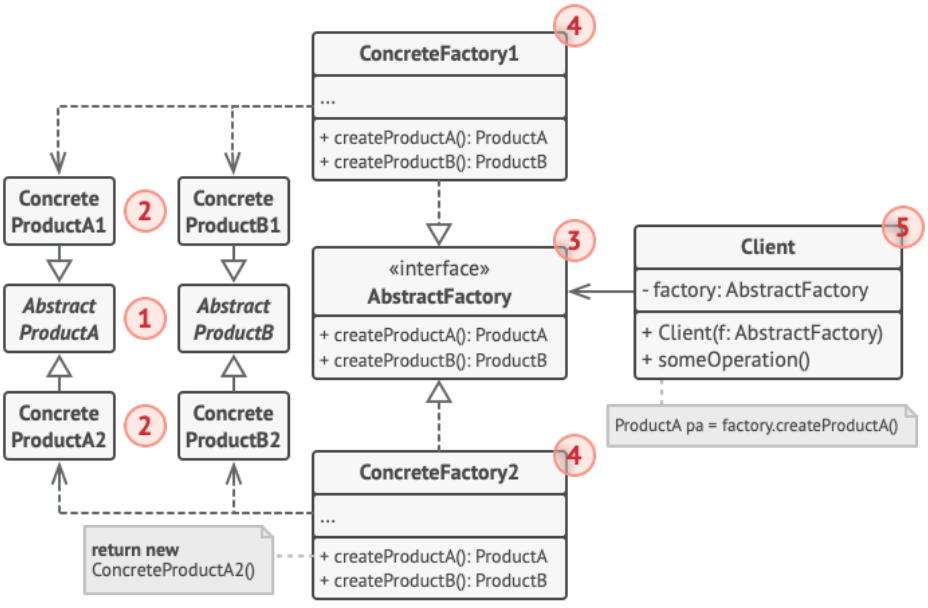


The client shouldn't care about the concrete class of the factory it works with.

Say the client wants a factory to produce a chair. The client doesn't have to be aware of the factory's class, nor does it matter what kind of chair it gets. Whether it's a Modern model or a Victorian-style chair, the client must treat all chairs in the same manner, using the abstract Chair interface. With this approach, the only thing that the client knows about the chair is that it implements the $sitOn$ method in some way. Also, whichever variant of the chair is returned, it'll always match the type of sofa or coffee table produced by the same factory object.

There's one more thing left to clarify: if the client is only exposed to the abstract interfaces, what creates the actual factory objects? Usually, the application creates a concrete factory object at the initialization stage. Just before that, the app must select the factory type depending on the configuration or the environment settings.

2.2.4 Structure



1. Abstract Products declare interfaces for a set of distinct but related products which make up a product family.

2. Concrete Products are various implementations of abstract products, grouped by variants. Each abstract product (chair/sofa) must be implemented in all given variants (Victorian/Modern).

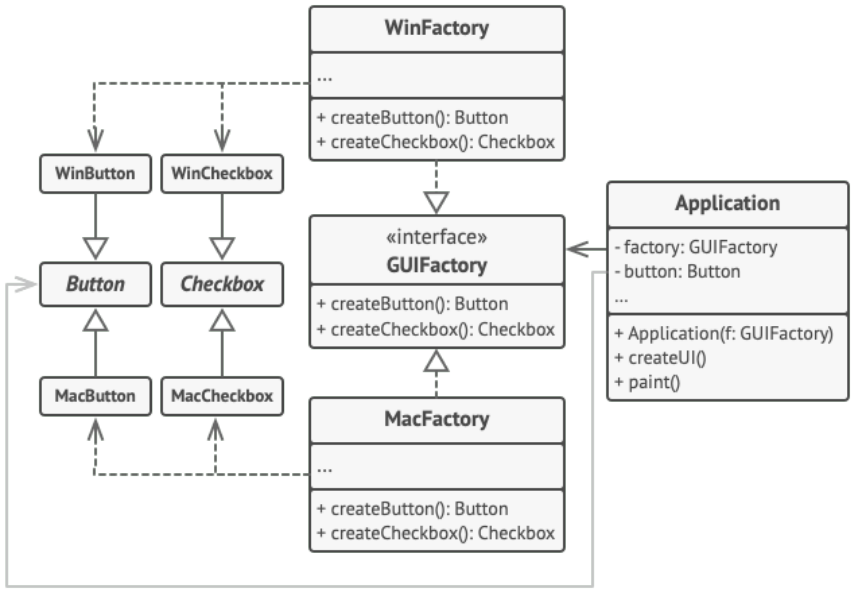
3. The Abstract Factory interface declares a set of methods for creating each of the abstract products.

4. Concrete Factories implement creation methods of the abstract factory. Each concrete factory corresponds to a specific variant of products and creates only those product variants.

5. Although concrete factories instantiate concrete products, signatures of their creation methods must return corresponding abstract products. This way the client code that uses a factory doesn't get coupled to the specific variant of the product it gets from a factory. The Client can work with any concrete factory/product variant, as long as it communicates with their objects via abstract interfaces.

2.2.5 Pseudocode

This example illustrates how the Abstract Factory pattern can be used for creating cross-platform UI elements without coupling the client code to concrete UI classes, while keeping all created elements consistent with a selected operating system.



The cross-platform UI classes example.

The same UI elements in a cross-platform application are expected to behave similarly, but look a little bit different under different operating systems. Moreover, it's your job to make sure that the UI elements match the style of the current operating system. You wouldn't want your program to render macOS controls when it's executed in Windows.

The Abstract Factory interface declares a set of creation methods that the client code can use to produce different types of UI elements. Concrete factories correspond to specific operating systems and create the UI elements that match that particular OS.

It works like this: when an application launches, it checks the type of the current operating system. The app uses this information to create a factory object from a class that matches the operating system. The rest of the code uses this factory to create UI elements. This prevents the wrong elements from being created.

With this approach, the client code doesn't depend on concrete classes of factories and UI elements as long as it works with these objects via their abstract interfaces. This also lets the client code support other factories or UI elements that you might add in the future.

As a result, you don't need to modify the client code each time you add a new variation of UI elements to your app. You just have to create a new factory class that produces these elements and slightly modify the app's initialization code so it selects that class when appropriate.

PSEUDO CODE

```
// The abstract factory interface declares a set of methods that return
//  different abstract products. These products are called a family and
//  are related by a high-level theme or concept.
// Products of one family are usually able to collaborate among themselves.
//  A family of products may have several variants, but the products of
//  one variant are incompatible with the products of another variant.
interface GUIFactory is
  method createButton():Button
  method createCheckbox():Checkbox


// Concrete factories produce a family of products that belong to a single
//  variant. The factory guarantees that the resulting products are compatible.
//  Signatures of the concrete factory's methods return an abstract product,
//  while inside the method a concrete product is instantiated.
class WinFactory implements GUIFactory is
  method createButton():Button is
    return new WinButton()

  method createCheckbox():Checkbox is
    return new WinCheckbox()

// Each concrete factory has a corresponding product variant.
class MacFactory implements GUIFactory is
  method createButton():Button is
    return new MacButton()

  method createCheckbox():Checkbox is
```

```
        return new MacCheckbox()


// Each distinct product of a product family should have a base interface.
//   All variants of the product must implement this interface.
interface Button is
  method paint()

// Concrete products are created by corresponding concrete factories.
class WinButton implements Button is
  method paint() is
    // Render a button in Windows style.

class MacButton implements Button is
  method paint() is
    // Render a button in macOS style.

// Here's the base interface of another product. All products can interact
//   with each other, but proper interaction is possible only between
//   products of the same concrete variant.
interface Checkbox is
  method paint()


class WinCheckbox implements Checkbox is
  method paint() is
    // Render a checkbox in Windows style.


class MacCheckbox implements Checkbox is
  method paint() is
    // Render a checkbox in macOS style.


// The client code works with factories and products only through abstract
//   types: GUIFactory, Button and Checkbox. This lets you pass any factory
//   or product subclass to the client code without breaking it.
class Application is
  private field factory: GUIFactory
  private field button: Button

  constructor Application(factory: GUIFactory) is
    this.factory = factory

  method createUI() is
    this.button = factory.createButton()

  method paint() is
    button.paint()


```

PSEUDO CODE

```
// The application picks the factory type depending on the current
// configuration or environment settings and creates it at runtime
// (usually at the initialization stage).
class ApplicationConfigurator is
  method main() is
    config = readApplicationConfigFile()

    if (config.OS == "Windows") then
      factory = new WinFactory()
    else if (config.OS == "Mac") then
      factory = new MacFactory()
    else
      throw new Exception("Error! Unknown operating system.")

    Application app = new Application(factory)
```

2.2.6 Applicability

- Use the Abstract Factory when your code needs to work with various families of related products, but you don't want it to depend on the concrete classes of those products—they might be unknown beforehand or you simply want to allow for future extensibility.

▷ The Abstract Factory provides you with an interface for creating objects from each class of the product family. As long as your code creates objects via this interface, you don't have to worry about creating the wrong variant of a product which doesn't match the products already created by your app.

  - Consider implementing the Abstract Factory when you have a class with a set of Factory Methods that blur its primary responsibility.

  - In a well-designed program *each class is responsible only for one thing*. When a class deals with multiple product types, it may be worth extracting its factory methods into a stand-alone factory class or a full-blown Abstract Factory implementation.

2.2.7 How to Implement

1. Map out a matrix of distinct product types versus variants of these products.
2. Declare abstract product interfaces for all product types. Then make all concrete product classes implement these interfaces.
3. Declare the abstract factory interface with a set of creation methods for all abstract products.
4. Implement a set of concrete factory classes, one for each product variant.

5. Create factory initialization code somewhere in the app. It should instantiate one of the concrete factory classes, depending on the application configuration or the current environment. Pass this factory object to all classes that construct products.

6. Scan through the code and find all direct calls to product constructors. Replace them with calls to the appropriate creation method on the factory object.

2.2.8 Pros and Cons

+ You can be sure that the products you're getting from a factory are compatible with each other.

+ You avoid tight coupling between concrete products and client code.

+ Single Responsibility Principle. You can extract the product creation code into one place, making the code easier to support.

+ Open/Closed Principle. You can introduce new variants of products without breaking existing client code.

- The code may become more complicated than it should be, since a lot of new interfaces and classes are introduced along with the pattern.

2.2.9 Relations with Other Patterns

- Many designs start by using Factory Method (less complicated and more customizable via subclasses) and evolve toward Abstract Factory, Prototype, or Builder (more flexible, but more complicated).

- Builder focuses on constructing complex objects step by step. Abstract Factory specializes in creating families of related objects. Abstract Factory returns the product immediately, whereas Builder lets you run some additional construction steps before fetching the product.

- Abstract Factory classes are often based on a set of Factory Methods, but you can also use Prototype to compose the methods on these classes.

- Abstract Factory can serve as an alternative to Facade when you only want to hide the way the subsystem objects are created from the client code.

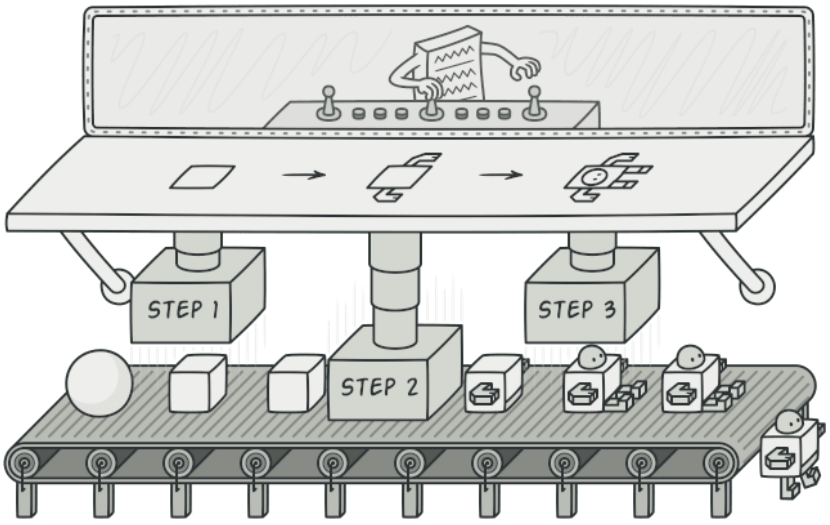
- You can use Abstract Factory along with Bridge. This pairing is useful when some abstractions defined by Bridge can only work with specific implementations. In this case, Abstract Factory can encapsulate these relations and hide the complexity from the client code.

- Abstract Factories, Builders and Prototypes can all be implemented as Singletons.

2.3 Builder Pattern

2.3.1 Intent

Builder is a creational design pattern that lets you construct complex objects step by step. The pattern allows you to produce different types and representations of an object using the same construction code.

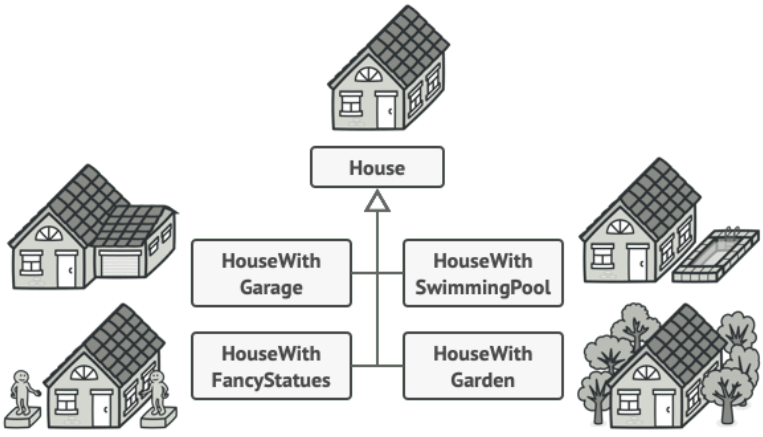


2.3.2 Problem

Imagine a complex object that requires laborious, step-by-step initialization of many fields and nested objects. Such initialization code is usually buried inside a monstrous constructor with lots of parameters. Or even worse: scattered all over the client code.

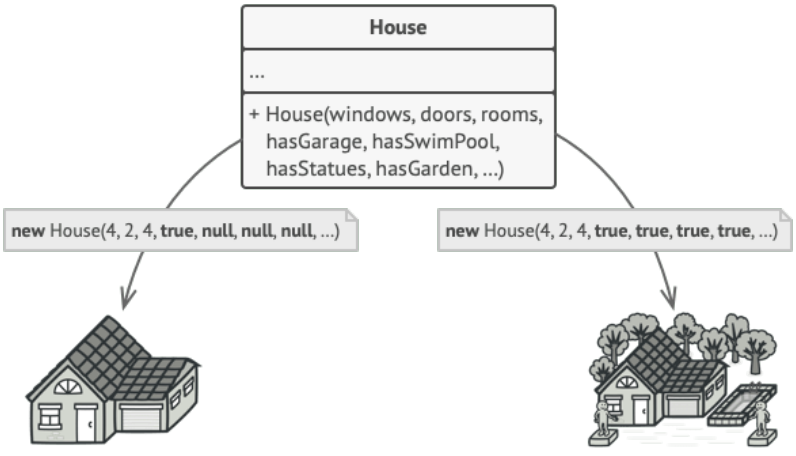
For example, let's think about how to create a House object. To build a simple house, you need to construct four walls and a floor, install a door, fit a pair of windows, and build a roof. But what if you want a bigger, brighter house, with a backyard and other goodies (like a heating system, plumbing, and electrical wiring)?

The simplest solution is to extend the base House class and create a set of subclasses to cover all combinations of the parameters. But eventually you'll end up with a considerable number of subclasses. Any new parameter, such as the porch style, will require growing this hierarchy even more.



You might make the program too complex by creating a subclass for every possible configuration of an object.

There's another approach that doesn't involve breeding subclasses. You can create a giant constructor right in the base House class with all possible parameters that control the house object. While this approach indeed eliminates the need for subclasses, it creates another problem.

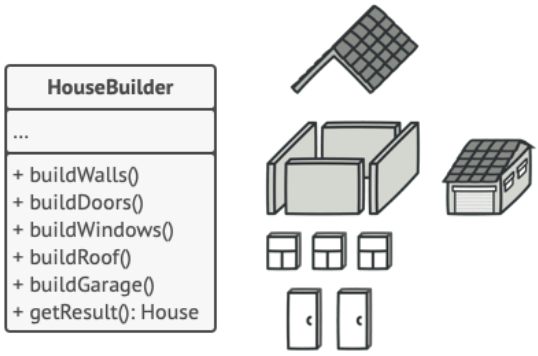


The constructor with lots of parameters has its downside: not all the parameters are needed at all times.

In most cases most of the parameters will be unused, making the constructor calls pretty ugly. For instance, only a fraction of houses have swimming pools, so the parameters related to swimming pools will be useless nine times out of ten.

2.3.3 Solution

The Builder pattern suggests that you extract the object construction code out of its own class and move it to separate objects called builders.



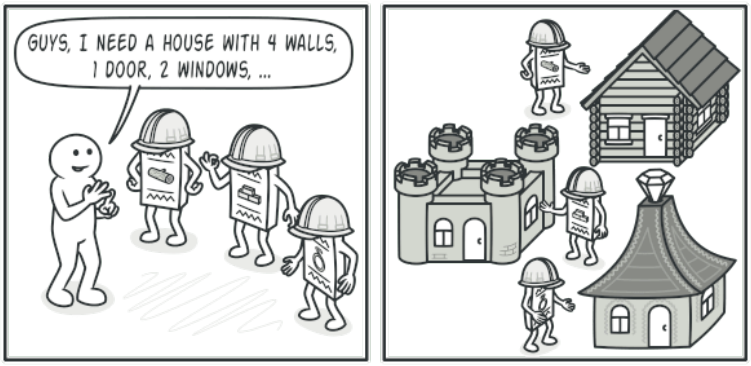
The Builder pattern lets you construct complex objects step by step. The Builder doesn't allow other objects to access the product while it's being built.

The pattern organizes object construction into a set of steps ($buildWalls$, $buildDoor$, etc.). To create an object, you execute a series of these steps on a builder object. The important part is that you don't need to call all of the steps. You can call only those steps that are necessary for producing a particular configuration of an object.

Some of the construction steps might require different implementation when you need to build various representations of the product. For example, walls of a cabin may be built of wood, but the castle walls must be built with stone.

In this case, you can create several different builder classes that implement the same set of building steps, but in a different manner. Then you can use these builders in the construction process (i.e., an ordered set of calls to the building steps) to produce different kinds of objects.

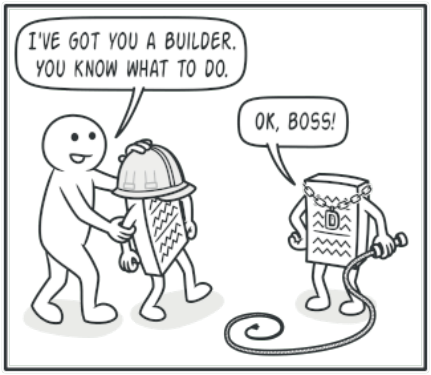
For example, imagine a builder that builds everything from wood and glass, a second one that builds everything with stone and iron and a third one that uses gold and diamonds. By calling the same set of steps, you get a regular house from the first builder, a small castle from the second and a palace from the third. However, this would only work if the client code that calls the building steps is able to interact with builders using a common interface.



Different builders execute the same task in various ways.

Director

You can go further and extract a series of calls to the builder steps you use to construct a product into a separate class called director. The director class defines the order in which to execute the building steps, while the builder provides the implementation for those steps.

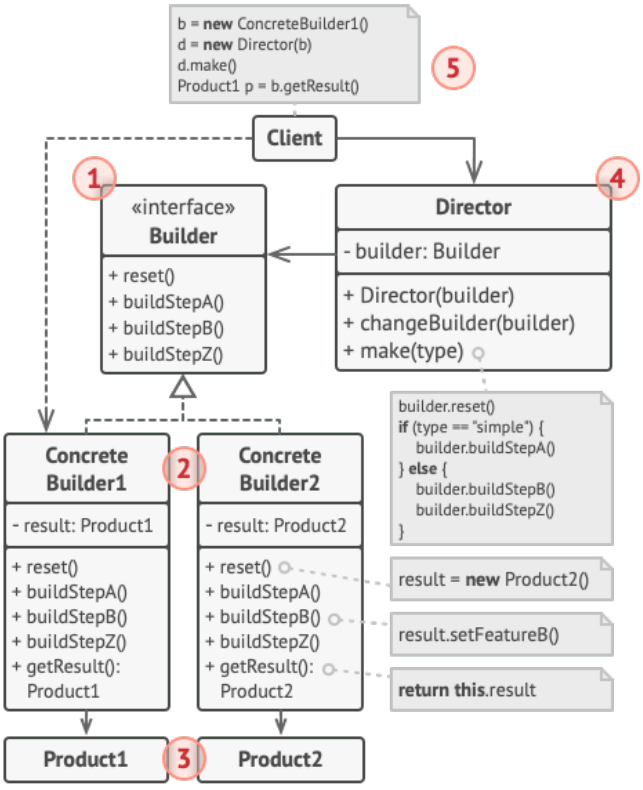


The director knows which building steps to execute to get a working product.

Having a director class in your program isn't strictly necessary. You can always call the building steps in a specific order directly from the client code. However, the director class might be a good place to put various construction routines so you can reuse them across your program.

In addition, the director class completely hides the details of product construction from the client code. The client only needs to associate a builder with a director, launch the construction with the director, and get the result from the builder.

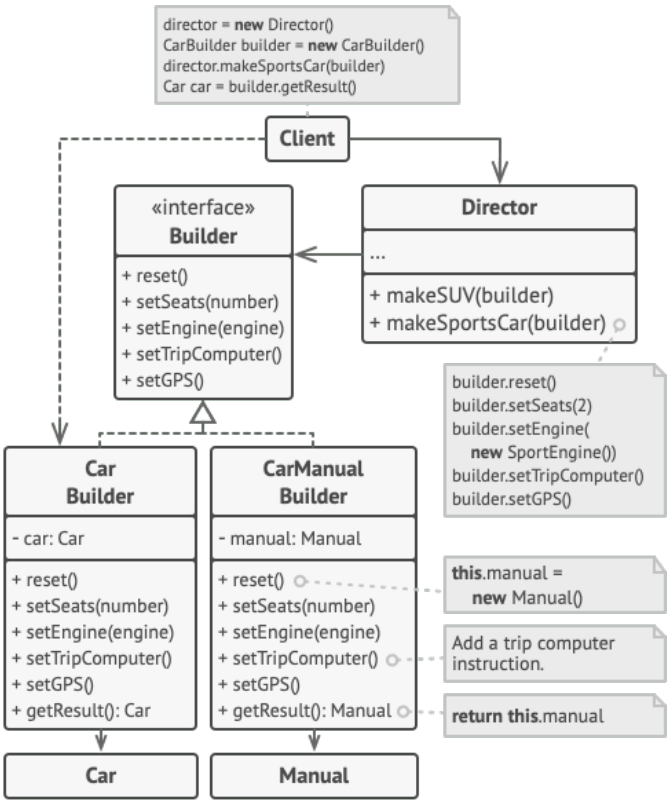
2.3.4 Structure



1. The Builder interface declares product construction steps that are common to all types of builders.
2. Concrete Builders provide different implementations of the construction steps. Concrete builders may produce products that don't follow the common interface.
3. Products are resulting objects. Products constructed by different builders don't have to belong to the same class hierarchy or interface.
4. The Director class defines the order in which to call construction steps, so you can create and reuse specific configurations of products.
5. The Client must associate one of the builder objects with the director. Usually, it's done just once, via parameters of the director's constructor. Then the director uses that builder object for all further construction. However, there's an alternative approach for when the client passes the builder object to the production method of the director. In this case, you can use a different builder each time you produce something with the director.

2.3.5 Pseudocode

This example of the Builder pattern illustrates how you can reuse the same object construction code when building different types of products, such as cars, and create the corresponding manuals for them.



The example of step-by-step construction of cars and the user guides that fit those car models.

A car is a complex object that can be constructed in a hundred different ways. Instead of bloating the Car class with a huge constructor, we extracted the car assembly code into a separate car builder class. This class has a set of methods for configuring various parts of a car.

If the client code needs to assemble a special, fine-tuned model of a car, it can work with the builder directly. On the other hand, the client can delegate the assembly to the director class, which knows how to use a builder to construct several of the most popular models of cars.

You might be shocked, but every car needs a manual (seriously, who reads them?). The manual describes every feature of the car, so the details in the manuals vary

across the different models. That's why it makes sense to reuse an existing construction process for both real cars and their respective manuals. Of course, building a manual isn't the same as building a car, and that's why we must provide another builder class that specializes in composing manuals. This class implements the same building methods as its car-building sibling, but instead of crafting car parts, it describes them. By passing these builders to the same director object, we can construct either a car or a manual.

The final part is fetching the resulting object. A metal car and a paper manual, although related, are still very different things. We can't place a method for fetching results in the director without coupling the director to concrete product classes. Hence, we obtain the result of the construction from the builder which performed the job.


```
// Using the Builder pattern makes sense only when your products are
//   quite complex and require extensive configuration. The following two
//   products are related, although they don't have a common interface.
class Car is
// A car can have a GPS, trip computer and some number of seats.
//   Different models of cars (sports car, SUV, cabriolet) might
//   have different features installed or enabled.

class Manual is
// Each car should have a user manual that corresponds to
//   the car's configuration and describes all its features.


// The builder interface specifies methods for creating the
//   different parts of the product objects.
interface Builder is
  method reset() : Builder
  method setSeats(...) : Builder
  method setEngine(...) : Builder
  method setTripComputer(...) : Builder
  method setGPS(...) : Builder

// The concrete builder classes follow the builder interface and
//   provide specific implementations of the building steps. Your
//   program may have several variations of builders, each
//   implemented differently.
class CarBuilder implements Builder is
  private field car:Car

  // A fresh builder instance should contain a blank product
  //   object which it uses in further assembly.
  constructor CarBuilder() is
    this.reset()

```


```
    // The reset method clears the object being built.
    method reset(): Builder is
        this.car = new Car()
        return this

    // All production steps work with the same product instance.
    method setSeats(...): Builder is
        // Set the number of seats in the car.

    method setEngine(...): Builder is
        // Install a given engine.

    method setTripComputer(...): Builder is
        // Install a trip computer.

    method setGPS(...): Builder is
        // Install a global positioning system.

    // Concrete builders are supposed to provide their own methods for
    //    retrieving results. That's because various types of builders may
    //    create entirely different products that don't all follow the same
    //    interface. Therefore such methods can't be declared in the builder
    //    interface (at least not in a statically-typed programming language).
    //
    // Usually, after returning the end result to the client, a builder
    //    instance is expected to be ready to start producing another
    //    product. That's why it's a usual practice to call the reset
    //    method at the end of the 'getProduct' method body. However, this
    //    behavior isn't mandatory, and you can make your builder wait for
    //    an explicit reset call from the client code before disposing of
    //    the previous result.
    method getProduct(): Car is
        product = this.car
        this.reset()
        return product


// Unlike other creational patterns, builder lets you construct
//    products that don't follow the common interface.
class CarManualBuilder implements Builder is
    private field manual:Manual

    constructor CarManualBuilder() is
        this.reset()

    method reset(): Builder is
        this.manual = new Manual()
        return this

    method setSeats(...): Builder is
        // Document car seat features.
```


```
86
    method setEngine(...): Builder is
88      // Add engine instructions.

90  method setTripComputer(...): Builder is
      // Add trip computer instructions.
92
    method setGPS(...): Builder is
94      // Add GPS instructions.

96  method getProduct(): Manual is
      // Return the manual and reset the builder.
98

100 // The director is only responsible for executing the building steps in a
    //  particular sequence. It's helpful when producing products according to
102 //  a specific order or configuration. Strictly speaking, the director
    //  class is optional, since the client can control builders directly.
104 class Director is
      // The director works with any builder instance that the client code
106   //  passes to it. This way, the client code may alter the final type
      //  of the newly assembled product. The director can construct
108   //  several product variations using the same building steps.
      method constructSportsCar(builder: Builder) is
110     builder.reset()
          .setSeats(2)
112       .setEngine(new SportEngine())
          .setTripComputer(true)
114       .setGPS(true)

116   method constructSUV(builder: Builder) is
        // ...
118

120 // The client code creates a builder object, passes it to the director
    //  and then initiates the construction process. The end result is
122 //  retrieved from the builder object.
    class Application is
124   method makeCar() is
        director = new Director()
126
        CarBuilder builder = new CarBuilder()
128     director.constructSportsCar(builder)
        Car car = builder.getProduct()
130
        CarManualBuilder builder = new CarManualBuilder()
132     director.constructSportsCar(builder)

134     // The final product is often retrieved from a builder object
        //  since the director isn't aware of and not dependent on
136     //  concrete builders and products.
```

```
Manual manual = builder.getProduct()
```

2.3.6 Applicability

- Use the Builder pattern to get rid of a "telescoping constructor".

▷ Say you have a constructor with ten optional parameters. Calling such a beast is very inconvenient; therefore, you overload the constructor and create several shorter versions with fewer parameters. These constructors still refer to the main one, passing some default values into any omitted parameters.

```
class Pizza {
    Pizza(int size) { ... }
    Pizza(int size, boolean cheese) { ... }
    Pizza(int size, boolean cheese, boolean pepperoni) { ... }
    // ...
```

Creating such a monster is only possible in languages that support method overloading, such as C++ or Java.

The Builder pattern lets you build objects step by step, using only those steps that you really need. After implementing the pattern, you don't have to cram dozens of parameters into your constructors anymore.

- Use the Builder pattern when you want your code to be able to create different representations of some product (for example, stone and wooden houses).

▷ The Builder pattern can be applied when construction of various representations of the product involves similar steps that differ only in the details.

The base Builder interface defines all possible construction steps, and concrete builders implement these steps to construct particular representations of the product. Meanwhile, the director class guides the order of construction.

- Use the Builder to construct Composite trees or other complex objects.

▷ The Builder pattern lets you construct products step-by-step. You could defer execution of some steps without breaking the final product. You can even call steps recursively, which comes in handy when you need to build an object tree.

A Builder doesn't expose the unfinished product while running construction steps. This prevents the client code from fetching an incomplete result.

2.3.7 How to Implement

1. Make sure that you can clearly define the common construction steps for building all available product representations. Otherwise, you won't be able to proceed with implementing the pattern.

2. Declare these steps in the base builder interface.

3. Create a concrete builder class for each of the product representations and implement their construction steps.

4. Don't forget about implementing a method for fetching the result of the construction. The reason why this method can't be declared inside the builder interface is that various builders may construct products that don't have a common interface. Therefore, you don't know what would be the return type for such a method. However, if you're dealing with products from a single hierarchy, the fetching method can be safely added to the base interface.

5. Think about creating a director class. It may encapsulate various ways to construct a product using the same builder object.

6. The client code creates both the builder and the director objects. Before construction starts, the client must pass a builder object to the director. Usually, the client does this only once, via parameters of the director's class constructor. The director uses the builder object in all further construction. There's an alternative approach, where the builder is passed to a specific product construction method of the director.

7. The construction result can be obtained directly from the director only if all products follow the same interface. Otherwise, the client should fetch the result from the builder.

2.3.8 Pros and Cons

+ You can construct objects step-by-step, defer construction steps or run steps recursively.

+ You can reuse the same construction code when building various representations of products.

+ Single Responsibility Principle. You can isolate complex construction code from the business logic of the product.

- The overall complexity of the code increases since the pattern requires creating multiple new classes.

2.3.9 Relations with Other Patterns

- Many designs start by using Factory Method (less complicated and more customizable via subclasses) and evolve toward Abstract Factory, Prototype, or Builder (more flexible, but more complicated).
- Builder focuses on constructing complex objects step by step. Abstract Factory specializes in creating families of related objects. Abstract Factory returns the product immediately, whereas Builder lets you run some additional construction steps before fetching the product.
- You can use Builder when creating complex Composite trees because you can program its construction steps to work recursively.
- You can combine Builder with Bridge: the director class plays the role of the abstraction, while different builders act as implementations.
- Abstract Factories, Builders and Prototypes can all be implemented as Singletons.

2.3.10 Examples

1. Builder using inner class

Some important points about implementing the Product class:

- Constructor is private, this means that this class cannot be instantiated directly from outside.
- All properties are private final, so it can only be assigned a value in the constructor and it can only be provided with getter() methods.
- Object initialization is only possible through Builder.

Some important points about implementing the Builder class:

- Create a static nested class (this is called a builder class) and will have the same fields as the outer class. We should name this class in the format: [class name] + Builder. For example, the class is BankAccount, the builder class will be BankAccountBuilder.
- Class Builder has a public constructor with all required properties.
- The Builder class has $setter()$ methods for optional parameters.
- Provide the $build()$ method in the class Builder to return the object the client needs.

Example. There are a few steps to take in order to implement the Builder pattern. We'll use the SmartHome class to show these steps:

- A static builder class should be nested in our SmartHome class
- The SmartHome constructor should be private so the end-user can't call it.
- The builder class should have an intuitive name, like SmartHomeBuilder.
- The SmartHomeBuilder class will have the same fields as the SmartHome class.
- The fields in the SmartHome class can be final or not, depending if you want it to be immutable or not.
- The SmartHomeBuilder class will contain methods that set the values, similar to setter methods. These methods will feature the SmartHomeBuilder as the return type, assign the passed values to the fields of the static builder class and follow the builder naming convention. They'll typically start with with, in, at, etc. instead of set.
- The static builder class will contain a build() method that injects these values into SmartHome and returns an instance of it.

```
package com.patterns.builder;

public class SmartHome {
    private final String name;
    private final int serialNumber;
    private final String addressName;
    private final String addressNumber;
    private final String city;
    private final String country;
    private final String postalCode;
    private final int light1PortNum;
    private final int light2PortNum;
    private final int door1PortNum;
    private final int door2PortNum;
    private final int microwavePortNum;
    private final int tvPortNum;
    private final int waterHeaterPortNum;

    // Private constructor means we can't instantiate it
    //  by simply calling 'new SmartHome()'
    private SmartHome() { }

    public static class SmartHomeBuilder {
        private String name;
        private int serialNumber;
        private String addressName;
        private String addressNumber;
        private String city;
        private String country;
```

```
30      private String postalCode;
        private int light1PortNum;
32      private int light2PortNum;
        private int door1PortNum;
34      private int door2PortNum;
        private int microwavePortNum;
36      private int tvPortNum;
        private int waterHeaterPortNum;
38
        public SmartHomeBuilder withName(String name) {
40        this.name = name;
          return this;
42      }

44      public SmartHomeBuilder withSerialNumber(int serialNumber) {
          this.serialNumber = serialNumber;
46        return this;
        }
48
        public SmartHomeBuilder withAddressName(String addressName) {
50        this.addressName = addressName;
          return this;
52      }

54      public SmartHomeBuilder inCity(String city) {
          this.city = city;
56        return this;
        }
58
        public SmartHomeBuilder inCountry(String country) {
60        this.country = country;
          return this;
62      }

64       .....
         .....
66
        public SmartHome build() {
68        SmartHome smartHome = new SmartHome();
          smartHome.name = this.name;
70        smartHome.serialNumber = this.serialNumber;
          smartHome.addressName = this.addressName;
72        smartHome.city = this.city;
          smartHome.country = this.country;
74        smartHome.postalCode = this.postalCode;
          smartHome.light1PortNum = this.light1PortNum;
76        smartHome.light2PortNum = this.light2PortNum;
          smartHome.door1PortNum = this.door1PortNum;
78        smartHome.door2PortNum = this.door2PortNum;
          smartHome.microwavePortNum = this.microwavePortNum;
80        smartHome.tvPortNum = this.tvPortNum;
```

```
            smartHome.waterHeaterPortNum = this.waterHeaterPortNum;

            return smartHome;
        }
    }
}
```

The SmartHome class doesn't have public constructors and the only way to create a SmartHome object is through the SmartHomeBuilder class, like this:

```
SmartHome smartHomeSystem = new SmartHome.SmartHomeBuilder()
    .withName("RaspberrySmartHomeSystem")
    .withSerialNumber(3627)
    .withAddressName("Main Street")
    .withAddressNumber("14a")
    .inCity("Kumanovo")
    .inCountry("Macedonia")
    .withPostalCode("1300")
    .withDoor1PortNum(342)
    .withDoor2PortNum(343)
    .withLight1PortNum(211)
    .withLight2PortNum(212)
    .withMicrowavePortNum(11)
    .withTvPortNum(12)
    .withWaterHeaterPortNum(13)
    .build();

System.out.println(smartHomeSystem);
```

It's evident what we're constructing when instantiating the object. It's readable, understandable, and anyone can use your classes to build objects.

An example of the real-world neural network, it would look a little something like this:

```
MultiLayerNetwork conf = new NeuralNetConfiguration.Builder()
    .seed(rngSeed)
    .optimizationAlgo(OptimizationAlgorithm.STOCHASTIC_GRADIENT_DESCENT)
    .updater(new Adam())
    .l2(1e-4)
    .list()
```

```
    .layer(new DenseLayer.Builder()
    .nIn(numRows * numColumns)      // Number of input datapoints.
    .nOut(1000)                     // Number of output datapoints.
    .activation(Activation.RELU)    // Activation function.
    .weightInit(WeightInit.XAVIER) // Weight initialization.
    .build())
    .layer(new OutputLayer.Builder(LossFunction.NEGATIVE_LOG_LIKELIHOOD)
    .nIn(1000)
    .nOut(outputNum)
    .activation(Activation.SOFTMAX)
    .weightInit(WeightInit.XAVIER)
    .build())
    .pretrain(false)
    .backprop(true)
    .build()
```

2. Real-World example

```
package com.patterns.builder.product;

public class House {
    private String foundation;
    private String structure;
    private String roof;
    private boolean furnished;
    private boolean painted;

    public void setFoundation(String foundation) {
        this.foundation = foundation;
    }

    public void setStructure(String structure) {
        this.structure = structure;
    }

    public void setRoof(String roof) {
        this.roof = roof;
    }

    public void setFurnished(boolean furnished) {
        this.furnished = furnished;
    }

    public void setPainted(boolean painted) {
        this.painted = painted;
    }
```

```
29
    @Override
31  public String toString() {
      return "Foundation - " + foundation
33      + " Structure - " + structure
        + " Roof - " + roof
35      + " Is Furnished? " + furnished
        + " Is Painted? " + painted;
37  }
}
```

```
package com.patterns.builder.builders;

import com.patterns.builder.product.House;

public interface HouseBuilder {
  void buildFoundation();
  void buildStructure();
  void buildRoof();
  void paintHouse();
  void furnishHouse();
  House getHouse();
}
```

```
package com.patterns.builder.builders;

import com.patterns.builder.product.House;

public class ConcreteHouseBuilder implements HouseBuilder {
  private House house;

  public ConcreteHouseBuilder() {
    this.house = new House();
  }

  @Override
  public void buildFoundation() {
    house.setFoundation("Concrete, brick, and stone");
    System.out.println("ConcreteHouseBuilder: Foundation complete ... ");
  }
```

```
18    @Override
      public void buildStructure() {
20      house.setStructure("Concrete, mortar, brick, and reinforced steel");
        System.out.println("ConcreteHouseBuilder: Structure complete ... ");
22    }

24    @Override
      public void buildRoof() {
26      house.setRoof("Concrete and reinforced steel");
        System.out.println("ConcreteHouseBuilder: Roof complete ... ");
28    }

30    @Override
      public void paintHouse() {
32      house.setPainted(true);
        System.out.println("ConcreteHouseBuilder: Painting complete...");
34    }

36    @Override
      public void furnishHouse() {
38      house.setFurnished(true);
        System.out.println("ConcreteHouseBuilder: Furnishing complete...");
40    }

42    public House getHouse() {
        System.out.println("ConcreteHouseBuilder: Concrete house complete...");
44      return this.house;
      }
46  }
```

```
  package com.patterns.builder.builders;
2
  import com.patterns.builder.product.House;
4
  public class PrefabricatedHouseBuilder implements HouseBuilder {
6   private House house;

8   public PrefabricatedHouseBuilder() {
      this.house = new House();
10  }

12  @Override
    public void buildFoundation() {
14    house.setFoundation("Wood, laminate, and PVC flooring");
      System.out.println("PrefabricatedHouseBuilder: Foundation complete...");
16  }
```

```
18    @Override
      public void buildStructure() {
20      house.setStructure("Structural steels and wooden wall panels");
        System.out.println("PrefabricatedHouseBuilder: Structure complete...");
22    }

24    @Override
      public void buildRoof() {
26      house.setRoof("Roofing sheets");
        System.out.println("PrefabricatedHouseBuilder: Roof complete...");
28    }

30    @Override
      public void paintHouse() {
32      house.setPainted(false);
        System.out.println("PrefabricatedHouseBuilder: Painting not required...");
34    }

36    @Override
      public void furnishHouse() {
38      house.setFurnished(true);
        System.out.println("PrefabricatedHouseBuilder: Furnishing complete...");
40    }

42    public House getHouse() {
        System.out.println("PrefabricatedHouseBuilder: Prefabricated house complete...");
44      return this.house;
      }
46  }
```

```
  package com.patterns.builder.director;
2
  import com.patterns.builder.builders.HouseBuilder;
4 import com.patterns.builder.product.House;

6 public class ConstructionEngineer {
    private HouseBuilder houseBuilder;
8
    public ConstructionEngineer(HouseBuilder houseBuilder) {
10    this.houseBuilder = houseBuilder;
    }
12
    public House constructHouse() {
14    this.houseBuilder.buildFoundation();
      this.houseBuilder.buildStructure();
```

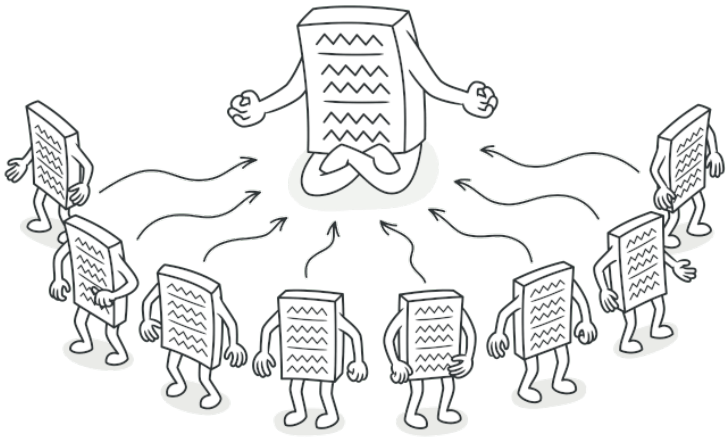
```
        this.houseBuilder.buildRoof();
        this.houseBuilder.paintHouse();
        this.houseBuilder.furnishHouse();

        return this.houseBuilder.getHouse();
    }
}
```

```
package com.patterns.builder.director;

import com.patterns.builder.builders.HouseBuilder;
import com.patterns.builder.builders.ConcreteHouseBuilder;
import com.patterns.builder.builders.PrefabricatedHouseBuilder;
import com.patterns.builder.product.House;

public class ConstructionEngineerTest {
    public static void main() {
        testConstructHouse();
    }

    public void testConstructHouse() {
        HouseBuilder concreteHouseBuilder = new ConcreteHouseBuilder();
        ConstructionEngineer engineerA
            = new ConstructionEngineer(concreteHouseBuilder);
        House houseA = engineerA.constructHouse();
        System.out.println("House is: " + houseA);

        PrefabricatedHouseBuilder prefabricatedHouseBuilder
            = new PrefabricatedHouseBuilder();
        ConstructionEngineer engineerB
            = new ConstructionEngineer(prefabricatedHouseBuilder);
        House houseB = engineerB.constructHouse();
        System.out.println("House is: " + houseB);
    }
}
```

2.4 Singleton Pattern

2.4.1 Intent

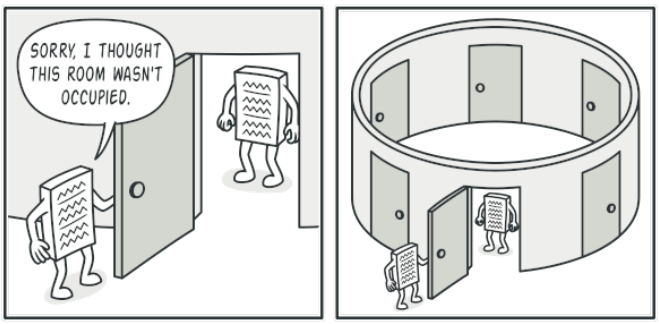
Singleton is a creational design pattern that lets you ensure that a class has only one instance, while providing a global access point to this instance.



2.4.2 Problem

The Singleton pattern solves two problems at the same time, violating the Single Responsibility Principle:

1. **Ensure that a class has just a single instance**. Why would anyone want to control how many instances a class has? The most common reason for this is to control access to some shared resource—for example, a database or a file.



Clients may not even realize that they're working with the same object all the time.

Here's how it works: imagine that you created an object, but after a while decided to create a new one. Instead of receiving a fresh object, you'll get the one you already created.

Note that this behavior is impossible to implement with a regular constructor since a constructor call must always return a new object by design.

2. **Provide a global access point to that instance**. Remember those global variables that you (all right, me) used to store some essential objects? While they're very handy, they're also very unsafe since any code can potentially overwrite the contents of those variables and crash the app.

   Just like a global variable, the Singleton pattern lets you access some object from anywhere in the program. However, it also protects that instance from being overwritten by other code.

   There's another side to this problem: you don't want the code that solves problem #1 to be scattered all over your program. It's much better to have it within one class, especially if the rest of your code already depends on it.

Nowadays, the Singleton pattern has become so popular that people may call something a singleton even if it solves just one of the listed problems.

2.4.3 Solution

All implementations of the Singleton have these two steps in common:

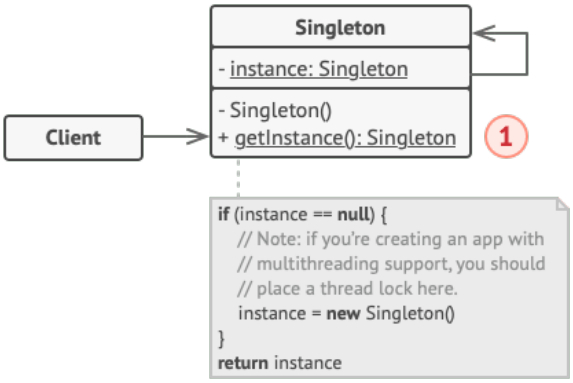
- Make the default constructor private, to prevent other objects from using the new operator with the Singleton class.
- Create a static creation method that acts as a constructor. Under the hood, this method calls the private constructor to create an object and saves it in a static field. All following calls to this method return the cached object.

If your code has access to the Singleton class, then it's able to call the Singleton's static method. So whenever that method is called, the same object is always returned.

2.4.4 Real-World Analogy

The government is an excellent example of the Singleton pattern. A country can have only one official government. Regardless of the personal identities of the individuals who form governments, the title, "The Government of X", is a global point of access that identifies the group of people in charge.

2.4.5 Structure



1. The Singleton class declares the static method getInstance that returns the same instance of its own class.

   The Singleton's constructor should be hidden from the client code. Calling the $getInstance()$ method should be the only way of getting the Singleton object.

2.4.6 Pseudocode

In this example, the database connection class acts as a Singleton. This class doesn't have a public constructor, so the only way to get its object is to call the getInstance method. This method caches the first created object and returns it in all subsequent calls.

PSEUDO CODE

```
// The Database class defines the 'getInstance' method that lets clients
//   access the same instance of a database connection throughout the program.
class Database is
  // The field for storing the singleton instance should be declared static.
  private static field instance: Database

  // The singleton's constructor should always be private to
  //   prevent direct construction calls with the 'new' operator.
  private constructor Database() is
    // Some initialization code, such as the actual connection to a database server.
    //   ...

  // The static method that controls access to the singleton instance.
  public static method getInstance() is
    if (Database.instance == null) then
      acquireThreadLock() and then
    // Ensure that the instance hasn't yet been initialized by another
```

```
PSEUDO CODE
        //    thread while this one has been waiting for the lock's release.
        if (Database.instance == null) then
            Database.instance = new Database()

        return Database.instance

    // Finally, any singleton should define some business logic
    //   which can be executed on its instance.
    public method query(sql) is
        // For instance, all database queries of an app go through this method.
        // Therefore, you can place throttling or caching logic here.
        //   ...


class Application is
    method main() is
        Database foo = Database.getInstance()
        foo.query("SELECT ...")
        //   ...
        Database bar = Database.getInstance()
        bar.query("SELECT ...")
        // The variable 'bar' will contain the same object as the variable 'foo'.
```

2.4.7 Applicability

- Use the Singleton pattern when a class in your program should have just a single instance available to all clients; for example, a single database object shared by different parts of the program.

▷ The Singleton pattern disables all other means of creating objects of a class except for the special creation method. This method either creates a new object or returns an existing one if it has already been created.

- Use the Singleton pattern when you need stricter control over global variables.

▷ Unlike global variables, the Singleton pattern guarantees that there's just one instance of a class. Nothing, except for the Singleton class itself, can replace the cached instance.

Note that you can always adjust this limitation and allow creating any number of Singleton instances. The only piece of code that needs changing is the body of the $getInstance()$ method.

2.4.8 How to Implement

1. Add a private static field to the class for storing the singleton instance.

2. Declare a public static creation method for getting the singleton instance.
3. Implement "lazy initialization" inside the static method. It should create a new object on its first call and put it into the static field. The method should always return that instance on all subsequent calls.
4. Make the constructor of the class private. The static method of the class will still be able to call the constructor, but not the other objects.
5. Go over the client code and replace all direct calls to the singleton's constructor with calls to its static creation method.

2.4.9 Example

It's pretty easy to implement a sloppy Singleton. You just need to hide the constructor and implement a static creation method.

```
package com.patterns.singleton;

public final class Singleton {
    private static Singleton instance;
    public String value;

    private Singleton(String value) {
        this.value = value;
    }

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

```
package com.patterns.singleton;

public class DemoSingleThread {
    public static void main(String[] args) {
        System.out.println("If you see the same value, then singleton was reused (yay!)"
            + "\n"
            + "If you see different values, then 2 singletons were created (booo!!)"
            + "\n\n"
            + "RESULT:" + "\n");
```

```
        Singleton singleton = Singleton.getInstance("FOO");
        System.out.println(singleton.value);

        Singleton anotherSingleton = Singleton.getInstance("BAR");
        System.out.println(anotherSingleton.value);
    }
}
```

2.4.10 Pros and Cons

+ You can be sure that a class has only a single instance.
+ You gain a global access point to that instance.
+ The singleton object is initialized only when it's requested for the first time.
- Violates the Single Responsibility Principle. The pattern solves two problems at the time.
- The Singleton pattern can mask bad design, for instance, when the components of the program know too much about each other.
- The pattern requires special treatment in a multithreaded environment so that multiple threads won't create a singleton object several times.
- It may be difficult to unit test the client code of the Singleton because many test frameworks rely on inheritance when producing mock objects. Since the constructor of the singleton class is private and overriding static methods is impossible in most languages, you will need to think of a creative way to mock the singleton. Or just don't write the tests. Or don't use the Singleton pattern.

2.4.11 Relations with Other Patterns

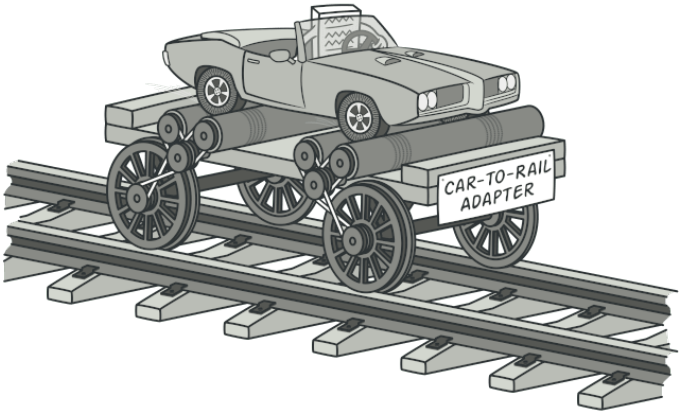
- A Facade class can often be transformed into a Singleton since a single facade object is sufficient in most cases.
- Flyweight would resemble Singleton if you somehow managed to reduce all shared states of the objects to just one flyweight object. But there are two fundamental differences between these patterns:
    1. There should be only one Singleton instance, whereas a Flyweight class can have multiple instances with different intrinsic states.
    2. The Singleton object can be mutable. Flyweight objects are immutable.
- Abstract Factories, Builders and Prototypes can all be implemented as Singletons.

3 Creational Design Patterns

3.1 Adapter Pattern

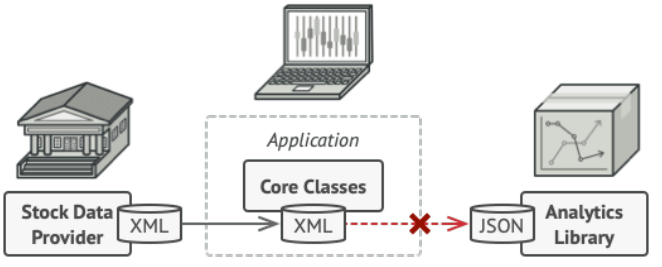
3.1.1 Intent

Adapter is a structural design pattern that allows objects with incompatible interfaces to collaborate.



3.1.2 Problem

Imagine that you're creating a stock market monitoring app. The app downloads the stock data from multiple sources in XML format and then displays nice-looking charts and diagrams for the user.



You can't use the analytics library "as is" because it expects the data in a format that's incompatible with your app.

At some point, you decide to improve the app by integrating a smart 3rd-party analytics library. But there's a catch: the analytics library only works with data in JSON format.

You could change the library to work with XML. However, this might break some existing code that relies on the library. And worse, you might not have access to the library's source code in the first place, making this approach impossible.

3.1.3 Solution

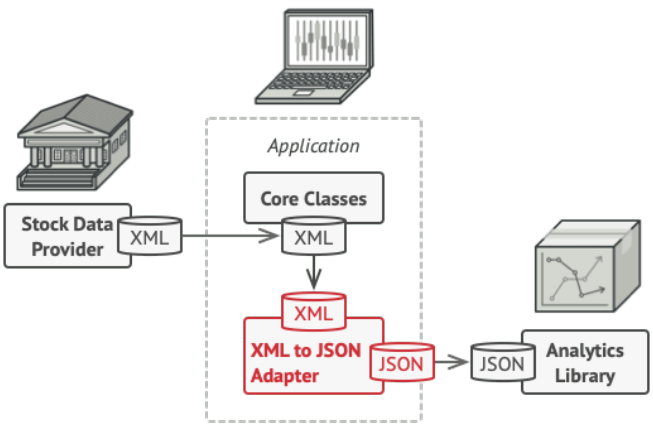
You can create an adapter. This is a special object that converts the interface of one object so that another object can understand it.

An adapter wraps one of the objects to hide the complexity of conversion happening behind the scenes. The wrapped object isn't even aware of the adapter. For example, you can wrap an object that operates in meters and kilometers with an adapter that converts all of the data to imperial units such as feet and miles.

Adapters can not only convert data into various formats but can also help objects with different interfaces collaborate. Here's how it works:

1. The adapter gets an interface, compatible with one of the existing objects.
2. Using this interface, the existing object can safely call the adapter's methods.
3. Upon receiving a call, the adapter passes the request to the second object, but in a format and order that the second object expects.

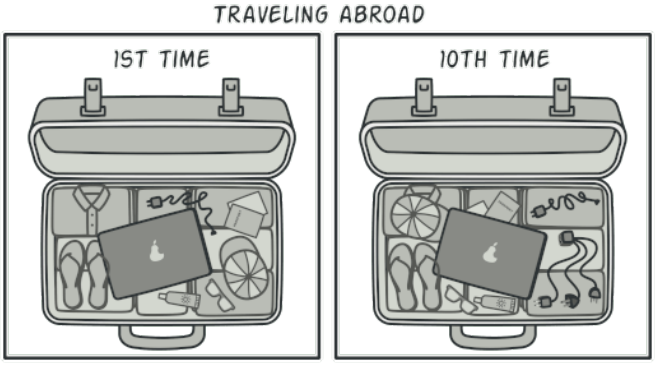
Sometimes it's even possible to create a two-way adapter that can convert the calls in both directions.



Let's get back to our stock market app. To solve the dilemma of incompatible formats, you can create XML-to-JSON adapters for every class of the analytics library that

your code works with directly. Then you adjust your code to communicate with the library only via these adapters. When an adapter receives a call, it translates the incoming XML data into a JSON structure and passes the call to the appropriate methods of a wrapped analytics object.

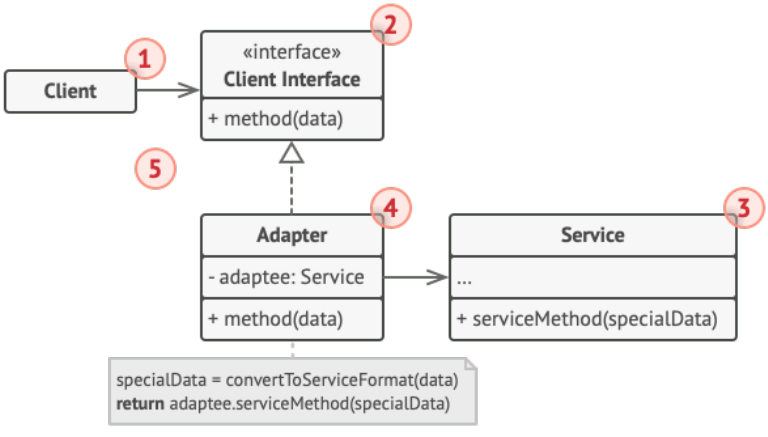
3.1.4 Real-World Analogy



A suitcase before and after a trip abroad

When you travel from the US to Europe for the first time, you may get a surprise when trying to charge your laptop. The power plug and sockets standards are different in different countries. That's why your US plug won't fit a German socket. The problem can be solved by using a power plug adapter that has the American-style socket and the European-style plug.

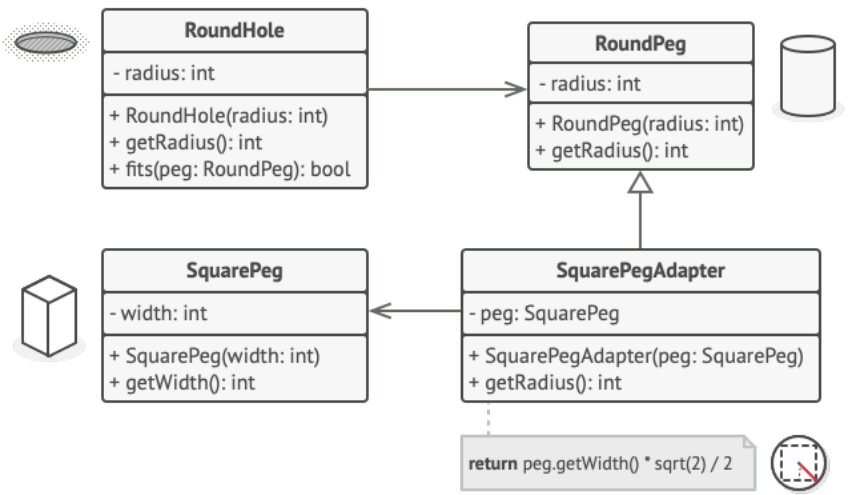
3.1.5 Structure



1. The Client is a class that contains the existing business logic of the program.
2. The Client Interface describes a protocol that other classes must follow to be able to collaborate with the client code.
3. The Service is some useful class (usually 3rd-party or legacy). The client can't use this class directly because it has an incompatible interface.
4. The Adapter is a class that's able to work with both the client and the service: it implements the client interface, while wrapping the service object. The adapter receives calls from the client via the adapter interface and translates them into calls to the wrapped service object in a format it can understand.
5. The client code doesn't get coupled to the concrete adapter class as long as it works with the adapter via the client interface. Thanks to this, you can introduce new types of adapters into the program without breaking the existing client code. This can be useful when the interface of the service class gets changed or replaced: you can just create a new adapter class without changing the client code.

3.1.6 Pseudocode

This example of the Adapter pattern is based on the classic conflict between square pegs and round holes.



Adapting square pegs to round holes

The Adapter pretends to be a round peg, with a radius equal to a half of the square's diameter (in other words, the radius of the smallest circle that can accommodate the square peg).

PSEUDO CODE

```
// Say you have two classes with compatible interfaces: RoundHole and RoundPeg.
class RoundHole is
  constructor RoundHole(radius) { ... }

  method getRadius() is
    // Return the radius of the hole.

  method fits(peg: RoundPeg) is
    return this.getRadius() >= peg.getRadius()

class RoundPeg is
  constructor RoundPeg(radius) { ... }

  method getRadius() is
    // Return the radius of the peg.


// But there's an incompatible class: SquarePeg.
class SquarePeg is
  constructor SquarePeg(width) { ... }

  method getWidth() is
    // Return the square peg width.


// An adapter class lets you fit square pegs into round holes.
// It extends the RoundPeg class to let the adapter objects act as round pegs.
class SquarePegAdapter extends RoundPeg is
  // In reality, the adapter contains an instance of the SquarePeg class.
  private field peg: SquarePeg

  constructor SquarePegAdapter(peg: SquarePeg) is
    this.peg = peg

  method getRadius() is
    // The adapter pretends that it's a round peg with a radius
    //  that could fit the square peg that the adapter actually wraps.
    return peg.getWidth() * Math.sqrt(2) / 2


// Somewhere in client code.
hole = new RoundHole(5)
roundPeg = new RoundPeg(5)
hole.fits(roundPeg) // true

smallSquarePeg = new SquarePeg(5)
largeSquarePeg = new SquarePeg(10)
hole.fits(small_sqpeg)  // This won't compile (incompatible types)

smallSquarePegAdapter = new SquarePegAdapter(smallSquarePeg)
```

```
largeSquarePegAdapter = new SquarePegAdapter(largeSquarePeg)
hole.fits(smallSquarePegAdapter)   // true
hole.fits(largeSquarePegAdapter)   // false
```

3.1.7 Applicability

- Use the Adapter class when you want to use some existing class, but its interface isn't compatible with the rest of your code.

▷ The Adapter pattern lets you create a middle-layer class that serves as a translator between your code and a legacy class, a 3rd-party class or any other class with a weird interface.

- Use the pattern when you want to reuse several existing subclasses that lack some common functionality that can't be added to the superclass.

▷ You could extend each subclass and put the missing functionality into new child classes. However, you'll need to duplicate the code across all of these new classes, which smells really bad.

The much more elegant solution would be to put the missing functionality into an adapter class. Then you would wrap objects with missing features inside the adapter, gaining needed features dynamically. For this to work, the target classes must have a common interface, and the adapter's field should follow that interface. This approach looks very similar to the Decorator pattern.

3.1.8 How to Implement

1. Make sure that you have at least two classes with incompatible interfaces:
   - A useful service class, which you can't change (often 3rd-party, legacy or with lots of existing dependencies).
   - One or several client classes that would benefit from using the service class.
2. Declare the client interface and describe how clients communicate with the service.
3. Create the adapter class and make it follow the client interface. Leave all the methods empty for now.
4. Add a field to the adapter class to store a reference to the service object. The common practice is to initialize this field via the constructor, but sometimes it's more convenient to pass it to the adapter when calling its methods.

5. One by one, implement all methods of the client interface in the adapter class. The adapter should delegate most of the real work to the service object, handling only the interface or data format conversion.

6. Clients should use the adapter via the client interface. This will let you change or extend the adapters without affecting the client code.

3.1.9 Example

This simple example shows how an Adapter can make incompatible objects work together.

```
1  package com.patterns.adapter.round;
2
3  /**
4   * RoundHoles are compatible with RoundPegs.
5   */
6  public class RoundHole {
7    private double radius;
8
9    public RoundHole(double radius) {
10     this.radius = radius;
11   }
12
13   public double getRadius() {
14     return radius;
15   }
16
17   public boolean fits(RoundPeg peg) {
18     boolean result;
19     result = (this.getRadius() >= peg.getRadius());
20     return result;
21   }
22 }
```

```
1  package com.patterns.adapter.round;
2
3  /**
4   * RoundPegs are compatible with RoundHoles.
5   */
6  public class RoundPeg {
7    private double radius;
8
9    public RoundPeg() {}
```

```
10
    public RoundPeg(double radius) {
12      this.radius = radius;
    }
14
    public double getRadius() {
16      return radius;
    }
18  }
```

```
  package com.patterns.adapter.square;
2
  /**
4  * SquarePegs are not compatible with RoundHoles (they were implemented by
   * previous development team). But we have to integrate them into our program.
6  */
  public class SquarePeg {
8   private double width;

10  public SquarePeg(double width) {
      this.width = width;
12  }

14  public double getWidth() {
      return width;
16  }

18  public double getSquare() {
      double result;
20      result = Math.pow(this.width, 2);
      return result;
22  }
  }
```

```
1 package com.patterns.adapter.adapters;

3 import com.patterns.adapter.round.RoundPeg;
  import com.patterns.adapter.square.SquarePeg;
5
  /**
7  * Adapter allows fitting square pegs into round holes.
```

```
 */
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;
  }
}
```

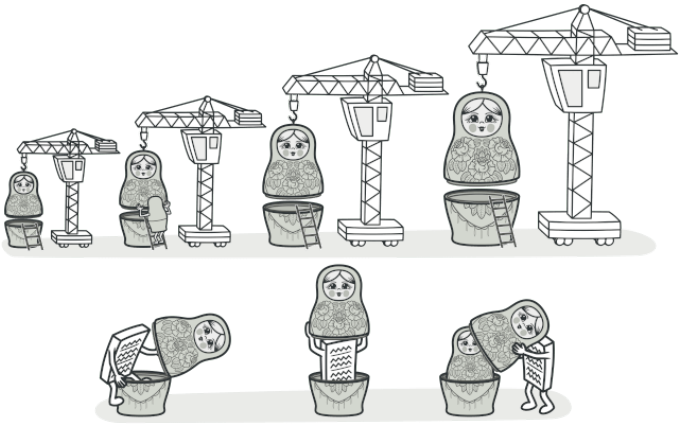
```
package com.patterns.adapter.app;

import com.patterns.adapter.adapters.SquarePegAdapter;
import com.patterns.adapter.round.RoundHole;
import com.patterns.adapter.round.RoundPeg;
import com.patterns.adapter.square.SquarePeg;

/**
 * Somewhere in client code...
 */
public class App {
  public static void main(String[] args) {
    // Round fits round, no surprise.
    RoundHole hole = new RoundHole(5);
    RoundPeg roundPeg = new RoundPeg(5);
    if (hole.fits(roundPeg)) {
      System.out.println("Round peg r5 fits round hole r5.");
    }

    SquarePeg smallSquarePeg = new SquarePeg(2);
    SquarePeg largeSquarePeg = new SquarePeg(20);
    // hole.fits(smallSqPeg); // Won't compile.

    // Adapter solves the problem.
    SquarePegAdapter smallSquarePegAdapter
      = new SquarePegAdapter(smallSquarePeg);
    SquarePegAdapter largeSquarePegAdapter
      = new SquarePegAdapter(largeSquarePeg);
    if (hole.fits(smallSqPegAdapter)) {
```

```
            System.out.println("Square peg w2 fits round hole r5.");
        }
        if (!hole.fits(largeSqPegAdapter)) {
            System.out.println("Square peg w20 does not fit into round hole r5.");
        }
    }
}
```

3.2 Decorator Pattern

3.2.1 Intent

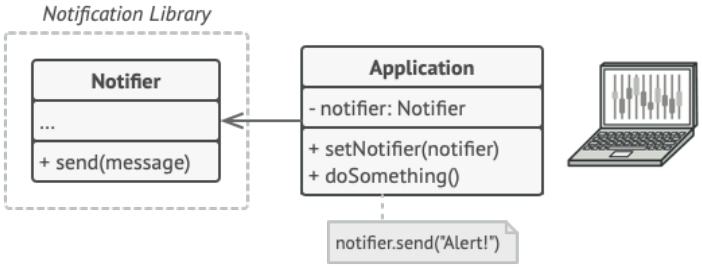
Decorator is a structural design pattern that lets you attach new behaviors to objects by placing these objects inside special wrapper objects that contain the behaviors.



3.2.2 Problem

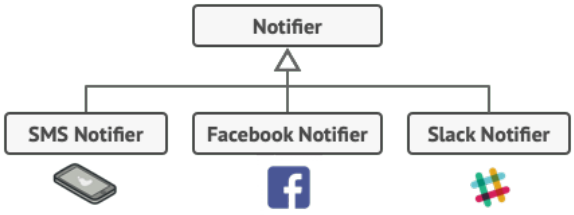
Imagine that you're working on a notification library which lets other programs notify their users about important events.

The initial version of the library was based on the Notifier class that had only a few fields, a constructor and a single *send* method. The method could accept a message argument from a client and send the message to a list of emails that were passed to the notifier via its constructor. A third-party app which acted as a client was supposed to create and configure the notifier object once, and then use it each time something important happened.



A program could use the notifier class to send notifications about important events to a predefined set of emails.

At some point, you realize that users of the library expect more than just email notifications. Many of them would like to receive an SMS about critical issues. Others would like to be notified on Facebook and, of course, the corporate users would love to get Slack notifications.

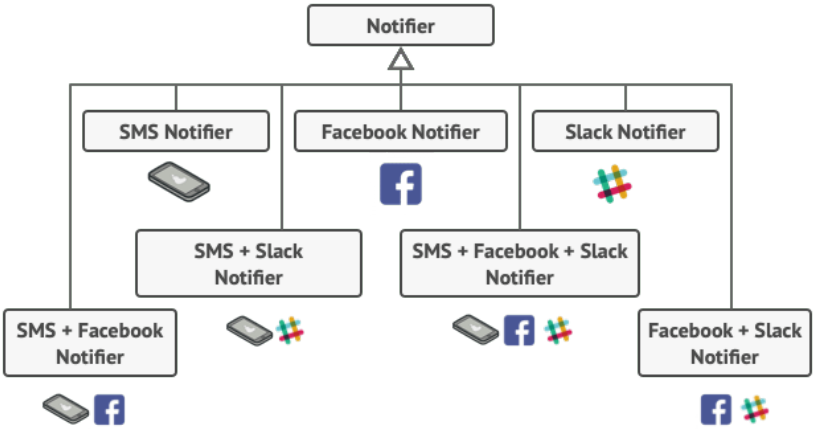


Each notification type is implemented as a notifier's subclass.

How hard can that be? You extended the Notifier class and put the additional notification methods into new subclasses. Now the client was supposed to instantiate the desired notification class and use it for all further notifications.

But then someone reasonably asked you, "Why can't you use several notification types at once? If your house is on fire, you'd probably want to be informed through every channel."

You tried to address that problem by creating special subclasses which combined several notification methods within one class. However, it quickly became apparent that this approach would bloat the code immensely, not only the library code but the client code as well.



Combinatorial explosion of subclasses.

You have to find some other way to structure notifications classes so that their number won't accidentally break some Guinness record.

3.2.3 Solution

Extending a class is the first thing that comes to mind when you need to alter an object's behavior. However, inheritance has several serious caveats that you need to be aware of.

- Inheritance is static. You can't alter the behavior of an existing object at runtime. You can only replace the whole object with another one that's created from a different subclass.
- Subclasses can have just one parent class. In most languages, inheritance doesn't let a class inherit behaviors of multiple classes at the same time.

One of the ways to overcome these caveats is by using Aggregation or Composition instead of Inheritance. Both of the alternatives work almost the same way: one object has a reference to another and delegates it some work, whereas with inheritance, the object itself is able to do that work, inheriting the behavior from its superclass.

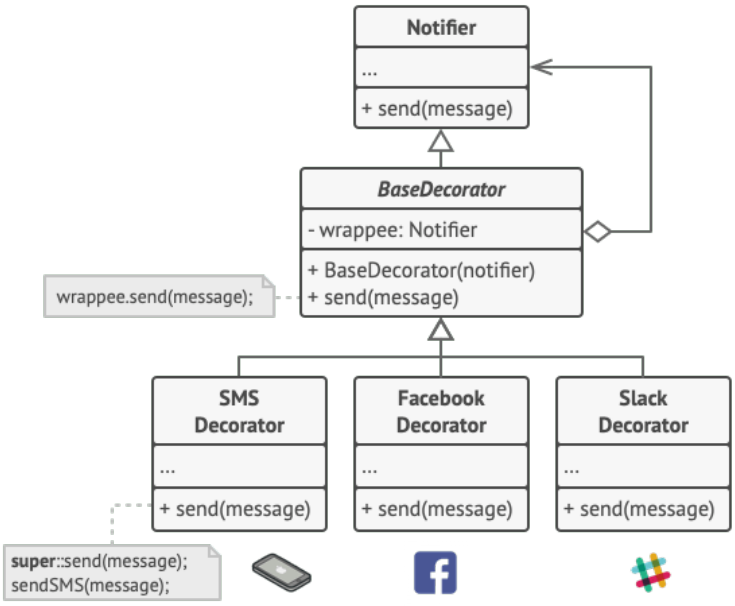
With this new approach you can easily substitute the linked "helper" object with another, changing the behavior of the container at runtime. An object can use the behavior of various classes, having references to multiple objects and delegating them all kinds of work. Aggregation/composition is the key principle behind many design patterns, including Decorator. On that note, let's return to the pattern discussion.

Inheritance vs. Aggregation.

"Wrapper" is the alternative nickname for the Decorator pattern that clearly expresses the main idea of the pattern. A wrapper is an object that can be linked with some target object. The wrapper contains the same set of methods as the target and delegates to it all requests it receives. However, the wrapper may alter the result by doing something either before or after it passes the request to the target.

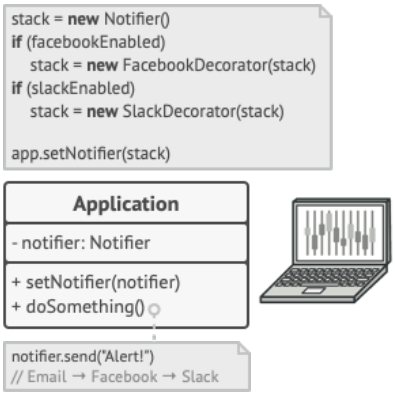
When does a simple wrapper become the real decorator? As I mentioned, the wrapper implements the same interface as the wrapped object. That's why from the client's perspective these objects are identical. Make the wrapper's reference field accept any object that follows that interface. This will let you cover an object in multiple wrappers, adding the combined behavior of all the wrappers to it.

In our notifications example, let's leave the simple email notification behavior inside the base Notifier class, but turn all other notification methods into decorators.



Various notification methods become decorators.

The client code would need to wrap a basic notifier object into a set of decorators that match the client's preferences. The resulting objects will be structured as a stack.



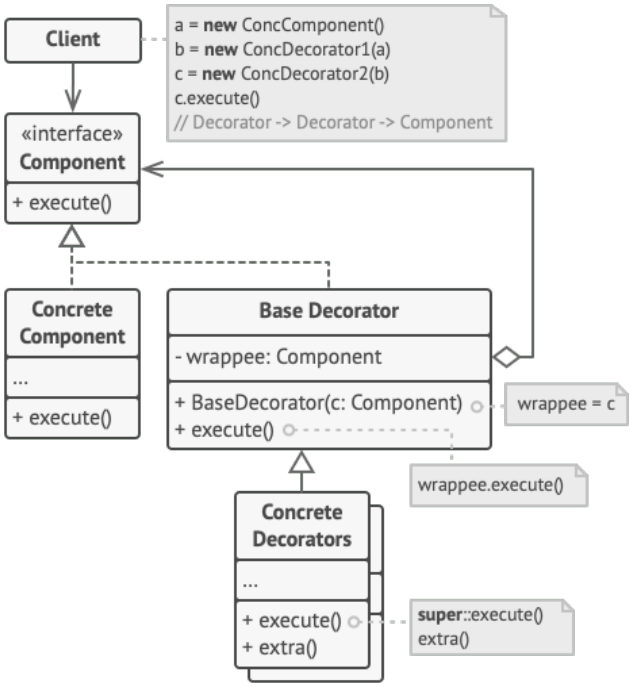
Apps might configure complex stacks of notification decorators.

The last decorator in the stack would be the object that the client actually works with. Since all decorators implement the same interface as the base notifier, the rest

of the client code won't care whether it works with the "pure" notifier object or the decorated one.

We could apply the same approach to other behaviors such as formatting messages or composing the recipient list. The client can decorate the object with any custom decorators, as long as they follow the same interface as the others.

3.2.4 Structure



1. The Component declares the common interface for both wrappers and wrapped objects.

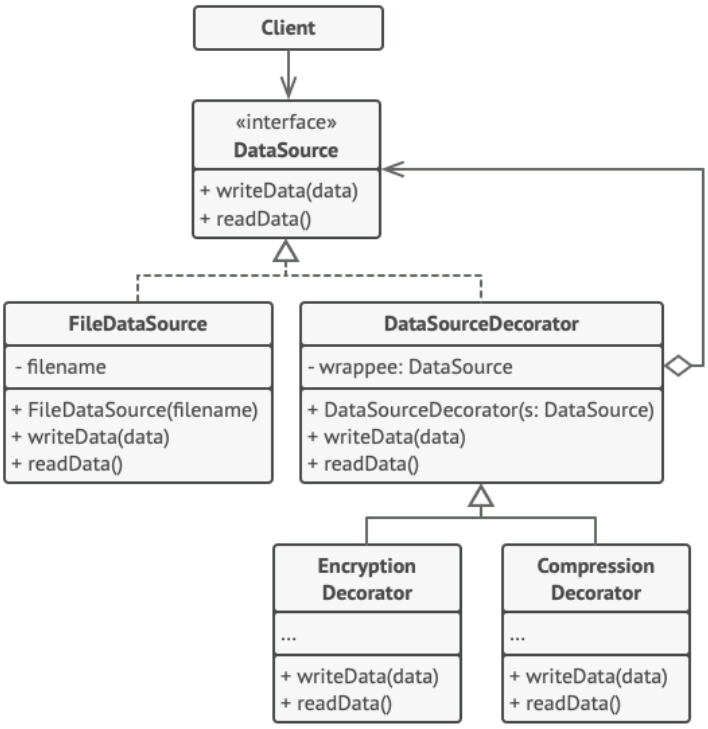
2. Concrete Component is a class of objects being wrapped. It defines the basic behavior, which can be altered by decorators.

3. The Base Decorator class has a field for referencing a wrapped object. The field's type should be declared as the component interface so it can contain both concrete components and decorators. The base decorator delegates all operations to the wrapped object.

4. Concrete Decorators define extra behaviors that can be added to components dynamically. Concrete decorators override methods of the base decorator and execute their behavior either before or after calling the parent method.

3.2.5 Pseudocode

In this example, the Decorator pattern lets you compress and encrypt sensitive data independently from the code that actually uses this data.



The encryption and compression decorators example.

The application wraps the data source object with a pair of decorators. Both wrappers change the way the data is written to and read from the disk:

- Just before the data is written to disk, the decorators encrypt and compress it. The original class writes the encrypted and protected data to the file without knowing about the change.

- Right after the data is read from disk, it goes through the same decorators, which decompress and decode it.

The decorators and the data source class implement the same interface, which makes them all interchangeable in the client code.


```
// The component interface defines operations that can be
//   altered by decorators.
interface DataSource is
  method writeData(data)
  method readData():data


// Concrete components provide default implementations for the
//   operations. There might be several variations of these
//   classes in a program.
class FileDataSource implements DataSource is
  constructor FileDataSource(filename) { ... }

  method writeData(data) is
    // Write data to file.

  method readData():data is
    // Read data from file.


// The base decorator class follows the same interface as the other
//   components. The primary purpose of this class is to define the
//   wrapping interface for all concrete decorators. The default
//   implementation of the wrapping code might include a field for
//   storing a wrapped component and the means to initialize it.
class DataSourceDecorator implements DataSource is
  protected field wrappee: DataSource

  constructor DataSourceDecorator(source: DataSource) is
    wrappee = source

  // The base decorator simply delegates all work to the wrapped
  //   component. Extra behaviors can be added in concrete decorators.
  method writeData(data) is
    wrappee.writeData(data)

  // Concrete decorators may call the parent implementation of
  //   the operation instead of calling the wrapped object directly.
  //   This approach simplifies extension of decorator classes.
  method readData():data is
    return wrappee.readData()


// Concrete decorators must call methods on the wrapped object, but may
//   add something of their own to the result. Decorators can execute the
//   added behavior either before or after the call to a wrapped object.
class EncryptionDecorator extends DataSourceDecorator is
  method writeData(data) is
    // 1. Encrypt passed data.
    // 2. Pass encrypted data to the wrappee's writeData
```


```
        // method.

    method readData():data is
        // 1. Get data from the wrappee's readData method.
        // 2. Try to decrypt it if it's encrypted.
        // 3. Return the result.


// You can wrap objects in several layers of decorators.
class CompressionDecorator extends DataSourceDecorator is
    method writeData(data) is
        // 1. Compress passed data.
        // 2. Pass compressed data to the wrappee's writeData
        // method.

    method readData():data is
        // 1. Get data from the wrappee's readData method.
        // 2. Try to decompress it if it's compressed.
        // 3. Return the result.


// Option 1. A simple example of a decorator assembly.
class Application is
    method dumbUsageExample() is
        source = new FileDataSource("somefile.dat")
        source.writeData(salaryRecords)
        // The target file has been written with plain data.

        source = new CompressionDecorator(source)
        source.writeData(salaryRecords)
        // The target file has been written with compressed data.

        source = new EncryptionDecorator(source)
        // The source variable now contains this:
        // Encryption > Compression > FileDataSource
        source.writeData(salaryRecords)
        // The file has been written with compressed and
        // encrypted data.


// Option 2. Client code that uses an external data source. SalaryManager
//    objects neither know nor care about data storage specifics. They work
//    with a pre-configured data source received from the app configurator.
class SalaryManager is
    field source: DataSource

    constructor SalaryManager(source: DataSource) { ... }

    method load() is
        return source.readData()
```

```
    method save() is
      source.writeData(salaryRecords)
      // ... Other useful methods ...


// The app can assemble different stacks of decorators at
//  runtime, depending on the configuration or environment.
class ApplicationConfigurator is
  method configurationExample() is
    source = new FileDataSource("salary.dat")
    if (enabledEncryption)
      source = new EncryptionDecorator(source)
    if (enabledCompression)
      source = new CompressionDecorator(source)

    logger = new SalaryManager(source)
    salary = logger.load()
    // ...
```

3.2.6 Applicability

- Use the Decorator pattern when you need to be able to assign extra behaviors to objects at runtime without breaking the code that uses these objects.

▷ The Decorator lets you structure your business logic into layers, create a decorator for each layer and compose objects with various combinations of this logic at runtime. The client code can treat all these objects in the same way, since they all follow a common interface.

- Use the pattern when it's awkward or not possible to extend an object's behavior using inheritance.

▷ Many programming languages have the final keyword that can be used to prevent further extension of a class. For a final class, the only way to reuse the existing behavior would be to wrap the class with your own wrapper, using the Decorator pattern.

3.2.7 How to Implement

1. Make sure your business domain can be represented as a primary component with multiple optional layers over it.

2. Figure out what methods are common to both the primary component and the optional layers. Create a component interface and declare those methods there.

3. Create a concrete component class and define the base behavior in it.

4. Create a base decorator class. It should have a field for storing a reference to a wrapped object. The field should be declared with the component interface type to allow linking to concrete components as well as decorators. The base decorator must delegate all work to the wrapped object.

5. Make sure all classes implement the component interface.

6. Create concrete decorators by extending them from the base decorator. A concrete decorator must execute its behavior before or after the call to the parent method (which always delegates to the wrapped object).

7. The client code must be responsible for creating decorators and composing them in the way the client needs.

3.2.8 Pros and Cons

+ You can extend an object's behavior without making a new subclass.

+ You can add or remove responsibilities from an object at runtime.

+ You can combine several behaviors by wrapping an object into multiple decorators.

+ Single Responsibility Principle. You can divide a monolithic class that implements many possible variants of behavior into several smaller classes.

- It's hard to remove a specific wrapper from the wrappers stack.

- It's hard to implement a decorator in such a way that its behavior doesn't depend on the order in the decorators stack.

- The initial configuration code of layers might look pretty ugly.

3.2.9 Relations with Other Patterns

- Adapter changes the interface of an existing object, while Decorator enhances an object without changing its interface. In addition, Decorator supports recursive composition, which isn't possible when you use Adapter.

- Adapter provides a different interface to the wrapped object, Proxy provides it with the same interface, and Decorator provides it with an enhanced interface.

- Chain of Responsibility and Decorator have very similar class structures. Both patterns rely on recursive composition to pass the execution through a series of objects. However, there are several crucial differences.

  The CoR handlers can execute arbitrary operations independently of each other. They can also stop passing the request further at any point. On the other hand,

various Decorators can extend the object's behavior while keeping it consistent with the base interface. In addition, decorators aren't allowed to break the flow of the request.

- Composite and Decorator have similar structure diagrams since both rely on recursive composition to organize an open-ended number of objects.

  A Decorator is like a Composite but only has one child component. There's another significant difference: Decorator adds additional responsibilities to the wrapped object, while Composite just "sums up" its children's results.

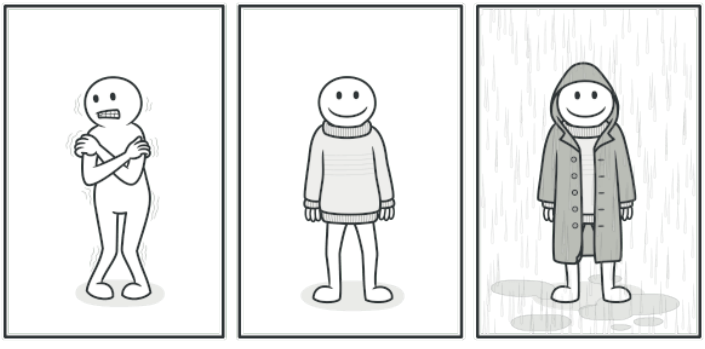
  However, the patterns can also cooperate: you can use Decorator to extend the behavior of a specific object in the Composite tree.

- Designs that make heavy use of Composite and Decorator can often benefit from using Prototype. Applying the pattern lets you clone complex structures instead of re-constructing them from scratch.

- Decorator lets you change the skin of an object, while Strategy lets you change the guts.

- Decorator and Proxy have similar structures, but very different intents. Both patterns are built on the composition principle, where one object is supposed to delegate some of the work to another. The difference is that a Proxy usually manages the life cycle of its service object on its own, whereas the composition of Decorators is always controlled by the client.

3.2.10 Real-World Analogy



You get a combined effect from wearing multiple pieces of clothing.

Wearing clothes is an example of using decorators. When you're cold, you wrap yourself in a sweater. If you're still cold with a sweater, you can wear a jacket on top. If it's raining, you can put on a raincoat. All of these garments "extend"

your basic behavior but aren't part of you, and you can easily take off any piece of clothing whenever you don't need it.

3.2.11 Examples

1. Structure Example

```java
package com.patterns.decorator;

public abstract class AbstractComponent {
    public abstract void operation();
}
```

```java
package com.patterns.decorator;

public class ConcreteComponent extends AbstractComponent {

    @Override
    public void execute() {
        System.out.println("ConcreteComponent.execute()");
    }
}
```

```java
package com.patterns.decorator;

public abstract class BaseDecorator extends AbstractComponent {
    private final AbstractComponent component;

    protected BaseDecorator(AbstractComponent component) {
        this.component = component;
    }

    @Override
    public void execute() {
        this.component.execute();
    }
}
```

```java
package com.patterns.decorator;

public class ConcreteDecorator extends BaseDecorator {

    public ConcreteDecorator(AbstractComponent component) {
        super(component);
    }

    @Override
    public void execute() {
        super.execute();
        System.out.println("[ADDITIONAL CODE BLOCK]");
    }
}
```

```java
package com.patterns.decorator;

public class App {
    public static void main(String[] args) {
        AbstractComponent component = new ConcreteComponent();
        BaseDecorator decorator = new ConcreteDecorator(component);
        decorator.operation();
    }
}
```

2. Real-World Example

```java
package com.patterns.decorator;

public abstract class Pizza {
    protected String description = "Basic Pizza";

    public String getDescription() {
        return description;
    }

    public abstract double cost();
}
```

```java
package com.patterns.decorator;

public class ThickcrustPizza extends Pizza {
    public ThickcrustPizza() {
        description = "Thick crust pizza, with tomato sauce";
    }

    public double cost() {
        return 7.99;
    }
}
```

```java
package com.patterns.decorator;

public class ThincrustPizza extends Pizza {
    public ThincrustPizza() {
        description = "Thin crust pizza, with tomato sauce";
    }

    public double cost() {
        return 7.99;
    }
}
```

```java
package com.patterns.decorator;

public abstract class ToppingDecorator extends Pizza {
    protected Pizza pizza;

    public abstract String getDescription();
}
```

```java
package com.patterns.decorator;

public class Cheese extends ToppingDecorator {
    public Cheese(Pizza pizza) {
```

```
        this.pizza = pizza;
    }

    public String getDescription() {
        return pizza.getDescription() + ", Cheese";
    }

    public double cost() {
        return pizza.cost(); // cheese is free
    }
}
```

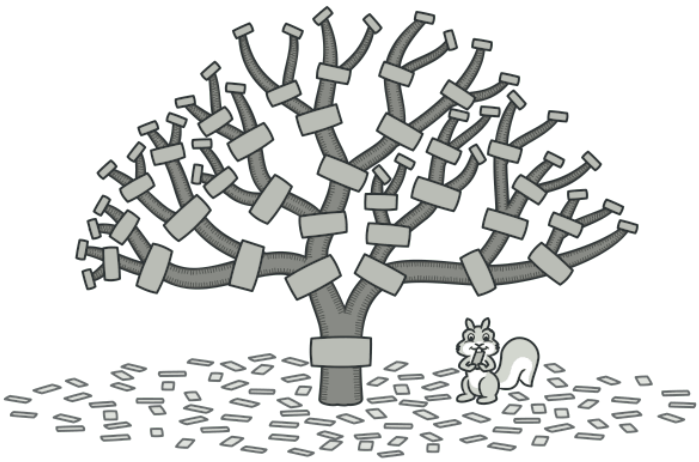
```
package com.patterns.decorator;

public class Olives extends ToppingDecorator {
    public Olives(Pizza pizza) {
        this.pizza = pizza;
    }

    public String getDescription() {
        return pizza.getDescription() + ", Olives";
    }

    public double cost() {
        return pizza.cost() + .30;
    }
}
```

```
package com.patterns.decorator;

public class PizzaStore {
    public static void main(String args[]) {
        Pizza pizza = new ThincrustPizza();
        Pizza cheesePizza = new Cheese(pizza);
        Pizza greekPizza = new Olives(cheesePizza);

        System.out.println(greekPizza.getDescription()
            + " $" + greekPizza.cost());
    }
}
```

3.3 Composite Pattern

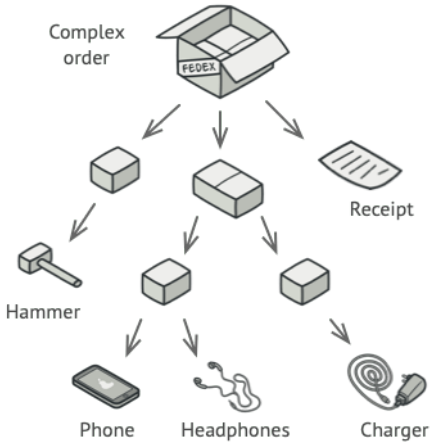
3.3.1 Intent

Composite is a structural design pattern that lets you compose objects into tree structures and then work with these structures as if they were individual objects.



3.3.2 Problem

Using the Composite pattern makes sense only when the core model of your app can be represented as a tree.



An order might comprise various products, packaged in boxes, which are packaged in bigger boxes and so on. The whole structure looks like an upside down tree.

For example, imagine that you have two types of objects: Products and Boxes. A Box can contain several Products as well as a number of smaller Boxes. These little Boxes can also hold some Products or even smaller Boxes, and so on.

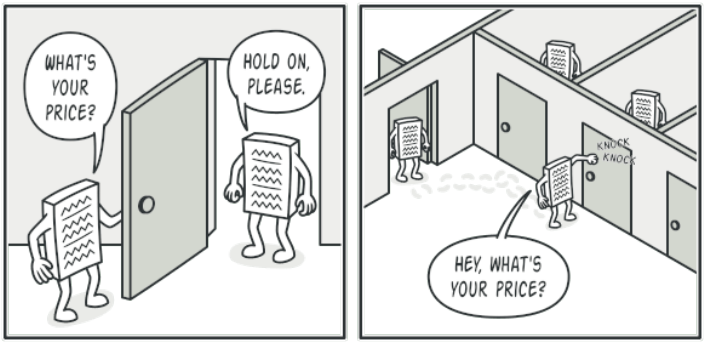
Say you decide to create an ordering system that uses these classes. Orders could contain simple products without any wrapping, as well as boxes stuffed with products...and other boxes. How would you determine the total price of such an order?

You could try the direct approach: unwrap all the boxes, go over all the products and then calculate the total. That would be doable in the real world; but in a program, it's not as simple as running a loop. You have to know the classes of Products and Boxes you're going through, the nesting level of the boxes and other nasty details beforehand. All of this makes the direct approach either too awkward or even impossible.

3.3.3 Solution

The Composite pattern suggests that you work with Products and Boxes through a common interface which declares a method for calculating the total price.

How would this method work? For a product, it'd simply return the product's price. For a box, it'd go over each item the box contains, ask its price and then return a total for this box. If one of these items were a smaller box, that box would also start going over its contents and so on, until the prices of all inner components were calculated. A box could even add some extra cost to the final price, such as packaging cost.

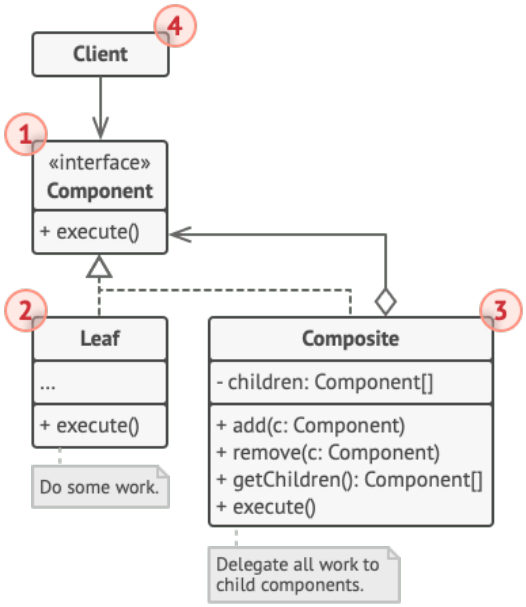


The Composite pattern lets you run a behavior recursively over all components of an object tree.

The greatest benefit of this approach is that you don't need to care about the concrete classes of objects that compose the tree. You don't need to know whether

an object is a simple product or a sophisticated box. You can treat them all the same via the common interface. When you call a method, the objects themselves pass the request down the tree.

3.3.4 Structure



1. The Component interface describes operations that are common to both simple and complex elements of the tree.

2. The Leaf is a basic element of a tree that doesn't have sub-elements.

   Usually, leaf components end up doing most of the real work, since they don't have anyone to delegate the work to.

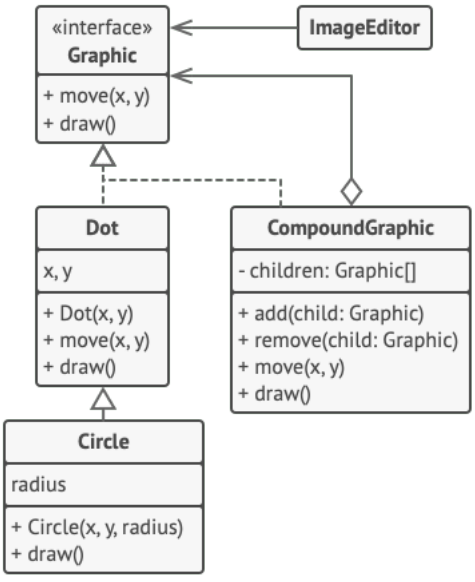
3. The Container (aka composite) is an element that has sub-elements: leaves or other containers. A container doesn't know the concrete classes of its children. It works with all sub-elements only via the component interface.

   Upon receiving a request, a container delegates the work to its sub-elements, processes intermediate results and then returns the final result to the client.

4. The Client works with all elements through the component interface. As a result, the client can work in the same way with both simple or complex elements of the tree.

3.3.5 Pseudocode

In this example, the Composite pattern lets you implement stacking of geometric shapes in a graphical editor.



The geometric shapes editor example.

The CompoundGraphic class is a container that can comprise any number of sub-shapes, including other compound shapes. A compound shape has the same methods as a simple shape. However, instead of doing something on its own, a compound shape passes the request recursively to all its children and "sums up" the result.

The client code works with all shapes through the single interface common to all shape classes. Thus, the client doesn't know whether it's working with a simple shape or a compound one. The client can work with very complex object structures without being coupled to concrete classes that form that structure.

PSEUDO CODE

```
// The component interface declares common operations for both simple and
//   complex objects of a composition.
interface Graphic is
  method move(x, y)
  method draw()

```


```
// The leaf class represents end objects of a composition. A leaf object can't
// have any sub-objects. Usually, it's leaf objects that do the actual work,
// while composite objects only delegate to their sub-components.
class Dot implements Graphic is
  field x
  field y

  constructor Dot(x, y) { ... }

  method move(x, y) is
    this.x += x, this.y += y

  method draw() is
    // Draw a dot at X and Y.


// All component classes can extend other components.
class Circle extends Dot is
  field radius

  constructor Circle(x, y, radius) { ... }

  method draw() is
    // Draw a circle at X and Y with radius R.


// The composite class represents complex components that may have children.
// Composite objects usually delegate the actual work to their children
// and then "sum up" the result.
class CompoundGraphic implements Graphic is
  field children: array of Graphic

  // A composite object can add or remove other components
  //   (both simple or complex) to or from its child list.
  method add(child: Graphic) is
    // Add a child to the array of children.

  method remove(child: Graphic) is
    // Remove a child from the array of children.

  method move(x, y) is
    foreach (child in children) do
      child.move(x, y)

  // A composite executes its primary logic in a particular way.
  //   It traverses recursively through all its children, collecting and
  //   summing up their results. Since the composite's children pass
  //   these calls to their own children and so forth, the whole object
  //   tree is traversed as a result.
  method draw() is
    // 1. For each child component:
```

```
        //         - Draw the component.
        //         - Update the bounding rectangle.
        //   2. Draw a dashed rectangle using the bounding
        //      coordinates.


// The client code works with all the components via their base
//  interface. This way the client code can support simple leaf
//  components as well as complex composites.
class ImageEditor is
  field all: CompoundGraphic

  method load() is
    all = new CompoundGraphic()
    all.add(new Dot(1, 2))
    all.add(new Circle(5, 3, 10))
    // ...

  // Combine selected components into one complex composite component.
  method groupSelected(components: array of Graphic) is
    group = new CompoundGraphic()
    foreach (component in components) do
      group.add(component)
      all.remove(component)
      all.add(group)
      // All components will be drawn.
      all.draw()
```

3.3.6 Applicability

- Use the Composite pattern when you have to implement a tree-like object structure.

▷ The Composite pattern provides you with two basic element types that share a common interface: simple leaves and complex containers. A container can be composed of both leaves and other containers. This lets you construct a nested recursive object structure that resembles a tree.

- Use the pattern when you want the client code to treat both simple and complex elements uniformly.

▷ All elements defined by the Composite pattern share a common interface. Using this interface, the client doesn't have to worry about the concrete class of the objects it works with.

3.3.7 How to Implement

1. Make sure that the core model of your app can be represented as a tree structure. Try to break it down into simple elements and containers. Remember that containers must be able to contain both simple elements and other containers.

2. Declare the component interface with a list of methods that make sense for both simple and complex components.

3. Create a leaf class to represent simple elements. A program may have multiple different leaf classes.

4. Create a container class to represent complex elements. In this class, provide an array field for storing references to sub-elements. The array must be able to store both leaves and containers, so make sure it's declared with the component interface type.

   While implementing the methods of the component interface, remember that a container is supposed to be delegating most of the work to sub-elements.

5. Finally, define the methods for adding and removal of child elements in the container.

   Keep in mind that these operations can be declared in the component interface. This would violate the **Interface Segregation Principle** because the methods will be empty in the leaf class. However, the client will be able to treat all the elements equally, even when composing the tree.

3.3.8 Pros and Cons

+ You can work with complex tree structures more conveniently: use polymorphism and recursion to your advantage.

+ **Open/Closed Principle**. You can introduce new element types into the app without breaking the existing code, which now works with the object tree.

- It might be difficult to provide a common interface for classes whose functionality differs too much. In certain scenarios, you'd need to overgeneralize the component interface, making it harder to comprehend.

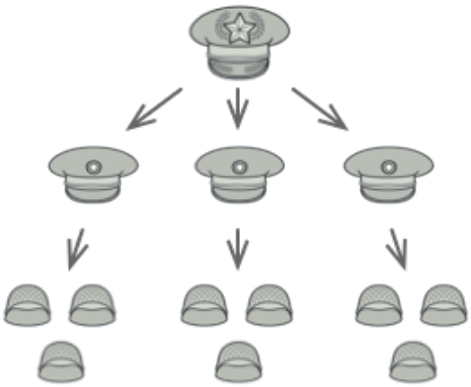
3.3.9 Relations with Other Patterns

- You can use Builder when creating complex Composite trees because you can program its construction steps to work recursively.

- Chain of Responsibility is often used in conjunction with Composite. In this case, when a leaf component gets a request, it may pass it through the chain of all of the parent components down to the root of the object tree.

- You can use Iterators to traverse Composite trees.
- You can use Visitor to execute an operation over an entire Composite tree.
- You can implement shared leaf nodes of the Composite tree as Flyweights to save some RAM.
- Composite and Decorator have similar structure diagrams since both rely on recursive composition to organize an open-ended number of objects.
- A Decorator is like a Composite but only has one child component. There's another significant difference: Decorator adds additional responsibilities to the wrapped object, while Composite just "sums up" its children's results.
- However, the patterns can also cooperate: you can use Decorator to extend the behavior of a specific object in the Composite tree.
- Designs that make heavy use of Composite and Decorator can often benefit from using Prototype. Applying the pattern lets you clone complex structures instead of re-constructing them from scratch.

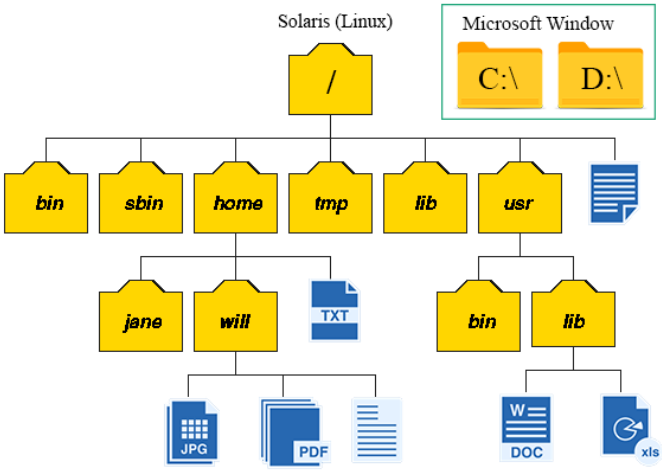
3.3.10 Real-World Analogy



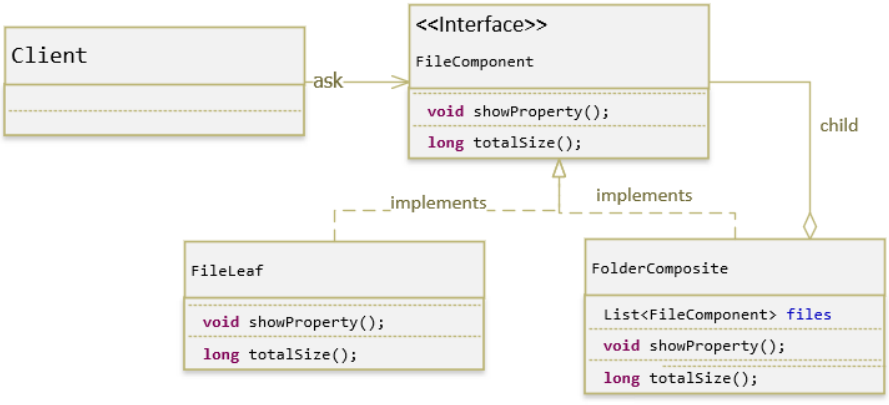
An example of a military structure.

Armies of most countries are structured as hierarchies. An army consists of several divisions; a division is a set of brigades, and a brigade consists of platoons, which can be broken down into squads. Finally, a squad is a small group of real soldiers. Orders are given at the top of the hierarchy and passed down onto each level until every soldier knows what needs to be done.

3.3.11 Examples



The composite example of folder structure.



The Composite Example UML.

```java
package com.patterns.composite;

public interface FileComponent {
    void showProperty();
    long totalSize();
}
```

```
package com.patterns.composite;

public class FileLeaf implements FileComponent {
    private String name;
    private long size;

    public FileLeaf(String name, long size) {
        super();
        this.name = name;
        this.size = size;
    }

    @Override
    public long totalSize() {
        return size;
    }

    @Override
    public void showProperty() {
        System.out.println("FileLeaf[name=" + name + ", size=" + size + "]");
    }
}
```

```
package com.patterns.composite;

import java.util.ArrayList;
import java.util.List;

public class FolderComposite implements FileComponent {
    private List<FileComponent> files;

    public FolderComposite(List<FileComponent> files) {
        this.files = files;
    }

    @Override
    public void showProperty() {
        for (FileComponent file : files) {
            file.showProperty();
        }
    }

    @Override
    public long totalSize() {
        long total = 0;
        for (FileComponent file : files) {
```

```
            total += file.totalSize();
        }
        return total;
    }
}
```

```
package com.patterns.composite;

import java.util.Arrays;
import java.util.List;

public class Client {
    public static void main(String[] args) {
        FileComponent file1 = new FileLeaf("file 1", 10);
        FileComponent file2 = new FileLeaf("file 2", 5);
        FileComponent file3 = new FileLeaf("file 3", 12);

        List<FileComponent> files = Arrays.asList(file1, file2, file3);
        FileComponent folder = new FolderComposite(files);
        folder.showProperty();
        System.out.println("Total Size: " + folder.totalSize());
    }
}
```

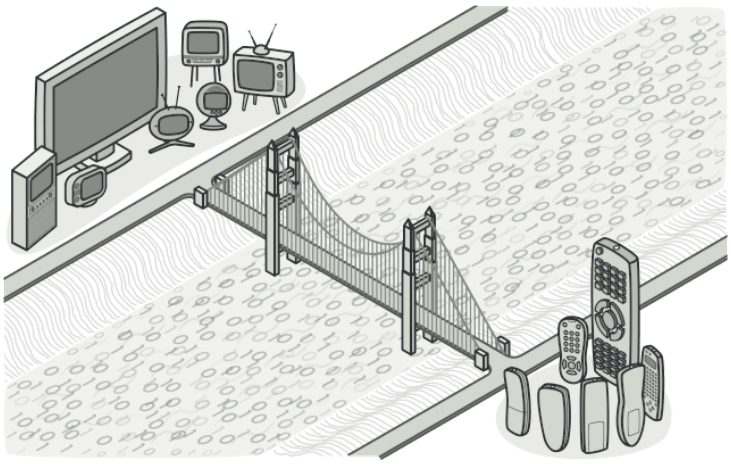
Command window

```
FileLeaf [name=file 1, size=10]
FileLeaf [name=file 2, size=5]
FileLeaf [name=file 3, size=12]
Total Size: 27
```

3.4 Bridge Pattern

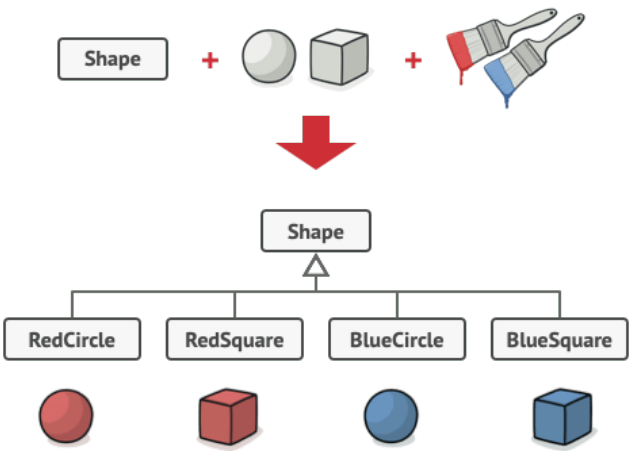
3.4.1 Intent

Bridge is a structural design pattern that lets you split a large class or a set of closely related classes into two separate hierarchies—abstraction and implementation—which can be developed independently of each other.



3.4.2 Problem

Abstraction? **Implementation**? Sound scary? Stay calm and let's consider a simple example.



Number of class combinations grows in geometric progression.

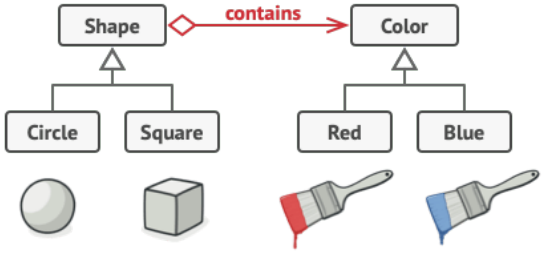
Say you have a geometric Shape class with a pair of subclasses: Circle and Square. You want to extend this class hierarchy to incorporate colors, so you plan to create Red and Blue shape subclasses. However, since you already have two subclasses, you'll need to create four class combinations such as BlueCircle and RedSquare.

Adding new shape types and colors to the hierarchy will grow it exponentially. For example, to add a triangle shape you'd need to introduce two subclasses, one for each color. And after that, adding a new color would require creating three subclasses, one for each shape type. The further we go, the worse it becomes.

3.4.3 Solution

This problem occurs because we're trying to extend the shape classes in two independent dimensions: by form and by color. That's a very common issue with class inheritance.

The Bridge pattern attempts to solve this problem by switching from inheritance to the object composition. What this means is that you extract one of the dimensions into a separate class hierarchy, so that the original classes will reference an object of the new hierarchy, instead of having all of its state and behaviors within one class.



You can prevent the explosion of a class hierarchy by transforming it into several related hierarchies.

Following this approach, we can extract the color-related code into its own class with two subclasses: Red and Blue. The Shape class then gets a reference field pointing to one of the color objects. Now the shape can delegate any color-related work to the linked color object. That reference will act as a bridge between the Shape and Color classes. From now on, adding new colors won't require changing the shape hierarchy, and vice versa.

Abstraction and Implementation

The GoF book introduces the terms Abstraction and Implementation as part of the Bridge definition. In my opinion, the terms sound too academic and make the pattern seem more complicated than it really is. Having read the simple example with shapes and colors, let's decipher the meaning behind the GoF book's scary words.

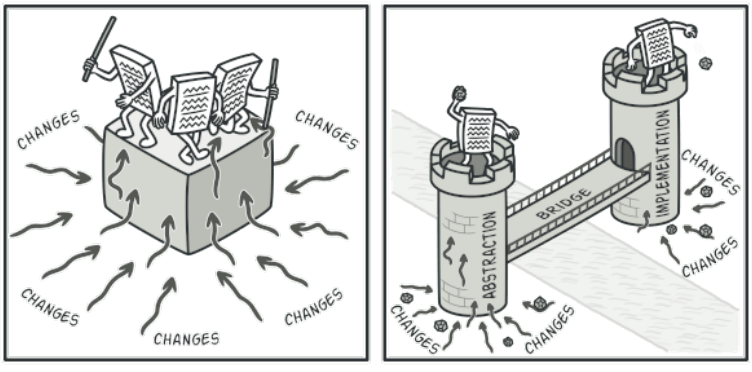
Abstraction (also called Interface) is a high-level control layer for some entity. This layer isn't supposed to do any real work on its own. It should delegate the work to the implementation layer (also called platform).

Note that we're not talking about interfaces or abstract classes from your programming language. These aren't the same things.

When talking about real applications, the abstraction can be represented by a graphical user interface (GUI), and the implementation could be the underlying operating system code (API) which the GUI layer calls in response to user interactions.

Generally speaking, you can extend such an app in two independent directions:

- Have several different GUIs (for instance, tailored for regular customers or admins).
- Support several different APIs (for example, to be able to launch the app under Windows, Linux, and macOS).



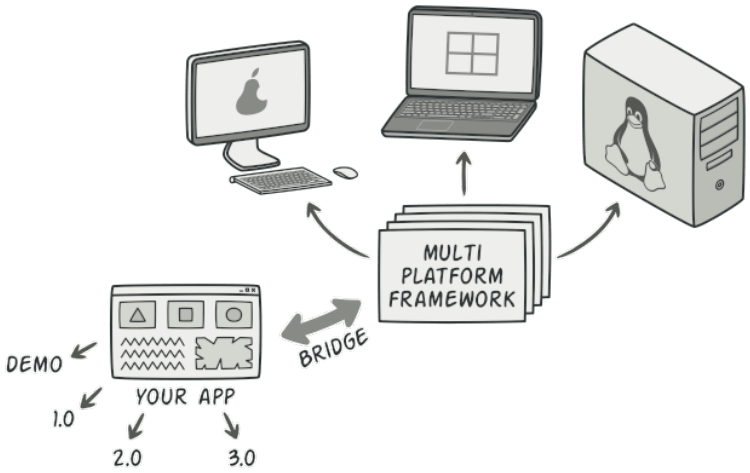
Making even a simple change to a monolithic codebase is pretty hard because you must understand the entire thing very well. Making changes to smaller, well-defined modules is much easier.

In a worst-case scenario, this app might look like a giant spaghetti bowl, where hundreds of conditionals connect different types of GUI with various APIs all over the code.

You can bring order to this chaos by extracting the code related to specific interface-platform combinations into separate classes. However, soon you'll discover that there are lots of these classes. The class hierarchy will grow exponentially because adding a new GUI or supporting a different API would require creating more and more classes.

Let's try to solve this issue with the Bridge pattern. It suggests that we divide the classes into two hierarchies:

- Abstraction: the GUI layer of the app.
- Implementation: the operating systems' APIs.

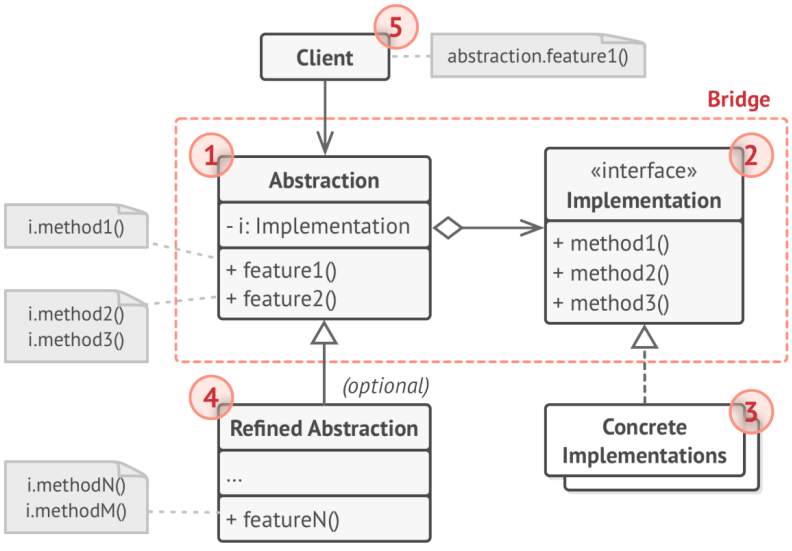


One of the ways to structure a cross-platform application.

The abstraction object controls the appearance of the app, delegating the actual work to the linked implementation object. Different implementations are interchangeable as long as they follow a common interface, enabling the same GUI to work under Windows and Linux.

As a result, you can change the GUI classes without touching the API-related classes. Moreover, adding support for another operating system only requires creating a subclass in the implementation hierarchy.

3.4.4 Structure



1. The Abstraction provides high-level control logic. It relies on the implementation object to do the actual low-level work.

2. The Implementation declares the interface that's common for all concrete implementations. An abstraction can only communicate with an implementation object via methods that are declared here.

   The abstraction may list the same methods as the implementation, but usually the abstraction declares some complex behaviors that rely on a wide variety of primitive operations declared by the implementation.

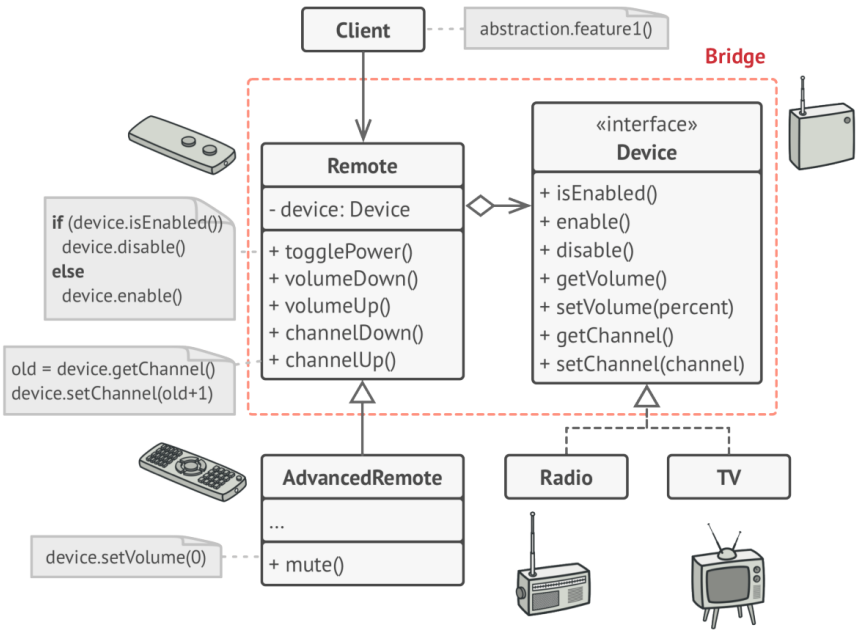
3. Concrete Implementations contain platform-specific code.

4. Refined Abstractions provide variants of control logic. Like their parent, they work with different implementations via the general implementation interface.

5. Usually, the Client is only interested in working with the abstraction. However, it's the client's job to link the abstraction object with one of the implementation objects.

3.4.5 Pseudocode

This example illustrates how the Bridge pattern can help divide the monolithic code of an app that manages devices and their remote controls. The Device classes act as the implementation, whereas the Remotes act as the abstraction.



The original class hierarchy is divided into two parts: devices and remote controls.

The base remote control class declares a reference field that links it with a device object. All remotes work with the devices via the general device interface, which lets the same remote support multiple device types.

You can develop the remote control classes independently from the device classes. All that's needed is to create a new remote subclass. For example, a basic remote control might only have two buttons, but you could extend it with additional features, such as an extra battery or a touchscreen.

The client code links the desired type of remote control with a specific device object via the remote's constructor.

PSEUDO CODE

```
// The "abstraction" defines the interface for the "control" part of the
//   two class hierarchies. It maintains a reference to an object of the
//   "implementation" hierarchy and delegates all of the real work to this object.
class RemoteControl is
  protected field device: Device

  constructor RemoteControl(device: Device) is
```


```
        this.device = device

    method togglePower() is
        if (device.isEnabled()) then
            device.disable()
        else
            device.enable()

    method volumeDown() is
        device.setVolume(device.getVolume() - 10)

    method volumeUp() is
        device.setVolume(device.getVolume() + 10)

    method channelDown() is
        device.setChannel(device.getChannel() - 1)

    method channelUp() is
        device.setChannel(device.getChannel() + 1)


// You can extend classes from the abstraction hierarchy independently
//   from device classes.
class AdvancedRemoteControl extends RemoteControl is
    method mute() is
        device.setVolume(0)


// The "implementation" interface declares methods common to all concrete
//   implementation classes. It doesn't have to match the abstraction's interface.
//   In fact, the two interfaces can be entirely different. Typically the
//   implementation interface provides only primitive operations, while the
//   abstraction defines higher-level operations based on those primitives.
interface Device is
    method isEnabled()
    method enable()
    method disable()
    method getVolume()
    method setVolume(percent)
    method getChannel()
    method setChannel(channel)


// All devices follow the same interface.
class Tv implements Device is
    // ...


class Radio implements Device is
    // ...
```

```
// Somewhere in client code.
tv = new Tv()
remote = new RemoteControl(tv)
remote.togglePower()

radio = new Radio()
remote = new AdvancedRemoteControl(radio)
```

3.4.6 Applicability

- Use the Bridge pattern when you want to divide and organize a monolithic class that has several variants of some functionality (for example, if the class can work with various database servers).

▷ The bigger a class becomes, the harder it is to figure out how it works, and the longer it takes to make a change. The changes made to one of the variations of functionality may require making changes across the whole class, which often results in making errors or not addressing some critical side effects.

The Bridge pattern lets you split the monolithic class into several class hierarchies. After this, you can change the classes in each hierarchy independently of the classes in the others. This approach simplifies code maintenance and minimizes the risk of breaking existing code.

- Use the pattern when you need to extend a class in several orthogonal (independent) dimensions.

▷ The Bridge suggests that you extract a separate class hierarchy for each of the dimensions. The original class delegates the related work to the objects belonging to those hierarchies instead of doing everything on its own.

- Use the Bridge if you need to be able to switch implementations at runtime.

▷ Although it's optional, the Bridge pattern lets you replace the implementation object inside the abstraction. It's as easy as assigning a new value to a field.

By the way, this last item is the main reason why so many people confuse the Bridge with the Strategy pattern. Remember that a pattern is more than just a certain way to structure your classes. It may also communicate intent and a problem being addressed.

3.4.7 How to Implement

1. Identify the orthogonal dimensions in your classes. These independent concepts could be: abstraction/platform, domain/infrastructure, front-end/back-end, or interface/implementation.

2. See what operations the client needs and define them in the base abstraction class.

3. Determine the operations available on all platforms. Declare the ones that the abstraction needs in the general implementation interface.

4. For all platforms in your domain create concrete implementation classes, but make sure they all follow the implementation interface.

5. Inside the abstraction class, add a reference field for the implementation type. The abstraction delegates most of the work to the implementation object that's referenced in that field.

6. If you have several variants of high-level logic, create refined abstractions for each variant by extending the base abstraction class.

7. The client code should pass an implementation object to the abstraction's constructor to associate one with the other. After that, the client can forget about the implementation and work only with the abstraction object.

3.4.8 Pros and Cons

+ You can create platform-independent classes and apps.

+ The client code works with high-level abstractions. It isn't exposed to the platform details.

+ Open/Closed Principle. You can introduce new abstractions and implementations independently from each other.

+ Single Responsibility Principle. You can focus on high-level logic in the abstraction and on platform details in the implementation.

- You might make the code more complicated by applying the pattern to a highly cohesive class.

3.4.9 Relations with Other Patterns

- Bridge is usually designed up-front, letting you develop parts of an application independently of each other. On the other hand, Adapter is commonly used with an existing app to make some otherwise-incompatible classes work together nicely.
- Bridge, State, Strategy (and to some degree Adapter) have very similar structures. Indeed, all of these patterns are based on composition, which is delegating work to other objects. However, they all solve different problems. A pattern isn't just a recipe for structuring your code in a specific way. It can also communicate to other developers the problem the pattern solves.
- You can use Abstract Factory along with Bridge. This pairing is useful when some abstractions defined by Bridge can only work with specific implementations. In this case, Abstract Factory can encapsulate these relations and hide the complexity from the client code.
- You can combine Builder with Bridge: the director class plays the role of the abstraction, while different builders act as implementations.

3.4.10 Examples

1. Structure Example

```
package com.patterns.bridge;

public abstract class Implemention {
    public abstract void operation();
}
```

```
package com.patterns.bridge;

public class ConcreteImplementation extends Implementation {

    @Override
    public void operation() {
        System.out.println("ConcreteImplemention's Operation");
    }
}
```

```java
package com.patterns.bridge;

public class Abstraction {
    protected Implementation implementation;

    public Implementation(Implementation implementation) {
        this.implementation = implementation;
    }

    @Override
    public void operation() {
        this.implementation.operation();
    }
}
```

```java
package com.patterns.bridge;

public class RefinedAbstraction extends Abstraction {

    public RefinedAbstraction(Implementation implementation) {
        super(implementation);
    }

    @Override
    public void operation() {
        this.implementation.operation();
    }
}
```

```java
package com.patterns.bridge;

public class App {
    public static void main(String[] args) {
        Implementation implementation = new ConcreteImplementation();
        Abstraction abstraction = new RefinedAbstraction(implementation);

        abstraction.operation();
    }
}
```

2. Real-World Example

```
package com.patterns.bridge.abstraction;

import com.patterns.bridge.implementation.MessageSender;

public abstract class Message {
    MessageSender messageSender;

    public Message(MessageSender messageSender) {
        this.messageSender = messageSender;
    }

    abstract public void send();
}
```

```
package com.patterns.bridge.abstraction;

import com.patterns.bridge.implementation.MessageSender;

public class TextMessage extends Message {
    public TextMessage(MessageSender messageSender) {
        super(messageSender);
    }

    @Override
    public void send() {
        messageSender.sendMessage();
    }
}
```

```
package com.patterns.bridge.abstraction;

import com.patterns.bridge.implementation.MessageSender;

public class EmailMessage extends Message {
    public EmailMessage(MessageSender messageSender) {
        super(messageSender);
    }

    @Override
```

```
    public void send() {
12      messageSender.sendMessage();
    }
14  }
```

```
package com.patterns.bridge.implementation;
2
public interface MessageSender {
4   public void sendMessage();
}
```

```
1  package com.patterns.bridge.implementation;

3  public class TextMessageSender implements MessageSender {
     @Override
5    public void sendMessage() {
       System.out.println("TextMessageSender: Sending text message ...");
7    }
   }
```

```
package com.patterns.bridge.implementation;
2
public class EmailMessageSender implements MessageSender {
4   @Override
    public void sendMessage() {
6     System.out.println("EmailMessageSender: Sending email message ...");
    }
8   }
```

```
package com.patterns.bridge.abstraction;
2
import com.patterns.bridge.implementation.EmailMessageSender;
```

```
import com.patterns.bridge.implementation.MessageSender;
import com.patterns.bridge.implementation.TextMessageSender;

public class MessageTest {

    public static void main(String[] args) throws Exception {
        MessageSender textMessageSender = new TextMessageSender();
        Message textMessage = new TextMessage(textMessageSender);
        textMessage.send();

        MessageSender emailMessageSender = new EmailMessageSender();
        Message emailMessage = new TextMessage(emailMessageSender);
        emailMessage.send();
    }
}
```

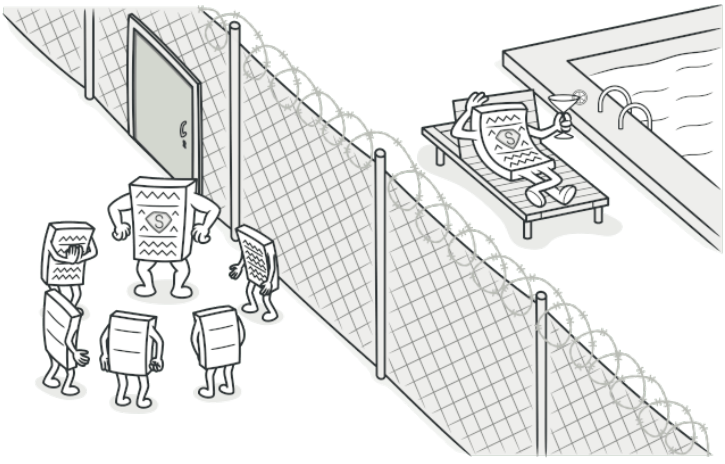
Command window


```
TextMessageSender: Sending text message ...
EmailMessageSender: Sending email message ...
```

3.5 Proxy Pattern

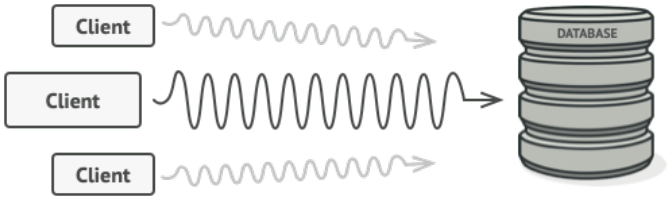
3.5.1 Intent

Proxy is a structural design pattern that lets you provide a substitute or placeholder for another object. A proxy controls access to the original object, allowing you to perform something either before or after the request gets through to the original object.



3.5.2 Problem

Why would you want to control access to an object? Here is an example: you have a massive object that consumes a vast amount of system resources. You need it from time to time, but not always.



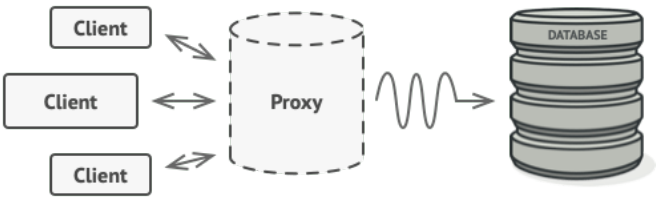
Database queries can be really slow.

You could implement lazy initialization: create this object only when it's actually needed. All of the object's clients would need to execute some deferred initialization code. Unfortunately, this would probably cause a lot of code duplication.

In an ideal world, we'd want to put this code directly into our object's class, but that isn't always possible. For instance, the class may be part of a closed 3rd-party library.

3.5.3 Solution

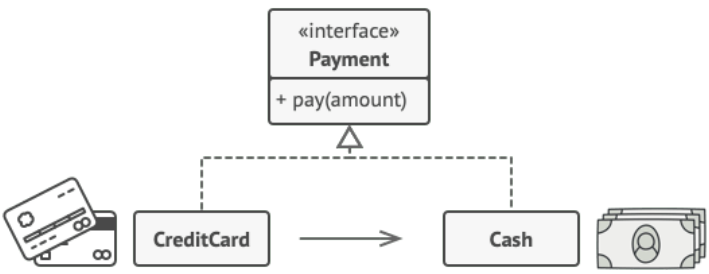
The Proxy pattern suggests that you create a new proxy class with the same interface as an original service object. Then you update your app so that it passes the proxy object to all of the original object's clients. Upon receiving a request from a client, the proxy creates a real service object and delegates all the work to it.



The proxy disguises itself as a database object. It can handle lazy initialization and result caching without the client or the real database object even knowing.

But what's the benefit? If you need to execute something either before or after the primary logic of the class, the proxy lets you do this without changing that class. Since the proxy implements the same interface as the original class, it can be passed to any client that expects a real service object.

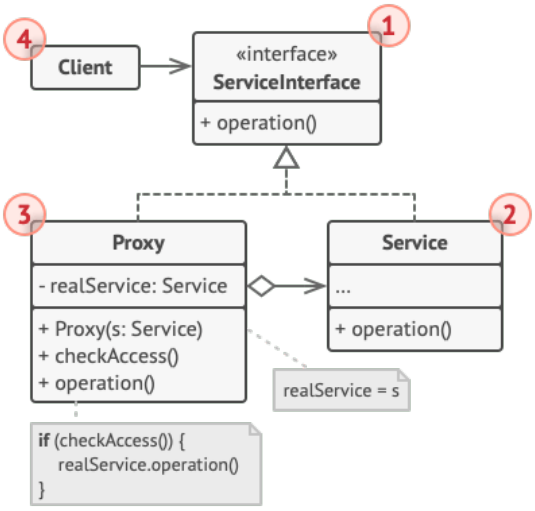
3.5.4 Real-World Analogy



Credit cards can be used for payments just the same as cash.

A credit card is a proxy for a bank account, which is a proxy for a bundle of cash. Both implement the same interface: they can be used for making a payment. A consumer feels great because there's no need to carry loads of cash around. A shop owner is also happy since the income from a transaction gets added electronically to the shop's bank account without the risk of losing the deposit or getting robbed on the way to the bank.

3.5.5 Structure



1. The Service Interface declares the interface of the Service. The proxy must follow this interface to be able to disguise itself as a service object.

2. The Service is a class that provides some useful business logic.

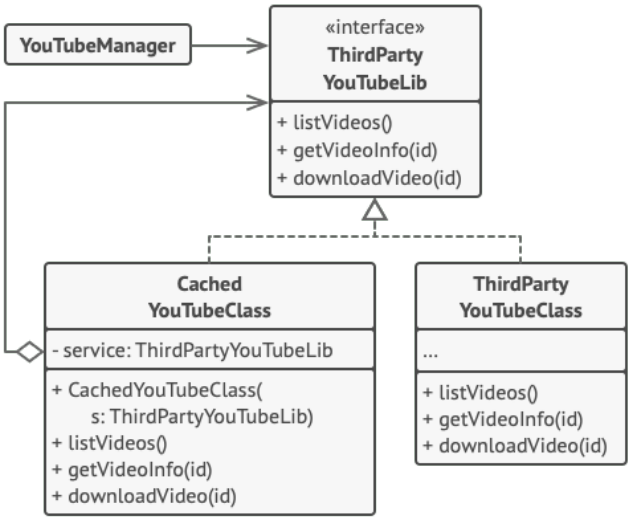
3. The Proxy class has a reference field that points to a service object. After the proxy finishes its processing (e.g., lazy initialization, logging, access control, caching, etc.), it passes the request to the service object.

   Usually, proxies manage the full lifecycle of their service objects.

4. The Client should work with both services and proxies via the same interface. This way you can pass a proxy into any code that expects a service object.

3.5.6 Pseudocode

This example illustrates how the Proxy pattern can help to introduce lazy initialization and caching to a 3rd-party YouTube integration library.



Caching results of a service with a proxy.

The library provides us with the video downloading class. However, it's very inefficient. If the client application requests the same video multiple times, the library just downloads it over and over, instead of caching and reusing the first downloaded file.

The proxy class implements the same interface as the original downloader and delegates it all the work. However, it keeps track of the downloaded files and returns the cached result when the app requests the same video multiple times.

PSEUDO CODE

```
// The interface of a remote service.
interface ThirdPartyYouTubeLib is
    method listVideos()
    method getVideoInfo(id)
    method downloadVideo(id)

// The concrete implementation of a service connector. Methods of this
//  class can request information from YouTube. The speed of the request
//  depends on a user's internet connection as well as YouTube's. The
//  application will slow down if a lot of requests are fired at the
//  same time, even if they all request the same information.
class ThirdPartyYouTubeClass implements ThirdPartyYouTubeLib is
    method listVideos() is
        // Send an API request to YouTube.

    method getVideoInfo(id) is
        // Get metadata about some video.

```


```
    method downloadVideo(id) is
20      // Download a video file from YouTube.


22
    // To save some bandwidth, we can cache request results and keep them for some
24  //  time. But it may be impossible to put such code directly into the service
    //  class. For example, it could have been provided as part of a third party
26  //  library and/or defined as 'final'. That's why we put the caching code into
    //  a new proxy class which implements the same interface as the service class. It
28  //  delegates to the service object only when the real requests have to be sent.
    class CachedYouTubeClass implements ThirdPartyYouTubeLib is
30    private field service: ThirdPartyYouTubeLib
      private field listCache
32    private field videoCache
      private field needReset
34
      constructor CachedYouTubeClass(service: ThirdPartyYouTubeLib) is
36      this.service = service

38    method listVideos() is
        if (listCache == null || needReset)
40      listCache = service.listVideos()
        return listCache
42
      method getVideoInfo(id) is
44      if (videoCache == null || needReset)
          videoCache = service.getVideoInfo(id)
46      return videoCache

48    method downloadVideo(id) is
        if (!downloadExists(id) || needReset)
50        service.downloadVideo(id)


52
    // The GUI class, which used to work directly with a service object,
54  //  stays unchanged as long as it works with the service object
    //  through an interface. We can safely pass a proxy object instead of
56  //  a real service object since they both implement the same interface.
    class YouTubeManager is
58    protected field service: ThirdPartyYouTubeLib

60    constructor YouTubeManager(service: ThirdPartyYouTubeLib) is
        this.service = service
62
      method renderVideoPage(id) is
64    info = service.getVideoInfo(id)
        // Render the video page.
66
      method renderListPanel() is
68      list = service.listVideos()
        // Render the list of video thumbnails.
```

```
    method reactOnUserInput() is
        renderVideoPage()
        renderListPanel ()


// The application can configure proxies on the fly.
class Application is
    method init () is
        aYouTubeService = new ThirdPartyYouTubeClass()
        aYouTubeProxy = new CachedYouTubeClass(aYouTubeService)
        manager = new YouTubeManager(aYouTubeProxy)
        manager.reactOnUserInput()
```

3.5.7 Applicability

- Lazy initialization (virtual proxy). This is when you have a heavyweight service object that wastes system resources by being always up, even though you only need it from time to time.

▷ Instead of creating the object when the app launches, you can delay the object's initialization to a time when it's really needed.

- Access control (protection proxy). This is when you want only specific clients to be able to use the service object; for instance, when your objects are crucial parts of an operating system and clients are various launched applications (including malicious ones).

▷ The proxy can pass the request to the service object only if the client's credentials match some criteria.

- Local execution of a remote service (remote proxy). This is when the service object is located on a remote server.

▷ In this case, the proxy passes the client request over the network, handling all of the nasty details of working with the network.

- Logging requests (logging proxy). This is when you want to keep a history of requests to the service object.

▷ The proxy can log each request before passing it to the service.

- Caching request results (caching proxy). This is when you need to cache results of client requests and manage the life cycle of this cache, especially if results are quite large.

▷ The proxy can implement caching for recurring requests that always yield the same results. The proxy may use the parameters of requests as the cache keys.

• Smart reference. This is when you need to be able to dismiss a heavyweight object once there are no clients that use it.

▷ The proxy can keep track of clients that obtained a reference to the service object or its results. From time to time, the proxy may go over the clients and check whether they are still active. If the client list gets empty, the proxy might dismiss the service object and free the underlying system resources.

The proxy can also track whether the client had modified the service object. Then the unchanged objects may be reused by other clients.

3.5.8 How to Implement

1. If there's no pre-existing service interface, create one to make proxy and service objects interchangeable. Extracting the interface from the service class isn't always possible, because you'd need to change all of the service's clients to use that interface. Plan B is to make the proxy a subclass of the service class, and this way it'll inherit the interface of the service.
2. Create the proxy class. It should have a field for storing a reference to the service. Usually, proxies create and manage the whole life cycle of their services. On rare occasions, a service is passed to the proxy via a constructor by the client.
3. Implement the proxy methods according to their purposes. In most cases, after doing some work, the proxy should delegate the work to the service object.
4. Consider introducing a creation method that decides whether the client gets a proxy or a real service. This can be a simple static method in the proxy class or a full-blown factory method.
5. Consider implementing lazy initialization for the service object.

3.5.9 Pros and Cons

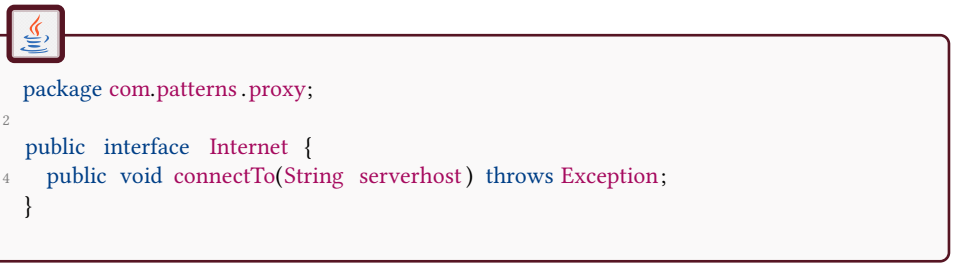
+ You can control the service object without clients knowing about it.
+ You can manage the lifecycle of the service object when clients don't care about it.
+ The proxy works even if the service object isn't ready or is not available.
+ Open/Closed Principle. You can introduce new proxies without changing the service or clients.
- The code may become more complicated since you need to introduce a lot of new classes.

- The response from the service might get delayed.

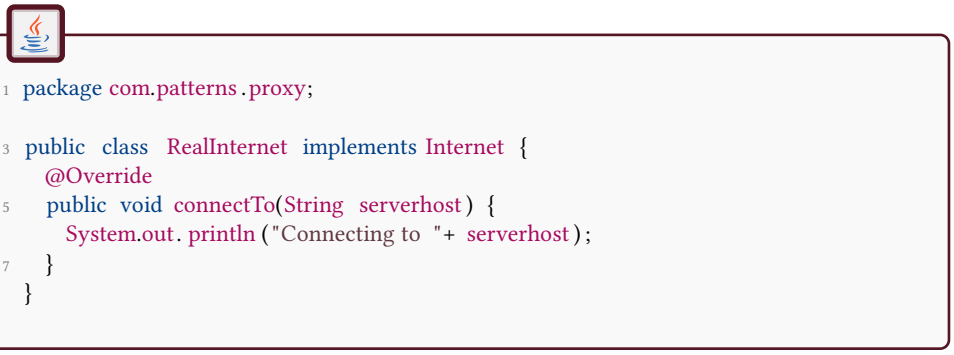
3.5.10 Relations with Other Patterns

- Adapter provides a different interface to the wrapped object, Proxy provides it with the same interface, and Decorator provides it with an enhanced interface.
- Facade is similar to Proxy in that both buffer a complex entity and initialize it on its own. Unlike Facade, Proxy has the same interface as its service object, which makes them interchangeable.
- Decorator and Proxy have similar structures, but very different intents. Both patterns are built on the composition principle, where one object is supposed to delegate some of the work to another. The difference is that a Proxy usually manages the life cycle of its service object on its own, whereas the composition of Decorators is always controlled by the client.

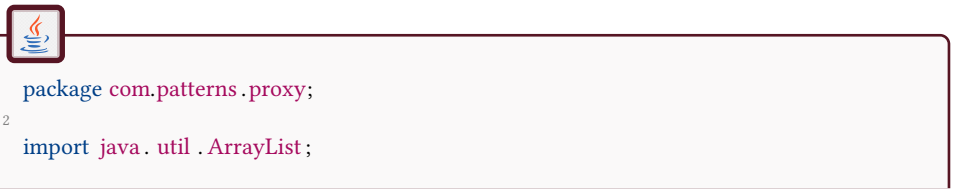
3.5.11 Examples



```java
package com.patterns.proxy;

public interface Internet {
    public void connectTo(String serverhost) throws Exception;
}
```



```java
package com.patterns.proxy;

public class RealInternet implements Internet {
    @Override
    public void connectTo(String serverhost) {
        System.out.println("Connecting to "+ serverhost);
    }
}
```



```java
package com.patterns.proxy;

import java.util.ArrayList;
```

```
import java.util.List;

public class ProxyInternet implements Internet {
    private Internet internet = new RealInternet();
    private static List<String> bannedSites;

    static {
        bannedSites = new ArrayList<String>();
        bannedSites.add("abc.com");
        bannedSites.add("def.com");
        bannedSites.add("ijk.com");
        bannedSites.add("lnm.com");
    }

    @Override
    public void connectTo(String serverhost) throws Exception {
        if (bannedSites.contains(serverhost.toLowerCase())) {
            throw new Exception("Access Denied");
        }

        internet.connectTo(serverhost);
    }
}
```

```
package com.patterns.proxy;

public class Client {
    public static void main(String[] args) {
        Internet internet = new ProxyInternet();
        try {
            internet.connectTo("geeksforgeeks.org");
            internet.connectTo("abc.com");
        } catch (Exception e) {
            System.out.println(e.getMessage());
        }
    }
}
```

4 Behavioral Design Patterns

4.1 Strategy Pattern

4.1.1 Intent

Strategy is a behavioral design pattern that lets you define a family of algorithms, put each of them into a separate class, and make their objects interchangeable.

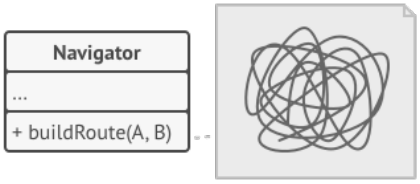
4.1.2 Problem

One day you decided to create a navigation app for casual travelers. The app was centered around a beautiful map which helped users quickly orient themselves in any city.

One of the most requested features for the app was automatic route planning. A user should be able to enter an address and see the fastest route to that destination displayed on the map.

The first version of the app could only build the routes over roads. People who traveled by car were bursting with joy. But apparently, not everybody likes to drive on their vacation. So with the next update, you added an option to build walking routes. Right after that, you added another option to let people use public transport in their routes.

However, that was only the beginning. Later you planned to add route building for cyclists. And even later, another option for building routes through all of a city's tourist attractions.



The code of the navigator became bloated.

While from a business perspective the app was a success, the technical part caused you many headaches. Each time you added a new routing algorithm, the main class of the navigator doubled in size. At some point, the beast became too hard to maintain.

Any change to one of the algorithms, whether it was a simple bug fix or a slight adjustment of the street score, affected the whole class, increasing the chance of creating an error in already-working code.

In addition, teamwork became inefficient. Your teammates, who had been hired right after the successful release, complain that they spend too much time resolving merge conflicts. Implementing a new feature requires you to change the same huge class, conflicting with the code produced by other people.

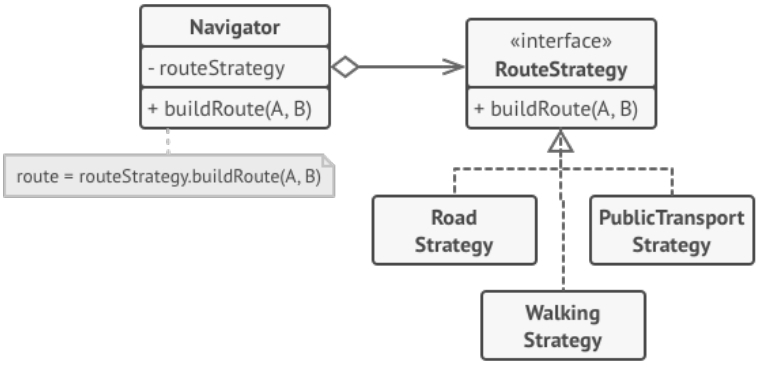
4.1.3 Solution

The Strategy pattern suggests that you take a class that does something specific in a lot of different ways and extract all of these algorithms into separate classes called strategies.

The original class, called context, must have a field for storing a reference to one of the strategies. The context delegates the work to a linked strategy object instead of executing it on its own.

The context isn't responsible for selecting an appropriate algorithm for the job. Instead, the client passes the desired strategy to the context. In fact, the context doesn't know much about strategies. It works with all strategies through the same generic interface, which only exposes a single method for triggering the algorithm encapsulated within the selected strategy.

This way the context becomes independent of concrete strategies, so you can add new algorithms or modify existing ones without changing the code of the context or other strategies.

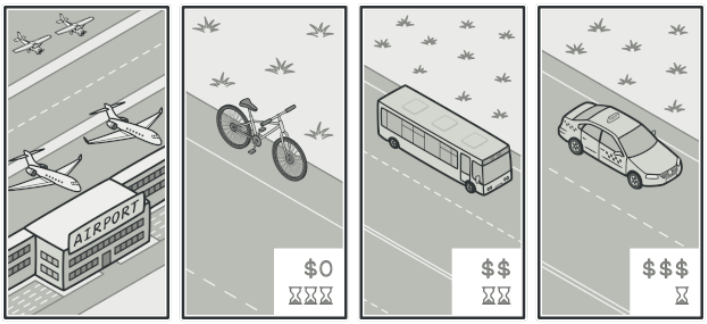


Route planning strategies.

In our navigation app, each routing algorithm can be extracted to its own class with a single $buildRoute()$ method. The method accepts an origin and destination and returns a collection of the route's checkpoints.

Even though given the same arguments, each routing class might build a different route, the main navigator class doesn't really care which algorithm is selected since its primary job is to render a set of checkpoints on the map. The class has a method for switching the active routing strategy, so its clients, such as the buttons in the user interface, can replace the currently selected routing behavior with another one.

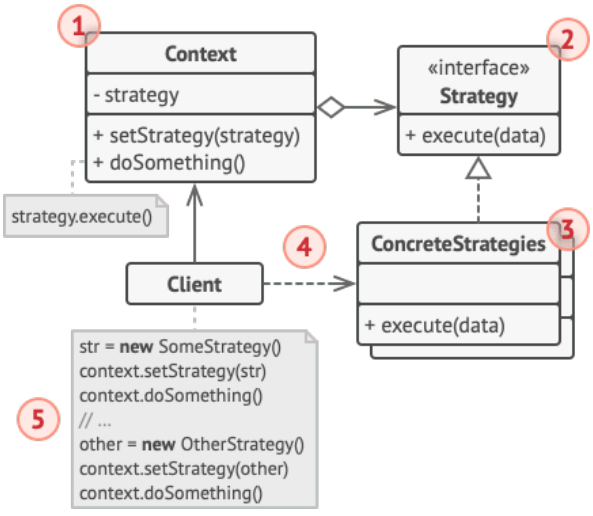
4.1.4 Real-World Analogy



Various strategies for getting to the airport.

Imagine that you have to get to the airport. You can catch a bus, order a cab, or get on your bicycle. These are your transportation strategies. You can pick one of the strategies depending on factors such as budget or time constraints.

4.1.5 Structure



1. The Context maintains a reference to one of the concrete strategies and communicates with this object only via the strategy interface.

2. The Strategy interface is common to all concrete strategies. It declares a method the context uses to execute a strategy.

3. Concrete Strategies implement different variations of an algorithm the context uses.

4. The context calls the execution method on the linked strategy object each time it needs to run the algorithm. The context doesn't know what type of strategy it works with or how the algorithm is executed.

5. The Client creates a specific strategy object and passes it to the context. The context exposes a setter which lets clients replace the strategy associated with the context at runtime.

4.1.6 Pseudocode

In this example, the context uses multiple strategies to execute various arithmetic operations.

PSEUDO CODE

```
1 // The strategy interface declares operations common to all supported
  //  versions of some algorithm. The context uses this interface to call
```


```
// the algorithm defined by the concrete strategies.
interface Strategy is
  method execute(a, b)


// Concrete strategies implement the algorithm while following the base strategy
//  interface. The interface makes them interchangeable in the context.
class ConcreteStrategyAdd implements Strategy is
  method execute(a, b) is
    return a + b


class ConcreteStrategySubtract implements Strategy is
  method execute(a, b) is
    return a - b


class ConcreteStrategyMultiply implements Strategy is
  method execute(a, b) is
    return a * b


// The context defines the interface of interest to clients.
class Context is
  // The context maintains a reference to one of the strategy objects.
  //  The context doesn't know the concrete class of a strategy.
  //  It should work with all strategies via the strategy interface.
  private strategy: Strategy

  // Usually the context accepts a strategy through the constructor, and also
  //  provides a setter so that the strategy can be switched at runtime.
  method setStrategy(Strategy strategy) is
    this.strategy = strategy

  // The context delegates some work to the strategy object instead of
  //  implementing multiple versions of the algorithm on its own.
  method executeStrategy(int a, int b) is
    return strategy.execute(a, b)


// The client code picks a concrete strategy and passes it to the
//  context. The client should be aware of the differences between
//  strategies in order to make the right choice.
class ExampleApplication is
  method main() is
    Create context object.

    Read first number.
    Read last number.
    Read the desired action from user input.
```

```
if (action == addition) then
  context.setStrategy(new ConcreteStrategyAdd())

if (action == subtraction) then
  context.setStrategy(new ConcreteStrategySubtract())

if (action == multiplication) then
  context.setStrategy(new ConcreteStrategyMultiply())

result = context.executeStrategy(First number, Second number)

Print result.
```

4.1.7 Applicability

- Use the Strategy pattern when you want to use different variants of an algorithm within an object and be able to switch from one algorithm to another during runtime.

▷ The Strategy pattern lets you indirectly alter the object's behavior at runtime by associating it with different sub-objects which can perform specific sub-tasks in different ways.

- Use the Strategy when you have a lot of similar classes that only differ in the way they execute some behavior.

▷ The Strategy pattern lets you extract the varying behavior into a separate class hierarchy and combine the original classes into one, thereby reducing duplicate code.

- Use the pattern to isolate the business logic of a class from the implementation details of algorithms that may not be as important in the context of that logic.

▷ The Strategy pattern lets you isolate the code, internal data, and dependencies of various algorithms from the rest of the code. Various clients get a simple interface to execute the algorithms and switch them at runtime.

- Use the pattern when your class has a massive conditional statement that switches between different variants of the same algorithm.

▷ The Strategy pattern lets you do away with such a conditional by extracting all algorithms into separate classes, all of which implement the same interface. The original object delegates execution to one of these objects, instead of implementing all variants of the algorithm.

4.1.8 How to Implement

1. In the context class, identify an algorithm that's prone to frequent changes. It may also be a massive conditional that selects and executes a variant of the same algorithm at runtime.
2. Declare the strategy interface common to all variants of the algorithm.
3. One by one, extract all algorithms into their own classes. They should all implement the strategy interface.
4. In the context class, add a field for storing a reference to a strategy object. Provide a setter for replacing values of that field. The context should work with the strategy object only via the strategy interface. The context may define an interface which lets the strategy access its data.
5. Clients of the context must associate it with a suitable strategy that matches the way they expect the context to perform its primary job.

4.1.9 Pros and Cons

+ You can swap algorithms used inside an object at runtime.
+ You can isolate the implementation details of an algorithm from the code that uses it.
+ You can replace inheritance with composition.
+ Open/Closed Principle. You can introduce new strategies without having to change the context.
- If you only have a couple of algorithms and they rarely change, there's no real reason to overcomplicate the program with new classes and interfaces that come along with the pattern.
- Clients must be aware of the differences between strategies to be able to select a proper one.
- A lot of modern programming languages have functional type support that lets you implement different versions of an algorithm inside a set of anonymous functions. Then you could use these functions exactly as you'd have used the strategy objects, but without bloating your code with extra classes and interfaces.

4.1.10 Relations with Other Patterns

- Bridge, State, Strategy (and to some degree Adapter) have very similar structures. Indeed, all of these patterns are based on composition, which is delegating work to other objects. However, they all solve different problems. A pattern isn't just a

recipe for structuring your code in a specific way. It can also communicate to other developers the problem the pattern solves.

- Command and Strategy may look similar because you can use both to parameterize an object with some action. However, they have very different intents.
  - You can use Command to convert any operation into an object. The operation's parameters become fields of that object. The conversion lets you defer execution of the operation, queue it, store the history of commands, send commands to remote services, etc.
  - On the other hand, Strategy usually describes different ways of doing the same thing, letting you swap these algorithms within a single context class.
- Decorator lets you change the skin of an object, while Strategy lets you change the guts.
- Template Method is based on inheritance: it lets you alter parts of an algorithm by extending those parts in subclasses. Strategy is based on composition: you can alter parts of the object's behavior by supplying it with different strategies that correspond to that behavior. Template Method works at the class level, so it's static. Strategy works on the object level, letting you switch behaviors at runtime.
- State can be considered as an extension of Strategy. Both patterns are based on composition: they change the behavior of the context by delegating some work to helper objects. Strategy makes these objects completely independent and unaware of each other. However, State doesn't restrict dependencies between concrete states, letting them alter the state of the context at will.

4.1.11 Example

In this example, the Strategy Pattern is used to implement the various payment methods in an e-commerce application. After selecting a product to purchase, a customer picks a payment method: either Paypal or Credit Card.

Concrete strategies not only perform the actual payment but also alter the behavior of the checkout form, providing appropriate fields to record payment details.

```java
package com.patterns.strategies;

/**
 * Common interface for all strategies.
 */
public interface PayStrategy {
  boolean pay(int paymentAmount);
```

```
    void collectPaymentDetails();
}
```

```
package com.patterns.strategy.strategies;

import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.util.HashMap;
import java.util.Map;

/**
 * Concrete strategy. Implements PayPal payment method.
 */
public class PayByPayPal implements PayStrategy {
    private static final Map<String, String> DATA_BASE = new HashMap<>();
    private final BufferedReader READER
        = new BufferedReader(new InputStreamReader(System.in));
    private String email;
    private String password;
    private boolean signedIn;

    static {
        DATA_BASE.put("amanda1985", "amanda@ya.com");
        DATA_BASE.put("qwerty", "john@amazon.eu");
    }

    // Collect customer's data.
    @Override
    public void collectPaymentDetails() {
        try {
            while (!signedIn) {
                System.out.print("Enter the user's email: ");
                email = READER.readLine();
                System.out.print("Enter the password: ");
                password = READER.readLine();
                if (verify()) {
                    System.out.println("Data verification has been successful.");
                } else {
                    System.out.println("Wrong email or password!");
                }
            }
        } catch (IOException ex) {
            ex.printStackTrace();
        }
    }
```

```
45    private boolean verify () {
        setSignedIn(email.equals(DATA_BASE.get(password)));
47      return signedIn;
      }
49
      // Save customer data for future shopping attempts.
51    @Override
      public boolean pay(int paymentAmount) {
53      if (signedIn) {
          System.out.println("Paying " + paymentAmount + " using PayPal.");
55        return true;
        }
57      return false;
      }
59
      private void setSignedIn(boolean signedIn) {
61      this.signedIn = signedIn;
      }
63  }
```

```
1   package com.patterns.strategy.strategies;

3   import java.io.BufferedReader;
    import java.io.IOException;
5   import java.io.InputStreamReader;

7   /**
     * Concrete strategy. Implements credit card payment method.
9    */
    public class PayByCreditCard implements PayStrategy {
11    private final BufferedReader READER
        = new BufferedReader(new InputStreamReader(System.in));
13    private CreditCard card;

15    // Collect credit card data.
      @Override
17    public void collectPaymentDetails () {
        try {
19        System.out.print("Enter the card number: ");
          String number = READER.readLine();
21        System.out.print("Enter the card expiration date 'mm/yy': ");
          String date = READER.readLine();
23        System.out.print("Enter the Card Verification Value code: ");
          String cardVerificationValue = READER.readLine();
25
```

```
            if (CreditCardValidator.isValid(number)) {
                card = new CreditCard(number, date, cardVerificationValue);
            }
        } catch (IOException ex) {
            ex.printStackTrace();
        }
    }

    // After card validation we can charge customer's credit card.
    @Override
    public boolean pay(int paymentAmount) {
        if (cardIsPresent()) {
            System.out.println("Paying " + paymentAmount + " using Credit Card.");
            card.setAmount(card.getAmount() - paymentAmount);
            return true;
        }
        return false;
    }

    private boolean cardIsPresent() {
        return card != null;
    }
}
```

```
package com.patterns.strategy.strategies;

/**
 * Dummy credit card class.
 */
public class CreditCard {
    private int amount;
    private String number;
    private String date;
    private String cardVerificationValue;

    CreditCard(String number, String date, String cardVerificationValue) {
        this.amount = 100000;
        this.number = number;
        this.date = date;
        this.cardVerificationValue = cardVerificationValue;
    }

    public void setAmount(int amount) {
        this.amount = amount;
    }

```

```
    public int getAmount() {
24      return amount;
    }
26
    pulic String getNumber() {
28      return this.number;
    }
30  }
```

```
  /**
2  * Java program to check if a given credit card is valid or not, using Luhn algorithm.
   */
4 public class CreditCardValidator {
    // Return true if the card number is valid
6   public static boolean isValid(long number) {
      return (getSize(number) >= 13
8       && getSize(number) <= 16)
        && (prefixMatched(number, 4)
10       || prefixMatched(number, 5)
         || prefixMatched(number, 37)
12       || prefixMatched(number, 6))
        && ((sumOfDoubleEvenPlace(number) + sumOfOddPlace(number)) % 10 == 0);
14  }

16  public static boolean isValid(String number) {
      return isValid(Long.parseLong(number));
18  }

20  // Get the result from Step 2
    private static int sumOfDoubleEvenPlace(long number) {
22    int sum = 0;
      String num = number + "";
24    for (int i = getSize(number) - 2; i >= 0; i -= 2) {
        sum += getDigit(Integer.parseInt(num.charAt(i) + "") * 2);
26    }

28    return sum;
    }
30
    // Return this number if it is a single digit, otherwise,
32  //   return the sum of the two digits
    private static int getDigit(int number) {
34    if (number < 9) {
        return number;
36    }
```

```
38      return number / 10 + number % 10;
    }
40
    // Return sum of odd-place digits in number
42  private static int sumOfOddPlace(long number) {
      int sum = 0;
44    String num = number + "";
      for (int i = getSize(number) - 1; i >= 0; i -= 2) {
46      sum += Integer.parseInt(num.charAt(i) + "");
      }
48
      return sum;
50  }

52  // Return true if the digit d is a prefix for number
    private static boolean prefixMatched(long number, int d) {
54    return getPrefix(number, getSize(d)) == d;
    }
56
    // Return the number of digits in d
58  private static int getSize(long d) {
      String num = d + "";
60    return num.length();
    }
62
    // Return the first k number of digits from number.
64  // If the number of digits in number is less than k, return number.
    private static long getPrefix(long number, int k) {
66    if (getSize(number) > k) {
        String num = number + "";
68      return Long.parseLong(num.substring(0, k));
      }
70
      return number;
72  }
}
```

```
1 package com.patterns.strategy.order;

3 import com.patterns.strategy.strategies.PayStrategy;

5 /**
  * Order class. Doesn't know the concrete payment method (strategy) user has picked.
7 * It uses common strategy interface to delegate collecting payment data to strategy object.
  * It can be used to save order to database.
9 */
```

```
public class Order {
    private int totalCost = 0;
    private boolean isClosed = false;

    public void processOrder(PayStrategy strategy) {
        strategy.collectPaymentDetails();
        // Here we could collect and store payment data from the strategy.
    }

    public void setTotalCost(int cost) {
        this.totalCost += cost;
    }

    public int getTotalCost() {
        return totalCost;
    }

    public boolean isClosed() {
        return isClosed;
    }

    public void setClosed() {
        isClosed = true;
    }
}
```

```
package com.patterns.strategy.strategies;

import com.patterns.strategy.order.Order;
import com.patterns.strategy.strategies.PayByCreditCard;
import com.patterns.strategy.strategies.PayByPayPal;
import com.patterns.strategy.strategies.PayStrategy;

import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.util.HashMap;
import java.util.Map;

/**
 * World first console e-commerce application.
 */
public class Demo {
    private static Map<Integer, Integer> priceOnProducts = new HashMap<>();
    private static BufferedReader reader
    = new BufferedReader(new InputStreamReader(System.in));
```

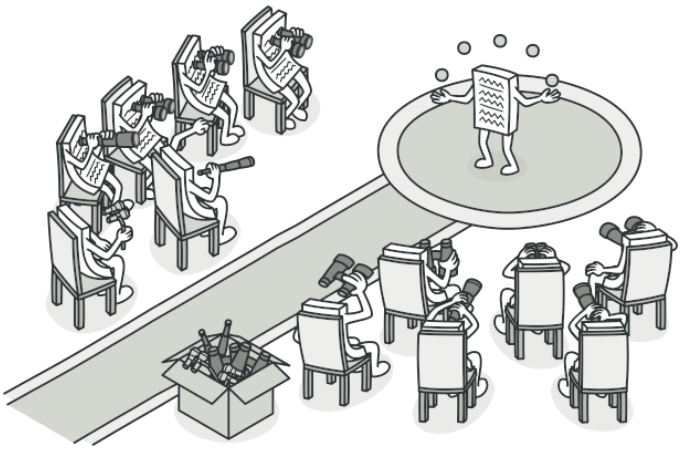
```
    private static Order order = new Order();
22  private static PayStrategy strategy;

24  static {
      priceOnProducts.put(1, 2200);
26    priceOnProducts.put(2, 1850);
      priceOnProducts.put(3, 1100);
28    priceOnProducts.put(4, 890);
    }
30
    public static void main(String[] args) throws IOException {
32    while (!order.isClosed()) {
        int cost;
34
        String continueChoice;
36      do {
          System.out.print("Please, select a product:" + "\n" +
38          "1 - Mother board" + "\n" +
            "2 - CPU" + "\n" +
40          "3 - HDD" + "\n" +
            "4 - Memory" + "\n");
42        int choice = Integer.parseInt(reader.readLine());
          cost = priceOnProducts.get(choice);
44        System.out.print("Count: ");
          int count = Integer.parseInt(reader.readLine());
46        order.setTotalCost(cost * count);
          System.out.print("Do you wish to continue selecting products? Y/N: ");
48        continueChoice = reader.readLine();
        } while (continueChoice.equalsIgnoreCase("Y"));
50
        if (strategy == null) {
52        System.out.println("Please, select a payment method:" + "\n"
            + "1 - PalPay" + "\n"
54          + "2 - Credit Card");
          String paymentMethod = reader.readLine();
56
          // Client creates different strategies based on input from user,
58        //   application configuration, etc.
          if (paymentMethod.equals("1")) {
60          strategy = new PayByPayPal();
          } else {
62          strategy = new PayByCreditCard();
          }
64      }

66      // Order object delegates gathering payment data to strategy object,
        //   since only strategies know what data they need to process a payment.
68      order.processOrder(strategy);

70      System.out.print("Pay " + order.getTotalCost()
          + " units or Continue shopping? P/C: ");
```

```
72          String proceed = reader.readLine();
            if (proceed.equalsIgnoreCase("P")) {
74            // Finally, strategy handles the payment.
              if (strategy.pay(order.getTotalCost())) {
76              System.out.println("Payment has been successful.");
              } else {
78              System.out.println("FAIL! Please, check your data.");
              }
80            order.setClosed();
            }
82        }
      }
84  }
```

4.2 Observer Pattern

4.2.1 Intent

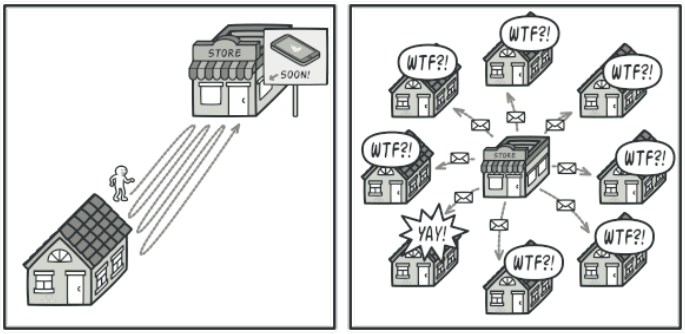
Observer is a behavioral design pattern that lets you define a subscription mechanism to notify multiple objects about any events that happen to the object they're observing.



4.2.2 Problem

Imagine that you have two types of objects: a Customer and a Store. The customer is very interested in a particular brand of product (say, it's a new model of the iPhone) which should become available in the store very soon.

The customer could visit the store every day and check product availability. But while the product is still en route, most of these trips would be pointless.



Visiting the store vs. sending spam.

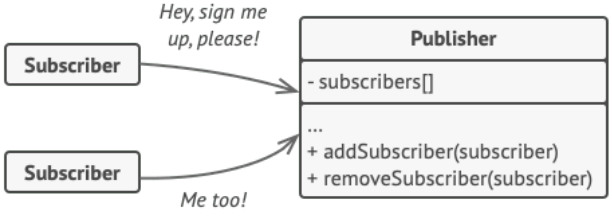
On the other hand, the store could send tons of emails (which might be considered spam) to all customers each time a new product becomes available. This would save some customers from endless trips to the store. At the same time, it'd upset other customers who aren't interested in new products.

It looks like we've got a conflict. Either the customer wastes time checking product availability or the store wastes resources notifying the wrong customers.

4.2.3 Solution

The object that has some interesting state is often called **subject**, but since it's also going to notify other objects about the changes to its state, we'll call it **publisher**. All other objects that want to track changes to the publisher's state are called **subscribers**.

The Observer pattern suggests that you add a subscription mechanism to the publisher class so individual objects can subscribe to or unsubscribe from a stream of events coming from that publisher. Fear not! Everything isn't as complicated as it sounds. In reality, this mechanism consists of 1) an array field for storing a list of references to subscriber objects and 2) several public methods which allow adding subscribers to and removing them from that list.

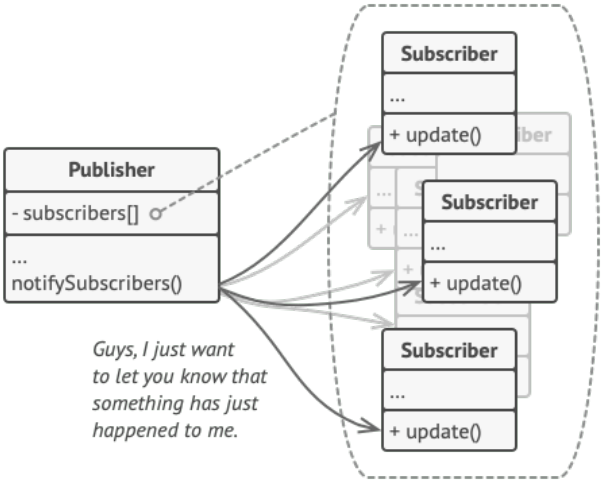


A subscription mechanism lets individual objects subscribe to event notifications.

Now, whenever an important event happens to the publisher, it goes over its subscribers and calls the specific notification method on their objects.

Real apps might have dozens of different subscriber classes that are interested in tracking events of the same publisher class. You wouldn't want to couple the publisher to all of those classes. Besides, you might not even know about some of them beforehand if your publisher class is supposed to be used by other people.

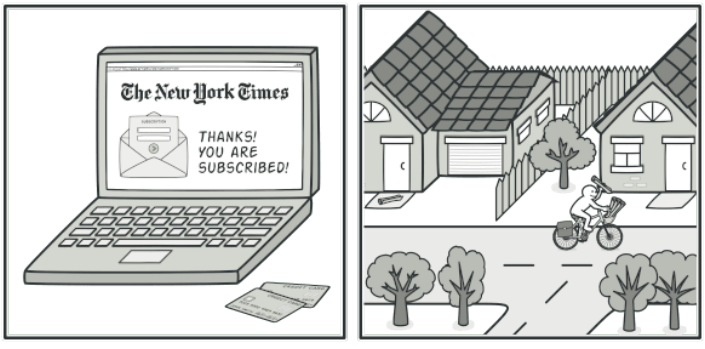
That's why it's crucial that all subscribers implement the same interface and that the publisher communicates with them only via that interface. This interface should declare the notification method along with a set of parameters that the publisher can use to pass some contextual data along with the notification.



Publisher notifies subscribers by calling the specific notification method on their objects.

If your app has several different types of publishers and you want to make your subscribers compatible with all of them, you can go even further and make all publishers follow the same interface. This interface would only need to describe a few subscription methods. The interface would allow subscribers to observe publishers' states without coupling to their concrete classes.

4.2.4 Real-World Analogy

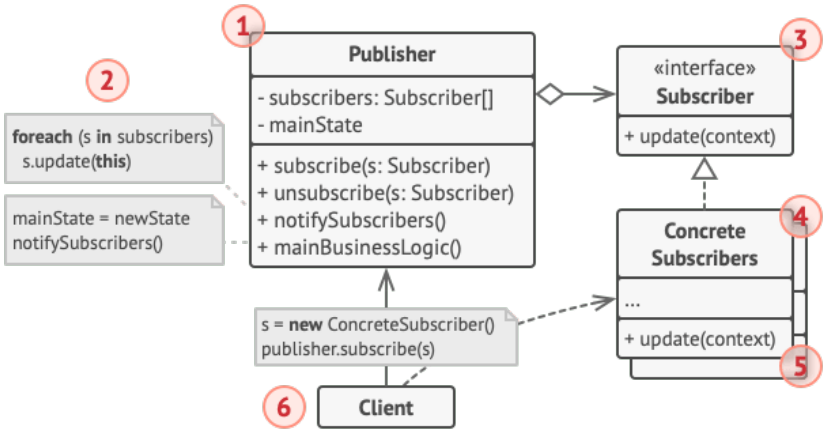


Magazine and newspaper subscriptions.

If you subscribe to a newspaper or magazine, you no longer need to go to the store to check if the next issue is available. Instead, the publisher sends new issues directly to your mailbox right after publication or even in advance.

The publisher maintains a list of subscribers and knows which magazines they're interested in. Subscribers can leave the list at any time when they wish to stop the publisher sending new magazine issues to them.

4.2.5 Structure



1. The Publisher issues events of interest to other objects. These events occur when the publisher changes its state or executes some behaviors. Publishers contain a subscription infrastructure that lets new subscribers join and current subscribers leave the list.

2. When a new event happens, the publisher goes over the subscription list and calls the notification method declared in the subscriber interface on each subscriber object.

3. The Subscriber interface declares the notification interface. In most cases, it consists of a single update method. The method may have several parameters that let the publisher pass some event details along with the update.

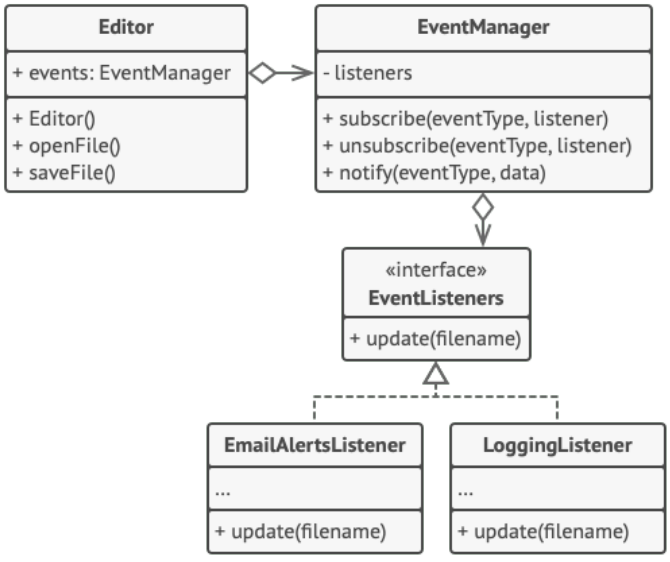
4. Concrete Subscribers perform some actions in response to notifications issued by the publisher. All of these classes must implement the same interface so the publisher isn't coupled to concrete classes.

5. Usually, subscribers need some contextual information to handle the update correctly. For this reason, publishers often pass some context data as arguments of the notification method. The publisher can pass itself as an argument, letting subscriber fetch any required data directly.

6. The Client creates publisher and subscriber objects separately and then registers subscribers for publisher updates.

4.2.6 Pseudocode

In this example, the Observer pattern lets the text editor object notify other service objects about changes in its state.



Notifying objects about events that happen to other objects.

The list of subscribers is compiled dynamically: objects can start or stop listening to notifications at runtime, depending on the desired behavior of your app.

In this implementation, the editor class doesn't maintain the subscription list by itself. It delegates this job to the special helper object devoted to just that. You could upgrade that object to serve as a centralized event dispatcher, letting any object act as a publisher.

Adding new subscribers to the program doesn't require changes to existing publisher classes, as long as they work with all subscribers through the same interface.

PSEUDO CODE

```
// The base publisher class includes subscription management
//  code and notification methods.
class EventManager is
  private field listeners : hash map of event types and listeners

  method subscribe(eventType, listener ) is
    listeners .add(eventType, listener )

```


```
    method unsubscribe(eventType, listener) is
10      listeners.remove(eventType, listener)

12  method notify(eventType, data) is
      foreach (listener in listeners.of(eventType)) do
14      listener.update(data)


16
  // The concrete publisher contains real business logic that's interesting
18 //  for some subscribers. We could derive this class from the base publisher,
  //  but that isn't always possible in real life because the concrete publisher
20 //  might already be a subclass. In this case, you can patch the subscription
  //  logic in with composition, as we did here.
22 class Editor is
    public field events: EventManager
24  private field file: File

26  constructor Editor() is
      events = new EventManager()
28
    // Methods of business logic can notify subscribers about changes.
30  method openFile(path) is
      this.file = new File(path)
32    events.notify("open", file.name)

34  method saveFile() is
      file.write()
36    events.notify("save", file.name)
      // ...
38


40 // Here's the subscriber interface. If your programming language
  //  supports functional types, you can replace the whole
42 //  subscriber hierarchy with a set of functions.
  interface EventListener is
44  method update(filename)


46
  // Concrete subscribers react to updates issued by the publisher
48 //  they are attached to.
  class LoggingListener implements EventListener is
50  private field log: File
    private field message: string
52
    constructor LoggingListener(log_filename, message) is
54  this.log = new File(log_filename)
    this.message = message
56
    method update(filename) is
58    log.write(replace('%s',filename,message))
```

```
class EmailAlertsListener implements EventListener is
  private field email: string
  private field message: string

  constructor EmailAlertsListener(email, message) is
    this.email = email
    this.message = message

  method update(filename) is
    system.email(email, replace('%s', filename, message))


// An application can configure publishers and subscribers at runtime.
class Application is
  method config() is
    editor = new Editor()

    logger = new LoggingListener(
      "/path/to/log.txt",
      "Someone has opened the file: %s")
    editor.events.subscribe("open", logger)

    emailAlerts = new EmailAlertsListener(
      "admin@example.com",
      "Someone has changed the file: %s")
    editor.events.subscribe("save", emailAlerts)
```

4.2.7 Applicability

- Use the Observer pattern when changes to the state of one object may require changing other objects, and the actual set of objects is unknown beforehand or changes dynamically.

▷ You can often experience this problem when working with classes of the graphical user interface. For example, you created custom button classes, and you want to let the clients hook some custom code to your buttons so that it fires whenever a user presses a button.

The Observer pattern lets any object that implements the subscriber interface subscribe for event notifications in publisher objects. You can add the subscription mechanism to your buttons, letting the clients hook up their custom code via custom subscriber classes.

- Use the pattern when some objects in your app must observe others, but only for a limited time or in specific cases.

▷ The subscription list is dynamic, so subscribers can join or leave the list whenever they need to.

4.2.8 How to Implement

1. Look over your business logic and try to break it down into two parts: the core functionality, independent from other code, will act as the publisher; the rest will turn into a set of subscriber classes.
2. Declare the subscriber interface. At a bare minimum, it should declare a single update method.
3. Declare the publisher interface and describe a pair of methods for adding a subscriber object to and removing it from the list. Remember that publishers must work with subscribers only via the subscriber interface.
4. Decide where to put the actual subscription list and the implementation of subscription methods. Usually, this code looks the same for all types of publishers, so the obvious place to put it is in an abstract class derived directly from the publisher interface. Concrete publishers extend that class, inheriting the subscription behavior.
5. However, if you're applying the pattern to an existing class hierarchy, consider an approach based on composition: put the subscription logic into a separate object, and make all real publishers use it.
6. Create concrete publisher classes. Each time something important happens inside a publisher, it must notify all its subscribers.
7. Implement the update notification methods in concrete subscriber classes. Most subscribers would need some context data about the event. It can be passed as an argument of the notification method.
8. But there's another option. Upon receiving a notification, the subscriber can fetch any data directly from the notification. In this case, the publisher must pass itself via the update method. The less flexible option is to link a publisher to the subscriber permanently via the constructor.
9. The client must create all necessary subscribers and register them with proper publishers.

4.2.9 Pros and Cons

+ Open/Closed Principle. You can introduce new subscriber classes without having to change the publisher's code (and vice versa if there's a publisher interface).
+ You can establish relations between objects at runtime.
- Subscribers are notified in random order.

4.2.10 Relations with Other Patterns

- Chain of Responsibility, Command, Mediator and Observer address various ways of connecting senders and receivers of requests:
  - Chain of Responsibility passes a request sequentially along a dynamic chain of potential receivers until one of them handles it.
  - Command establishes unidirectional connections between senders and receivers.
  - Mediator eliminates direct connections between senders and receivers, forcing them to communicate indirectly via a mediator object.
  - Observer lets receivers dynamically subscribe to and unsubscribe from receiving requests.
- The difference between Mediator and Observer is often elusive. In most cases, you can implement either of these patterns; but sometimes you can apply both simultaneously. Let's see how we can do that.

  The primary goal of Mediator is to eliminate mutual dependencies among a set of system components. Instead, these components become dependent on a single mediator object. The goal of Observer is to establish dynamic one-way connections between objects, where some objects act as subordinates of others.

  There's a popular implementation of the Mediator pattern that relies on Observer. The mediator object plays the role of publisher, and the components act as subscribers which subscribe to and unsubscribe from the mediator's events. When Mediator is implemented this way, it may look very similar to Observer.

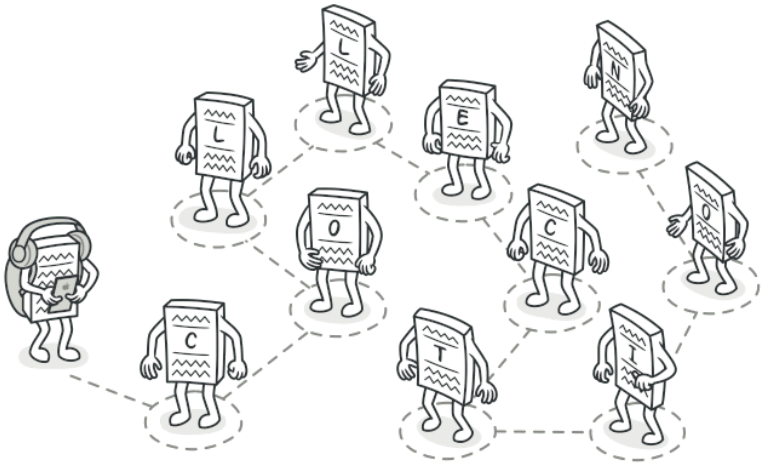
  When you're confused, remember that you can implement the Mediator pattern in other ways. For example, you can permanently link all the components to the same mediator object. This implementation won't resemble Observer but will still be an instance of the Mediator pattern.

  Now imagine a program where all components have become publishers, allowing dynamic connections between each other. There won't be a centralized mediator object, only a distributed set of observers.

4.3 Iterator Pattern

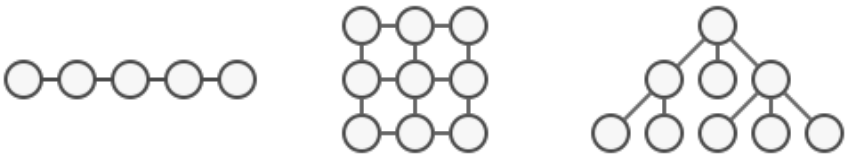
4.3.1 Intent

Iterator is a behavioral design pattern that lets you traverse elements of a collection without exposing its underlying representation (list, stack, tree, etc.).



4.3.2 Problem

Collections are one of the most used data types in programming. Nonetheless, a collection is just a container for a group of objects.

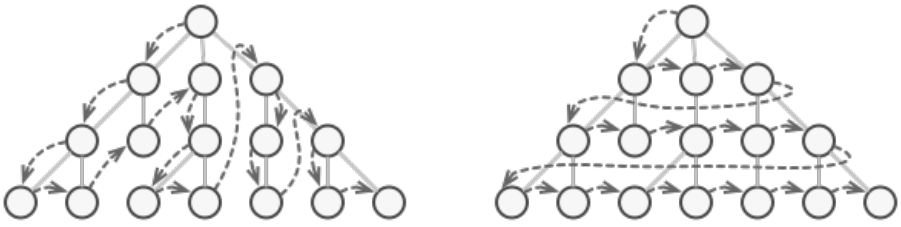


Various types of collections.

Most collections store their elements in simple lists. However, some of them are based on stacks, trees, graphs and other complex data structures.

But no matter how a collection is structured, it must provide some way of accessing its elements so that other code can use these elements. There should be a way to go through each element of the collection without accessing the same elements over and over.

This may sound like an easy job if you have a collection based on a list. You just loop over all of the elements. But how do you sequentially traverse elements of a complex data structure, such as a tree? For example, one day you might be just fine with depth-first traversal of a tree. Yet the next day you might require breadth-first traversal. And the next week, you might need something else, like random access to the tree elements.



The same collection can be traversed in several different ways.

Adding more and more traversal algorithms to the collection gradually blurs its primary responsibility, which is efficient data storage. Additionally, some algorithms might be tailored for a specific application, so including them into a generic collection class would be weird.

On the other hand, the client code that's supposed to work with various collections may not even care how they store their elements. However, since collections all provide different ways of accessing their elements, you have no option other than to couple your code to the specific collection classes.

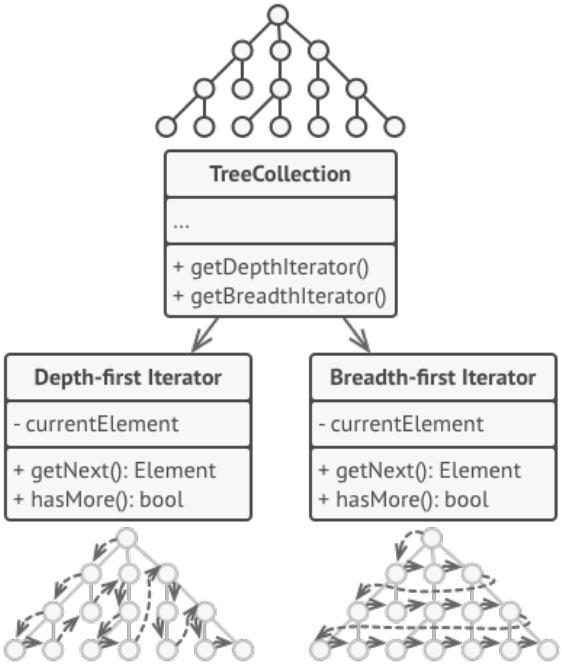
4.3.3 Solution

The main idea of the Iterator pattern is to extract the traversal behavior of a collection into a separate object called an iterator.

In addition to implementing the algorithm itself, an iterator object encapsulates all of the traversal details, such as the current position and how many elements are left till the end. Because of this, several iterators can go through the same collection at the same time, independently of each other.

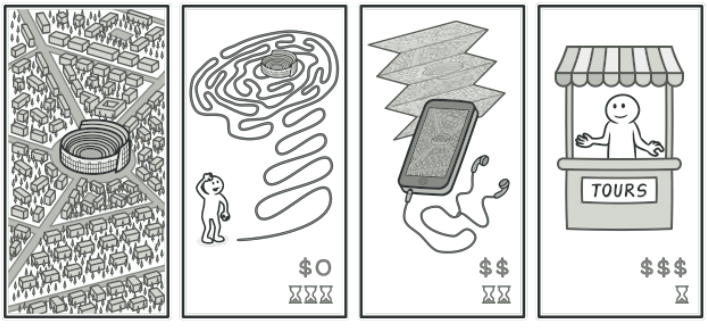
Usually, iterators provide one primary method for fetching elements of the collection. The client can keep running this method until it doesn't return anything, which means that the iterator has traversed all of the elements.

All iterators must implement the same interface. This makes the client code compatible with any collection type or any traversal algorithm as long as there's a proper iterator. If you need a special way to traverse a collection, you just create a new iterator class, without having to change the collection or the client.



Iterators implement various traversal algorithms. Several iterator objects can traverse the same collection at the same time.

4.3.4 Real-World Analogy



Various ways to walk around Rome.

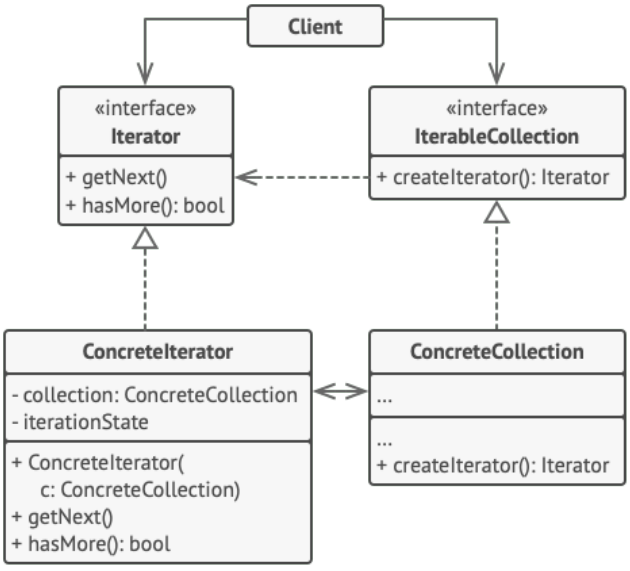
You plan to visit Rome for a few days and visit all of its main sights and attractions. But once there, you could waste a lot of time walking in circles, unable to find even the Colosseum.

On the other hand, you could buy a virtual guide app for your smartphone and use it for navigation. It's smart and inexpensive, and you could be staying at some interesting places for as long as you want.

A third alternative is that you could spend some of the trip's budget and hire a local guide who knows the city like the back of his hand. The guide would be able to tailor the tour to your likings, show you every attraction and tell a lot of exciting stories. That'll be even more fun; but, alas, more expensive, too.

All of these options—the random directions born in your head, the smartphone navigator or the human guide—act as iterators over the vast collection of sights and attractions located in Rome.

4.3.5 Structure



1. The Iterator interface declares the operations required for traversing a collection: fetching the next element, retrieving the current position, restarting iteration, etc.

2. Concrete Iterators implement specific algorithms for traversing a collection. The iterator object should track the traversal progress on its own. This allows several iterators to traverse the same collection independently of each other.

3. The Collection interface declares one or multiple methods for getting iterators compatible with the collection. Note that the return type of the methods must be declared as the iterator interface so that the concrete collections can return various kinds of iterators.

4. Concrete Collections return new instances of a particular concrete iterator class each time the client requests one. You might be wondering, where's the rest of

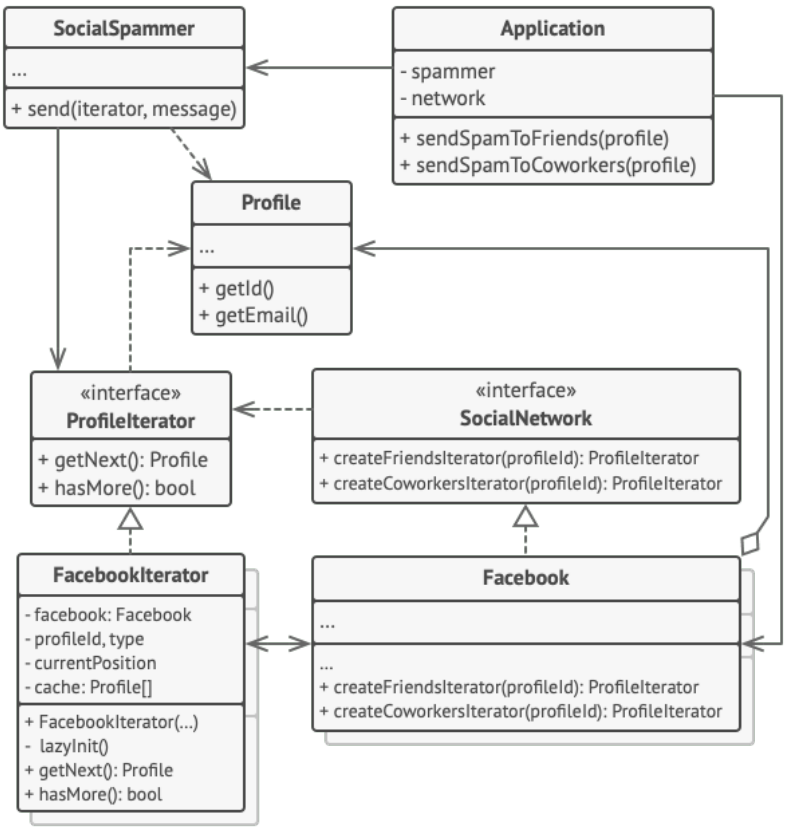
the collection's code? Don't worry, it should be in the same class. It's just that these details aren't crucial to the actual pattern, so we're omitting them.

5. The Client works with both collections and iterators via their interfaces. This way the client isn't coupled to concrete classes, allowing you to use various collections and iterators with the same client code.

   Typically, clients don't create iterators on their own, but instead get them from collections. Yet, in certain cases, the client can create one directly; for example, when the client defines its own special iterator.

4.3.6 Pseudocode

In this example, the Iterator pattern is used to walk through a special kind of collection which encapsulates access to Facebook's social graph. The collection provides several iterators that can traverse profiles in various ways.



Example of iterating over social profiles.

The 'friends' iterator can be used to go over the friends of a given profile. The 'colleagues' iterator does the same, except it omits friends who don't work at the same company as a target person. Both iterators implement a common interface which allows clients to fetch profiles without diving into implementation details such as authentication and sending REST requests.

The client code isn't coupled to concrete classes because it works with collections and iterators only through interfaces. If you decide to connect your app to a new social network, you simply need to provide new collection and iterator classes without changing the existing code.


```
// The collection interface must declare a factory method for
// producing iterators. You can declare several methods if there
// are different kinds of iteration available in your program.
interface SocialNetwork is
  method createFriendsIterator(profileId): ProfileIterator
  method createCoworkersIterator(profileId): ProfileIterator


// Each concrete collection is coupled to a set of concrete
// iterator classes it returns. But the client isn't, since the
// signature of these methods returns iterator interfaces.
class Facebook implements SocialNetwork is
  // ... The bulk of the collection's code should go here ...

  // Iterator creation code.
  method createFriendsIterator(profileId) is
    return new FacebookIterator(this, profileId, "friends")

  method createCoworkersIterator(profileId) is
    return new FacebookIterator(this, profileId, "coworkers")


// The common interface for all iterators.
interface ProfileIterator is
  method getNext(): Profile
  method hasMore():bool


// The concrete iterator class.
class FacebookIterator implements ProfileIterator is
  // The iterator needs a reference to the collection that it traverses.
  private field facebook: Facebook
  private field profileId, type: string

  // An iterator object traverses the collection independently from other
  // iterators. Therefore it has to store the iteration state.
  private field currentPosition
  private field cache: array of Profile
```


```
    constructor FacebookIterator(facebook, profileId, type) is
      this.facebook = facebook
      this.profileId = profileId
      this.type = type

    private method lazyInit() is
      if (cache == null)
        cache = facebook.socialGraphRequest(profileId, type)

    // Each concrete iterator class has its own implementation
    //   of the common iterator interface.
    method getNext() is
      if (hasMore())
        currentPosition++
      return cache[currentPosition]

    method hasMore() is
      lazyInit()
      return currentPosition < cache.length


// Here is another useful trick: you can pass an iterator to a client
//   class instead of giving it access to a whole collection.
//   This way, you don't expose the collection to the client.
//
// And there's another benefit: you can change the way the client works
//   with the collection at runtime by passing it a different iterator.
//   This is possible because the client code isn't coupled to concrete
//   iterator classes.
class SocialSpammer is
  method send(iterator: ProfileIterator, message: string) is
    while (iterator.hasMore())
      profile = iterator.getNext()
    System.sendEmail(profile.getEmail(), message)


// The application class configures collections and iterators
//   and then passes them to the client code.
class Application is
  field network: SocialNetwork
  field spammer: SocialSpammer

  method config() is
    if working with Facebook
      this.network = new Facebook()
    if working with LinkedIn
      this.network = new LinkedIn()
    this.spammer = new SocialSpammer()

  method sendSpamToFriends(profile) is
```

```
PSEUDO CODE
90      iterator = network.createFriendsIterator(profile.getId())
        spammer.send(iterator, "Very important message")
92
    method sendSpamToCoworkers(profile) is
94      iterator = network.createCoworkersIterator(profile.getId())
        spammer.send(iterator, "Very important message")
```

4.3.7 Applicability

- Use the Iterator pattern when your collection has a complex data structure under the hood, but you want to hide its complexity from clients (either for convenience or security reasons).

▷ The iterator encapsulates the details of working with a complex data structure, providing the client with several simple methods of accessing the collection elements. While this approach is very convenient for the client, it also protects the collection from careless or malicious actions which the client would be able to perform if working with the collection directly.

- Use the pattern to reduce duplication of the traversal code across your app.

▷ The code of non-trivial iteration algorithms tends to be very bulky. When placed within the business logic of an app, it may blur the responsibility of the original code and make it less maintainable. Moving the traversal code to designated iterators can help you make the code of the application more lean and clean.

- Use the Iterator when you want your code to be able to traverse different data structures or when types of these structures are unknown beforehand.

▷ The pattern provides a couple of generic interfaces for both collections and iterators. Given that your code now uses these interfaces, it'll still work if you pass it various kinds of collections and iterators that implement these interfaces.

4.3.8 How to Implement

1. Declare the iterator interface. At the very least, it must have a method for fetching the next element from a collection. But for the sake of convenience you can add a couple of other methods, such as fetching the previous element, tracking the current position, and checking the end of the iteration.

2. Declare the collection interface and describe a method for fetching iterators. The return type should be equal to that of the iterator interface. You may declare similar methods if you plan to have several distinct groups of iterators.

3. Implement concrete iterator classes for the collections that you want to be traversable with iterators. An iterator object must be linked with a single collection instance. Usually, this link is established via the iterator's constructor.

4. Implement the collection interface in your collection classes. The main idea is to provide the client with a shortcut for creating iterators, tailored for a particular collection class. The collection object must pass itself to the iterator's constructor to establish a link between them.

5. Go over the client code to replace all of the collection traversal code with the use of iterators. The client fetches a new iterator object each time it needs to iterate over the collection elements.

4.3.9 Pros and Cons

+ Single Responsibility Principle. You can clean up the client code and the collections by extracting bulky traversal algorithms into separate classes.

+ Open/Closed Principle. You can implement new types of collections and iterators and pass them to existing code without breaking anything.

+ You can iterate over the same collection in parallel because each iterator object contains its own iteration state.

+ For the same reason, you can delay an iteration and continue it when needed.

- Applying the pattern can be an overkill if your app only works with simple collections.

- Using an iterator may be less efficient than going through elements of some specialized collections directly.

4.3.10 Relations with Other Patterns

- You can use Iterators to traverse Composite trees.

- You can use Factory Method along with Iterator to let collection subclasses return different types of iterators that are compatible with the collections.

- You can use Memento along with Iterator to capture the current iteration state and roll it back if necessary.

- You can use Visitor along with Iterator to traverse a complex data structure and execute some operation over its elements, even if they all have different classes.

4.3.11 Examples

1. Cafe

```java
package com.patterns.iterator;

public interface Iterator {
    boolean hasNext();
    Object next();
}
```

```java
package com.patterns.iterator;

public interface Menu {
    public Iterator createIterator();
}
```

```java
package com.patterns.iterator;

public class DinerMenuIterator implements Iterator {
    private String[] items;
    private int position = 0;

    public DinerMenuIterator(String[] items) {
        this.items = items;
    }

    public String next() {
        String menuItem = items[position];
        position = position + 1;
        return menuItem;
    }

    public boolean hasNext() {
        if (position >= items.length || items[position] == null) {
            return false;
        }

        return true;
    }
```

```
}
```

```
package com.patterns.iterator.cafe;

import java.util.List;
import java.util.ArrayList;

public class PancakeHouseMenuIterator implements Iterator {
    private List<String> items;
    private int position = 0;

    public PancakeHouseMenuIterator(ArrayList<String> items) {
        this.items = items;
    }

    public String next() {
        String menuItem = items.get(position);
        position = position + 1;
        return menuItem;
    }

    public boolean hasNext() {
        if (position >= items.size()) {
            return false;
        }

        return true;
    }
}
```

```
package com.patterns.iterator.cafe;

import java.util.List;
import java.util.ArrayList;

public class PancakeHouseMenu implements Menu {
    private List<String> menuItems;

    public PancakeHouseMenu() {
        menuItems = new ArrayList<String>();

```

```
        addItem("K&B's Pancake Breakfast");
        addItem("Regular Pancake Breakfast");
        addItem("Blueberry Pancakes");
        addItem("Waffles");
    }

    public void addItem(String name) {
        menuItems.add(name);
    }

    public ArrayList<String> getMenuItems() {
        return menuItems;
    }

    public Iterator createIterator() {
        return new PancakeHouseMenuIterator(menuItems);
    }

    public String toString() {
        return "Pancake House Menu";
    }

    // Other menu methods here
}
```

```
package com.patterns.iterator.cafe;

public class DinerMenu implements Menu {
    private static final int MAX_ITEMS = 6;
    private int numberOfItems = 0;
    private String[] menuItems;

    public DinerMenu() {
        menuItems = new String[MAX_ITEMS];
        addItem("Vegetarian BLT");
        addItem("BLT");
        addItem("Soup of the day");
        addItem("Hotdog");
        addItem("Steamed Veggies and Brown Rice");
        addItem("Pasta");
    }

    public void addItem(String name) {
        if (numberOfItems >= MAX_ITEMS) {
            System.err.println("Sorry, menu is full! Can't add item to menu");
        } else {
```

```
            menuItems[numberOfItems] = name;
            numberOfItems = numberOfItems + 1;
        }
    }

    public String[] getMenuItems() {
        return menuItems;
    }

    public Iterator createIterator() {
        return new DinerMenuIterator(menuItems);
    }

    public String toString() {
        return "Diner Menu";
    }

    // Other menu methods here
}
```

```
package com.patterns.iterator.cafe;

import java.util.*;

public class Cafe {
    public static void main(String args[]) {
        // With no iterators
        System.out.println("\nMENU\n----\nBREAKFAST");
        PancakeHouseMenu pancakeHouseMenu = new PancakeHouseMenu();
        List<String> breakfastItems = pancakeHouseMenu.getMenuItems();
        for (int i = 0; i < breakfastItems.size(); i++) {
            String menuItem = breakfastItems.get(i);
            System.out.println(menuItem);
        }

        System.out.println("\nLUNCH");
        DinerMenu dinerMenu = new DinerMenu();
        String[] lunchItems = dinerMenu.getMenuItems();

        for (int i = 0; i < lunchItems.length; i++) {
            String menuItem = lunchItems[i];
            System.out.println(menuItem);
        }

        // With iterators
        Iterator pancakeIterator = pancakeHouseMenu.createIterator();
```

```
        Iterator dinerIterator = dinerMenu.createIterator();

        System.out.println("\nMENU (with iterators)\n----\nBREAKFAST");
        printMenu(pancakeIterator);
        System.out.println("\nLUNCH");
        printMenu(dinerIterator);
    }

    private static void printMenu(Iterator it) {
        while (it.hasNext()) {
            String menuItem = (String) it.next();
            System.out.println(menuItem);
        }
    }
}
```

2. Employee

```
package com.patterns.iterator.employee;

public interface Iterator {
    public boolean hasNext();
    public Object next();
}
```

```
package com.patterns.iterator.employee;

public interface EmployeeIterable {
    public Iterator getIterator();
}
```

```
public class EmployeeRepository implements EmployeeIterable {
    private String[] employees;

    public EmployeeRepository() {
        this.employees = {"David", "Scott", "Rhett", "Andrew", "Jessica"};
```

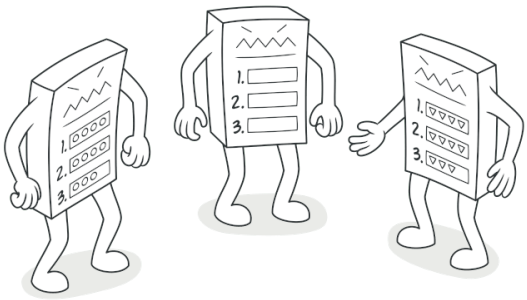
```
    }

    @Override
    public Iterator getIterator() {
        return new EmployeeIterator();
    }

    private class EmployeeIterator implements Iterator {
        private int position;

        public EmployeeIterator() {
            this.position = 0;
        }

        @Override
        public boolean hasNext() {
            if (this.position < employees.length) {
                return true;
            }
            return false;
        }

        @Override
        public Object next() {
            if (this.hasNext()) {
                return employees[this.position++];
            }
            return null;
        }
    }
}
```

```
package com.patterns.iterator.employee;

public class App {
    public static void main(String[] args) {
        EmployeeRepository employeeRepository = new EmployeeRepository();

        for (Iterator it = employeeRepository.getIterator(); it.hasNext();) {
            String employee = (String) it.next();
            System.out.println("Employee: " + employee);
        }
    }
}
```

4.4 Template Method Pattern

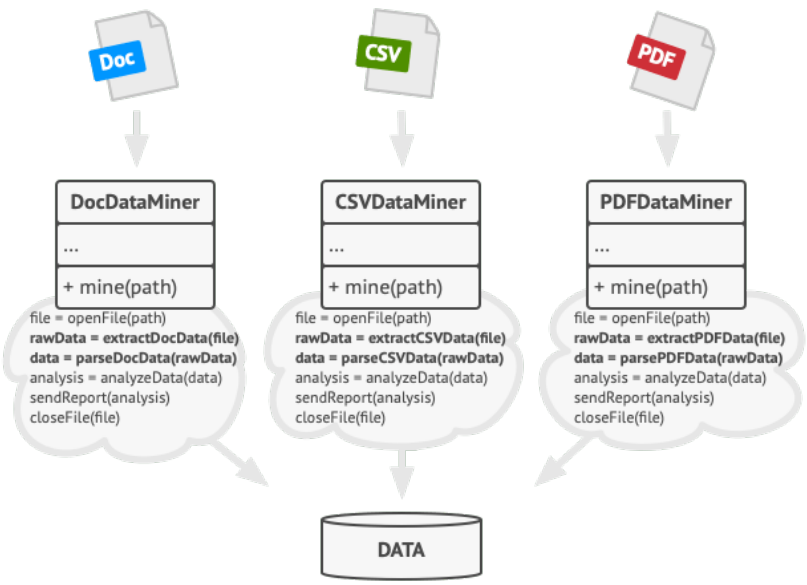
4.4.1 Intent

Template Method is a behavioral design pattern that defines the skeleton of an algorithm in the superclass but lets subclasses override specific steps of the algorithm without changing its structure.



4.4.2 Problem

Imagine that you're creating a data mining application that analyzes corporate documents. Users feed the app documents in various formats (PDF, DOC, CSV), and it tries to extract meaningful data from these docs in a uniform format.



Data mining classes contained a lot of duplicate code.

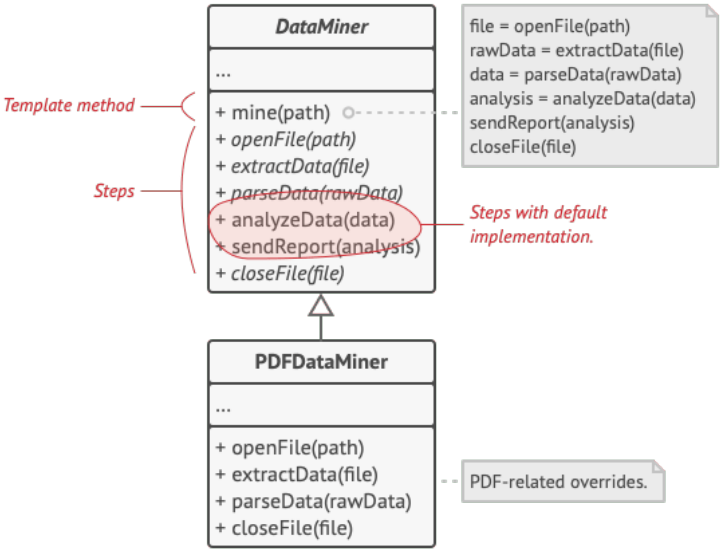
The first version of the app could work only with DOC files. In the following version, it was able to support CSV files. A month later, you "taught" it to extract data from PDF files.

At some point, you noticed that all three classes have a lot of similar code. While the code for dealing with various data formats was entirely different in all classes, the code for data processing and analysis is almost identical. Wouldn't it be great to get rid of the code duplication, leaving the algorithm structure intact?

There was another problem related to client code that used these classes. It had lots of conditionals that picked a proper course of action depending on the class of the processing object. If all three processing classes had a common interface or a base class, you'd be able to eliminate the conditionals in client code and use polymorphism when calling methods on a processing object.

4.4.3 Solution

The Template Method pattern suggests that you break down an algorithm into a series of steps, turn these steps into methods, and put a series of calls to these methods inside a single template method. The steps may either be abstract, or have some default implementation. To use the algorithm, the client is supposed to provide its own subclass, implement all abstract steps, and override some of the optional ones if needed (but not the template method itself).



Template method breaks the algorithm into steps, allowing subclasses to override these steps but not the actual method.

Let's see how this will play out in our data mining app. We can create a base class for all three parsing algorithms. This class defines a template method consisting of a series of calls to various document-processing steps.

At first, we can declare all steps abstract, forcing the subclasses to provide their own implementations for these methods. In our case, subclasses already have all necessary implementations, so the only thing we might need to do is adjust signatures of the methods to match the methods of the superclass.

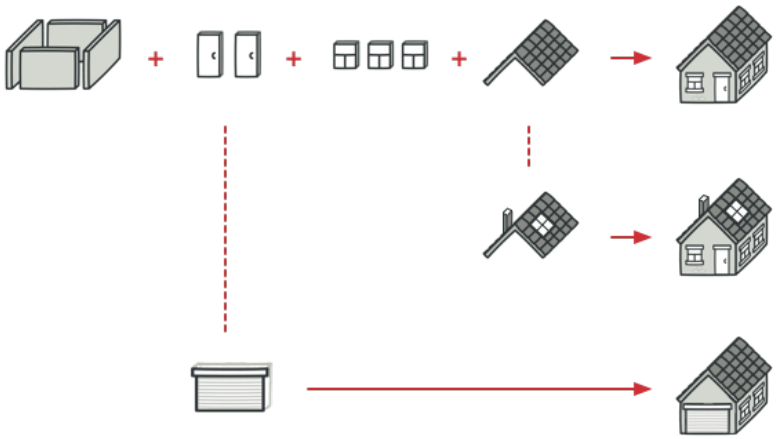
Now, let's see what we can do to get rid of the duplicate code. It looks like the code for opening/closing files and extracting/parsing data is different for various data formats, so there's no point in touching those methods. However, implementation of other steps, such as analyzing the raw data and composing reports, is very similar, so it can be pulled up into the base class, where subclasses can share that code.

As you can see, we've got two types of steps:

- **Abstract steps** must be implemented by every subclass.
- **Optional steps** already have some default implementation, but still can be overridden if needed.

There's another type of step, called hooks. A hook is an optional step with an empty body. A template method would work even if a hook isn't overridden. Usually, hooks are placed before and after crucial steps of algorithms, providing subclasses with additional extension points for an algorithm.

4.4.4 Real-World Analogy

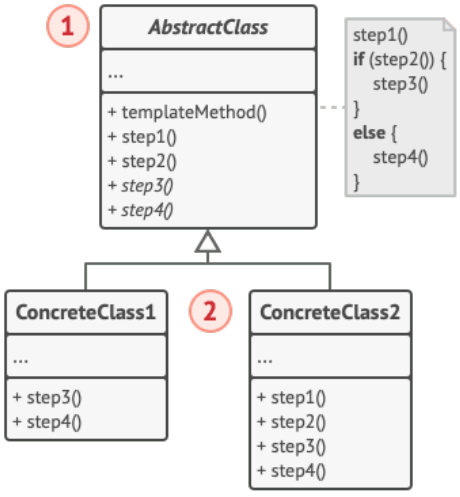


A typical architectural plan can be slightly altered to better fit the client's needs.

The template method approach can be used in mass housing construction. The architectural plan for building a standard house may contain several extension points that would let a potential owner adjust some details of the resulting house.

Each building step, such as laying the foundation, framing, building walls, installing plumbing and wiring for water and electricity, etc., can be slightly changed to make the resulting house a little bit different from others.

4.4.5 Structure



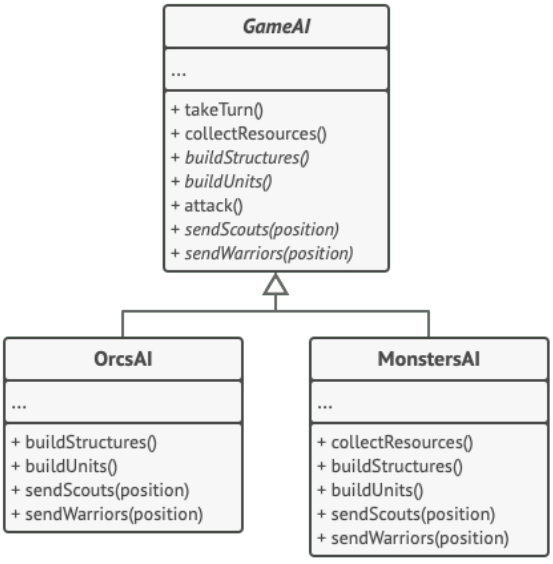
1. The **Abstract Class** declares methods that act as steps of an algorithm, as well as the actual template method which calls these methods in a specific order. The steps may either be declared abstract or have some default implementation.

2. **Concrete Classes** can override all of the steps, but not the template method itself.

4.4.6 Pseudocode

In this example, the Template Method pattern provides a "skeleton" for various branches of artificial intelligence in a simple strategy video game.

All races in the game have almost the same types of units and buildings. Therefore you can reuse the same AI structure for various races, while being able to override some of the details. With this approach, you can override the orcs' AI to make it more aggressive, make humans more defense-oriented, and make monsters unable to build anything. Adding a new race to the game would require creating a new AI subclass and overriding the default methods declared in the base AI class.



AI classes of a simple video game.

PSEUDO CODE

```
// The abstract class defines a template method that contains a skeleton of
// some algorithm composed of calls, usually to abstract primitive operations.
// Concrete subclasses implement these operations, but leave the template method
//  itself intact.
class GameAI is
  // The template method defines the skeleton of an algorithm.
  method turn() is
    collectResources()
    buildStructures()
    buildUnits()
    attack()

  // Some of the steps may be implemented right in a base class.
  method collectResources() is
    foreach (s in this.builtStructures) do
      s.collect()

  // And some of them may be defined as abstract.
  abstract method buildStructures()
  abstract method buildUnits()

  // A class can have several template methods.
  method attack() is
    enemy = closestEnemy()
    if (enemy == null)
      sendScouts(map.center)
```

```
      else
28      sendWarriors(enemy.position)

30  abstract method sendScouts(position)
    abstract method sendWarriors(position)
32

34 // Concrete classes have to implement all abstract operations of the base class
   //  but they must not override the template method itself.
36 class OrcsAI extends GameAI is
    method buildStructures() is
38    if (there are some resources) then
        // Build farms, then barracks, then stronghold.
40
    method buildUnits() is
42    if (there are plenty of resources) then
        if (there are no scouts)
44        // Build peon, add it to scouts group.
        else
46        // Build grunt, add it to warriors group.

48    //  ...

50  method sendScouts(position) is
      if (scouts.length > 0) then
52      // Send scouts to position.

54  method sendWarriors(position) is
      if (warriors.length > 5) then
56      // Send warriors to position.


58
   // Subclasses can also override some operations with a default implementation.
60 class MonstersAI extends GameAI is
    method collectResources() is
62    // Monsters don't collect resources.

64  method buildStructures() is
      // Monsters don't build structures.
66
    method buildUnits() is
68    // Monsters don't build units.
```

4.4.7 Applicability

- Use the Template Method pattern when you want to let clients extend only particular steps of an algorithm, but not the whole algorithm or its structure.

▷ The Template Method lets you turn a monolithic algorithm into a series of individual steps which can be easily extended by subclasses while keeping intact the structure defined in a superclass.

• Use the pattern when you have several classes that contain almost identical algorithms with some minor differences. As a result, you might need to modify all classes when the algorithm changes.

▷ When you turn such an algorithm into a template method, you can also pull up the steps with similar implementations into a superclass, eliminating code duplication. Code that varies between subclasses can remain in subclasses.

4.4.8 How to Implement

1. Analyze the target algorithm to see whether you can break it into steps. Consider which steps are common to all subclasses and which ones will always be unique.

2. Create the abstract base class and declare the template method and a set of abstract methods representing the algorithm's steps. Outline the algorithm's structure in the template method by executing corresponding steps. Consider making the template method final to prevent subclasses from overriding it.

3. It's okay if all the steps end up being abstract. However, some steps might benefit from having a default implementation. Subclasses don't have to implement those methods.

4. Think of adding hooks between the crucial steps of the algorithm.

5. For each variation of the algorithm, create a new concrete subclass. It must implement all of the abstract steps, but may also override some of the optional ones.

4.4.9 Pros and Cons

+ You can let clients override only certain parts of a large algorithm, making them less affected by changes that happen to other parts of the algorithm.

+ You can pull the duplicate code into a superclass.

- Some clients may be limited by the provided skeleton of an algorithm.

- You might violate the Liskov's Substitution Principle by suppressing a default step implementation via a subclass.

- Template methods tend to be harder to maintain the more steps they have.

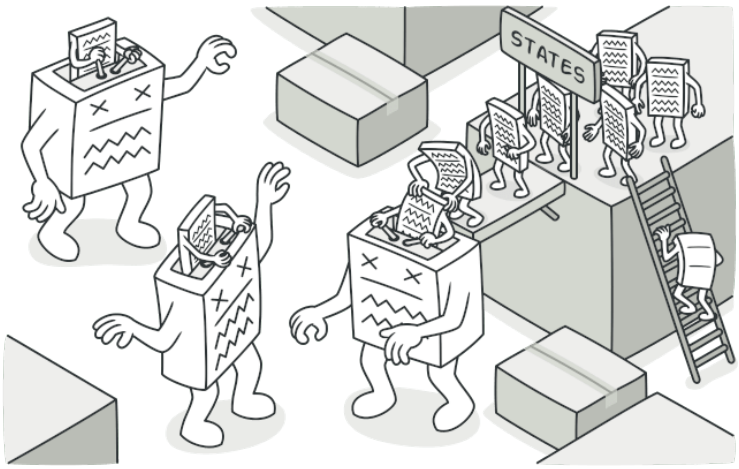
4.4.10 Relations with Other Patterns

- Factory Method is a specialization of Template Method. At the same time, a Factory Method may serve as a step in a large Template Method.
- Template Method is based on inheritance: it lets you alter parts of an algorithm by extending those parts in subclasses. Strategy is based on composition: you can alter parts of the object's behavior by supplying it with different strategies that correspond to that behavior. Template Method works at the class level, so it's static. Strategy works on the object level, letting you switch behaviors at runtime.

4.5 State Pattern

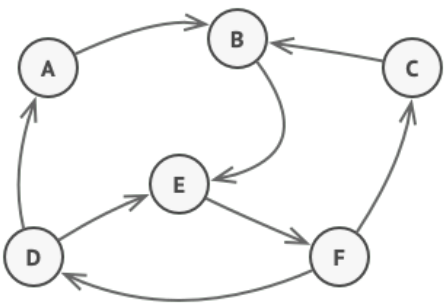
4.5.1 Intent

State is a behavioral design pattern that lets an object alter its behavior when its internal state changes. It appears as if the object changed its class.



4.5.2 Problem

The State pattern is closely related to the concept of a **Finite-State Machine**.



Finite-State Machine.

The main idea is that, at any given moment, there's a finite number of states which a program can be in. Within any unique state, the program behaves differently, and the program can be switched from one state to another instantaneously. However, depending on a current state, the program may or may not switch to certain other states. These switching rules, called transitions, are also finite and predetermined.

You can also apply this approach to objects. Imagine that we have a Document class. A document can be in one of three states: Draft, Moderation and Published. The **publish** method of the document works a little bit differently in each state:

- In Draft, it moves the document to moderation.
- In Moderation, it makes the document public, but only if the current user is an administrator.
- In Published, it doesn't do anything at all.

Possible states and transitions of a document object.

State machines are usually implemented with lots of conditional statements (if or switch) that select the appropriate behavior depending on the current state of the object. Usually, this "state" is just a set of values of the object's fields. Even if you've never heard about finite-state machines before, you've probably implemented a state at least once. Does the following code structure ring a bell?

PSEUDO CODE

```
class Document is
  field state: string
  // ...

  method publish() is
    switch (state)
```

```
      "draft":
8       state = "moderation"
        break
10    "moderation":
        if (currentUser.role == "admin")
12        state = "published"
        break
14    "published":
        // Do nothing.
16      break

18  // ...
```

The biggest weakness of a state machine based on conditionals reveals itself once we start adding more and more states and state-dependent behaviors to the Document class. Most methods will contain monstrous conditionals that pick the proper behavior of a method according to the current state. Code like this is very difficult to maintain because any change to the transition logic may require changing state conditionals in every method.

The problem tends to get bigger as a project evolves. It's quite difficult to predict all possible states and transitions at the design stage. Hence, a lean state machine built with a limited set of conditionals can grow into a bloated mess over time.

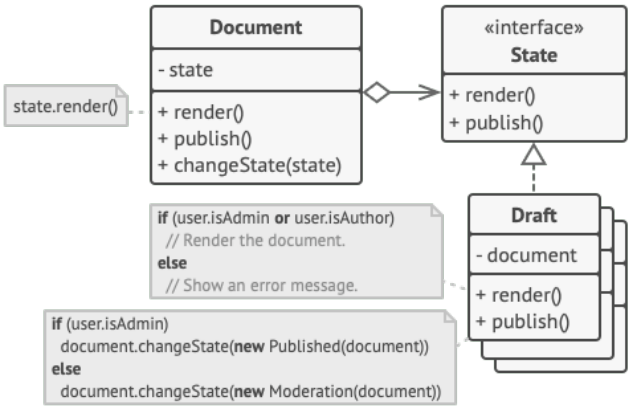
4.5.3 Solution

The State Pattern suggests that you create new classes for all possible states of an object and extract all state-specific behaviors into these classes.

Instead of implementing all behaviors on its own, the original object, called **context**, stores a reference to one of the state objects that represents its current state, and delegates all the state-related work to that object.

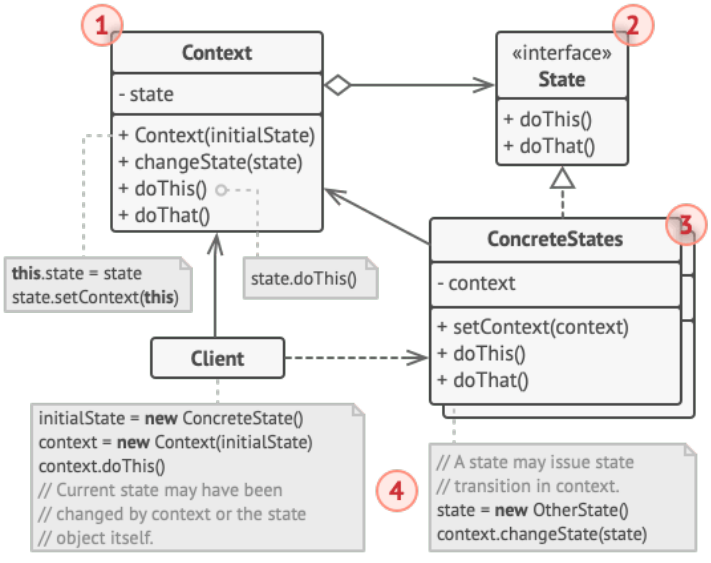
To transition the context into another state, replace the active state object with another object that represents that new state. This is possible only if all state classes follow the same interface and the context itself works with these objects through that interface.

This structure may look similar to the Strategy Pattern, but there's one key difference. In the State pattern, the particular states may be aware of each other and initiate transitions from one state to another, whereas strategies almost never know about each other.



Document delegates the work to a state object.

4.5.4 Structure



1. Context stores a reference to one of the concrete state objects and delegates to it all state-specific work. The context communicates with the state object via the state interface. The context exposes a setter for passing it a new state object.

2. The State interface declares the state-specific methods. These methods should make sense for all concrete states because you don't want some of your states to have useless methods that will never be called.

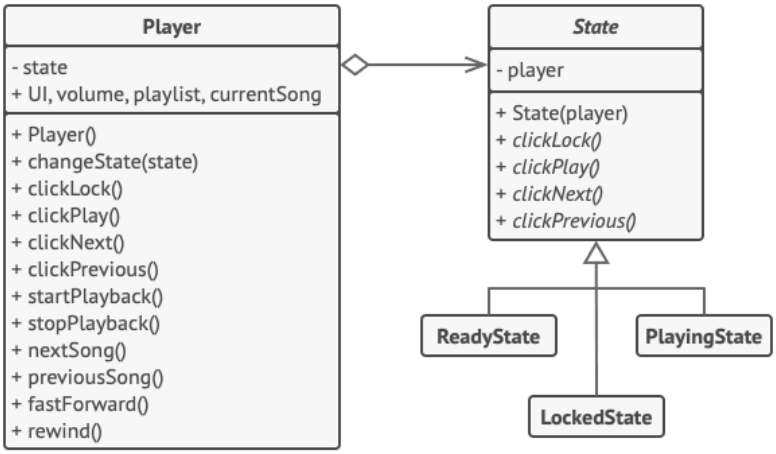
3. Concrete States provide their own implementations for the state-specific methods. To avoid duplication of similar code across multiple states, you may provide intermediate abstract classes that encapsulate some common behavior.

   State objects may store a backreference to the context object. Through this reference, the state can fetch any required info from the context object, as well as initiate state transitions.

4. Both context and concrete states can set the next state of the context and perform the actual state transition by replacing the state object linked to the context.

4.5.5 Pseudocode

In this example, the State pattern lets the same controls of the media player behave differently, depending on the current playback state.



Example of changing object behavior with state objects.

The main object of the player is always linked to a state object that performs most of the work for the player. Some actions replace the current state object of the player with another, which changes the way the player reacts to user interactions.

PSEUDO CODE

```
// The AudioPlayer class acts as a context. It also maintains a reference to
//   an instance of one of the state classes that represents the current state
//   of the audio player.
class AudioPlayer is
    field state: State
    field UI, volume, playlist, currentSong
```


```
class AudioPlayer() is
    this.state = new ReadyState(this)

    // Context delegates handling user input to a state object. Naturally,
    //  the outcome depends on what state is currently active, since
    //  each state can handle the input differently.
    UI = new UserInterface()
    UI.lockButton.onClick(this.clickLock)
    UI.playButton.onClick(this.clickPlay)
    UI.nextButton.onClick(this.clickNext)
    UI.prevButton.onClick(this.clickPrevious)

  // Other objects must be able to switch the audio player's active state.
  method changeState(state: State) is
    this.state = state

  // UI methods delegate execution to the active state.
  method clickLock() is
    state.clickLock()

  method clickPlay() is
    state.clickPlay()

  method clickNext() is
    state.clickNext()

  method clickPrevious() is
    state.clickPrevious()

  // A state may call some service methods on the context.
  method startPlayback() is
    // ...

  method stopPlayback() is
    // ...

  method nextSong() is
    // ...

  method previousSong() is
    // ...

  method fastForward(time) is
    // ...

  method rewind(time) is
    // ...


// The base state class declares methods that all concrete states should
```


```
// implement and also provides a backreference to the context object associated
// with the state. States can use the backreference to transition the context
// to another state.
abstract class State is
  protected field player: AudioPlayer

  // Context passes itself through the state constructor. This
  // may help a state fetch some useful context data if it's needed.
  constructor State(player) is
    this.player = player

  abstract method clickLock()
  abstract method clickPlay()
  abstract method clickNext()
  abstract method clickPrevious()


// Concrete states implement various behaviors associated with a
// state of the context.
class LockedState extends State is

  // When you unlock a locked player, it may assume one of two states.
  method clickLock() is
    if (player.playing)
      player.changeState(new PlayingState(player))
    else
      player.changeState(new ReadyState(player))

  method clickPlay() is
    // Locked, so do nothing.

  method clickNext() is
    // Locked, so do nothing.

  method clickPrevious() is
    // Locked, so do nothing.


// They can also trigger state transitions in the context.
class ReadyState extends State is
  method clickLock() is
    player.changeState(new LockedState(player))

  method clickPlay() is
    player.startPlayback()
    player.changeState(new PlayingState(player))

  method clickNext() is
    player.nextSong()

  method clickPrevious() is
```

```
        player.previousSong()

class PlayingState extends State is
    method clickLock() is
        player.changeState(new LockedState(player))

    method clickPlay() is
        player.stopPlayback()
        player.changeState(new ReadyState(player))

    method clickNext() is
        if (event.doubleclick)
            player.nextSong()
        else
            player.fastForward(5)

    method clickPrevious() is
        if (event.doubleclick)
            player.previous()
        else
            player.rewind(5)
```

4.5.6 Applicability

- Use the State pattern when you have an object that behaves differently depending on its current state, the number of states is enormous, and the state-specific code changes frequently.

▷ The pattern suggests that you extract all state-specific code into a set of distinct classes. As a result, you can add new states or change existing ones independently of each other, reducing the maintenance cost.

- Use the pattern when you have a class polluted with massive conditionals that alter how the class behaves according to the current values of the class's fields.

▷ The State pattern lets you extract branches of these conditionals into methods of corresponding state classes. While doing so, you can also clean temporary fields and helper methods involved in state-specific code out of your main class.

- Use State when you have a lot of duplicate code across similar states and transitions of a condition-based state machine.

▷ The State pattern lets you compose hierarchies of state classes and reduce duplication by extracting common code into abstract base classes.

4.5.7 How to Implement

1. Decide what class will act as the context. It could be an existing class which already has the state-dependent code; or a new class, if the state-specific code is distributed across multiple classes.

2. Declare the state interface. Although it may mirror all the methods declared in the context, aim only for those that may contain state-specific behavior.

3. For every actual state, create a class that derives from the state interface. Then go over the methods of the context and extract all code related to that state into your newly created class.

   While moving the code to the state class, you might discover that it depends on private members of the context. There are several workarounds:

   - Make these fields or methods public.
   - Turn the behavior you're extracting into a public method in the context and call it from the state class. This way is ugly but quick, and you can always fix it later.
   - Nest the state classes into the context class, but only if your programming language supports nesting classes.

4. In the context class, add a reference field of the state interface type and a public setter that allows overriding the value of that field.

5. Go over the method of the context again and replace empty state conditionals with calls to corresponding methods of the state object.

6. To switch the state of the context, create an instance of one of the state classes and pass it to the context. You can do this within the context itself, or in various states, or in the client. Wherever this is done, the class becomes dependent on the concrete state class that it instantiates.

4.5.8 Real-World Analogy

The buttons and switches in your smartphone behave differently depending on the current state of the device:

- When the phone is unlocked, pressing buttons leads to executing various functions.
- When the phone is locked, pressing any button leads to the unlock screen.
- When the phone's charge is low, pressing any button shows the charging screen.

4.5.9 Pros and Cons

+ Single Responsibility Principle. Organize the code related to particular states into separate classes.
+ Open/Closed Principle. Introduce new states without changing existing state classes or the context.
+ Simplify the code of the context by eliminating bulky state machine conditionals.
- Applying the pattern can be overkill if a state machine has only a few states or rarely changes.

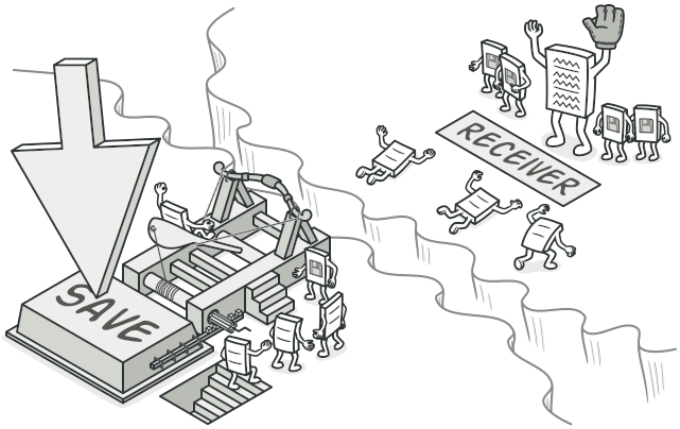
4.5.10 Relations with Other Patterns

- Bridge, State, Strategy (and to some degree Adapter) have very similar structures. Indeed, all of these patterns are based on composition, which is delegating work to other objects. However, they all solve different problems. A pattern isn't just a recipe for structuring your code in a specific way. It can also communicate to other developers the problem the pattern solves.
- State can be considered as an extension of Strategy. Both patterns are based on composition: they change the behavior of the context by delegating some work to helper objects. Strategy makes these objects completely independent and unaware of each other. However, State doesn't restrict dependencies between concrete states, letting them alter the state of the context at will.

4.6 Command Pattern

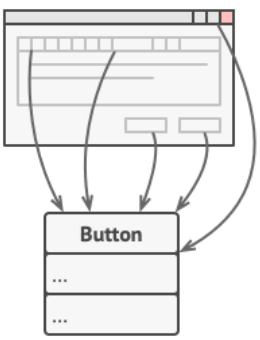
4.6.1 Intent

Command is a behavioral design pattern that turns a request into a stand-alone object that contains all information about the request. This transformation lets you pass requests as a method arguments, delay or queue a request's execution, and support undoable operations.



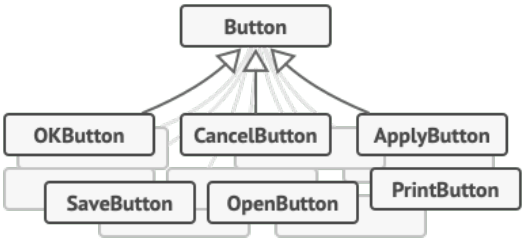
4.6.2 Problem

Imagine that you're working on a new text-editor app. Your current task is to create a toolbar with a bunch of buttons for various operations of the editor. You created a very neat Button class that can be used for buttons on the toolbar, as well as for generic buttons in various dialogs.



All buttons of the app are derived from the same class.

While all of these buttons look similar, they're all supposed to do different things. Where would you put the code for the various click handlers of these buttons? The simplest solution is to create tons of subclasses for each place where the button is used. These subclasses would contain the code that would have to be executed on a button click.



Lots of button subclasses. What can go wrong?

Before long, you realize that this approach is deeply flawed. First, you have an enormous number of subclasses, and that would be okay if you weren't risking breaking the code in these subclasses each time you modify the base Button class. Put simply, your GUI code has become awkwardly dependent on the volatile code of the business logic.

Several classes implement the same functionality.

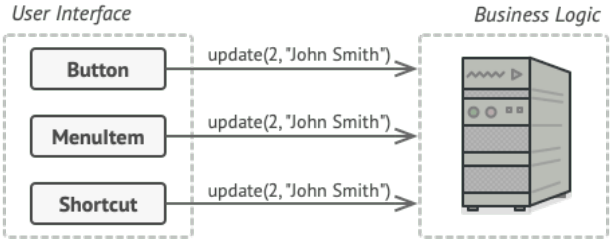
And here's the ugliest part. Some operations, such as copying/pasting text, would need to be invoked from multiple places. For example, a user could click a small "Copy" button on the toolbar, or copy something via the context menu, or just hit Ctrl+C on the keyboard.

Initially, when our app only had the toolbar, it was okay to place the implementation of various operations into the button subclasses. In other words, having the code for copying text inside the CopyButton subclass was fine. But then, when you implement context menus, shortcuts, and other stuff, you have to either duplicate the operation's code in many classes or make menus dependent on buttons, which is an even worse option.

4.6.3 Solution

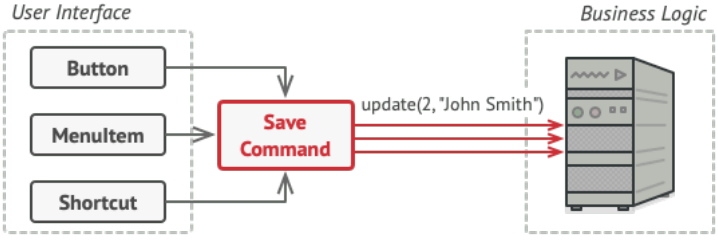
Good software design is often based on the **principle of separation of concerns**, which usually results in breaking an app into layers. The most common example: a layer for the graphical user interface and another layer for the business logic. The GUI layer is responsible for rendering a beautiful picture on the screen, capturing any input and showing results of what the user and the app are doing. However, when it comes to doing something important, like calculating the trajectory of the moon or composing an annual report, the GUI layer delegates the work to the underlying layer of business logic.

In the code it might look like this: a GUI object calls a method of a business logic object, passing it some arguments. This process is usually described as one object sending another a **request**.



The GUI objects may access the business logic objects directly.

The Command pattern suggests that GUI objects shouldn't send these requests directly. Instead, you should extract all of the request details, such as the object being called, the name of the method and the list of arguments into a separate command class with a single method that triggers this request.



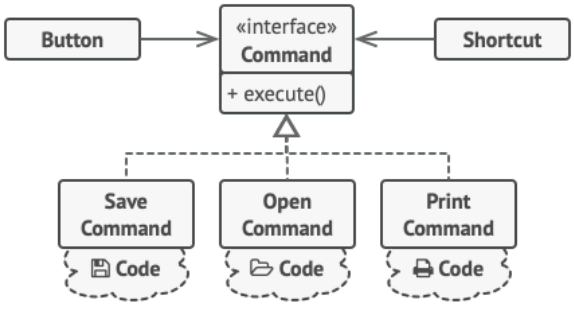
Accessing the business logic layer via a command.

Command objects serve as links between various GUI and business logic objects. From now on, the GUI object doesn't need to know what business logic object will

receive the request and how it'll be processed. The GUI object just triggers the command, which handles all the details.

The next step is to make your commands implement the same interface. Usually it has just a single execution method that takes no parameters. This interface lets you use various commands with the same request sender, without coupling it to concrete classes of commands. As a bonus, now you can switch command objects linked to the sender, effectively changing the sender's behavior at runtime.

You might have noticed one missing piece of the puzzle, which is the request parameters. A GUI object might have supplied the business-layer object with some parameters. Since the command execution method doesn't have any parameters, how would we pass the request details to the receiver? It turns out the command should be either pre-configured with this data, or capable of getting it on its own.



The GUI objects delegate the work to commands.

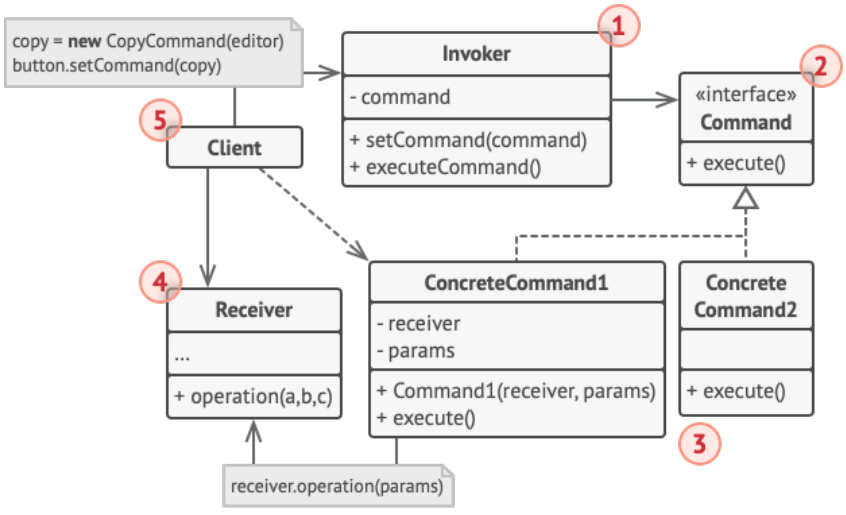
Let's get back to our text editor. After we apply the Command pattern, we no longer need all those button subclasses to implement various click behaviors. It's enough to put a single field into the base Button class that stores a reference to a command object and make the button execute that command on a click.

You'll implement a bunch of command classes for every possible operation and link them with particular buttons, depending on the buttons' intended behavior.

Other GUI elements, such as menus, shortcuts or entire dialogs, can be implemented in the same way. They'll be linked to a command which gets executed when a user interacts with the GUI element. As you've probably guessed by now, the elements related to the same operations will be linked to the same commands, preventing any code duplication.

As a result, commands become a convenient middle layer that reduces coupling between the GUI and business logic layers. And that's only a fraction of the benefits that the Command pattern can offer!

4.6.4 Structure



1. The Sender class (aka invoker) is responsible for initiating requests. This class must have a field for storing a reference to a command object. The sender triggers that command instead of sending the request directly to the receiver. Note that the sender isn't responsible for creating the command object. Usually, it gets a pre-created command from the client via the constructor.

2. The Command interface usually declares just a single method for executing the command.

3. Concrete Commands implement various kinds of requests. A concrete command isn't supposed to perform the work on its own, but rather to pass the call to one of the business logic objects. However, for the sake of simplifying the code, these classes can be merged.

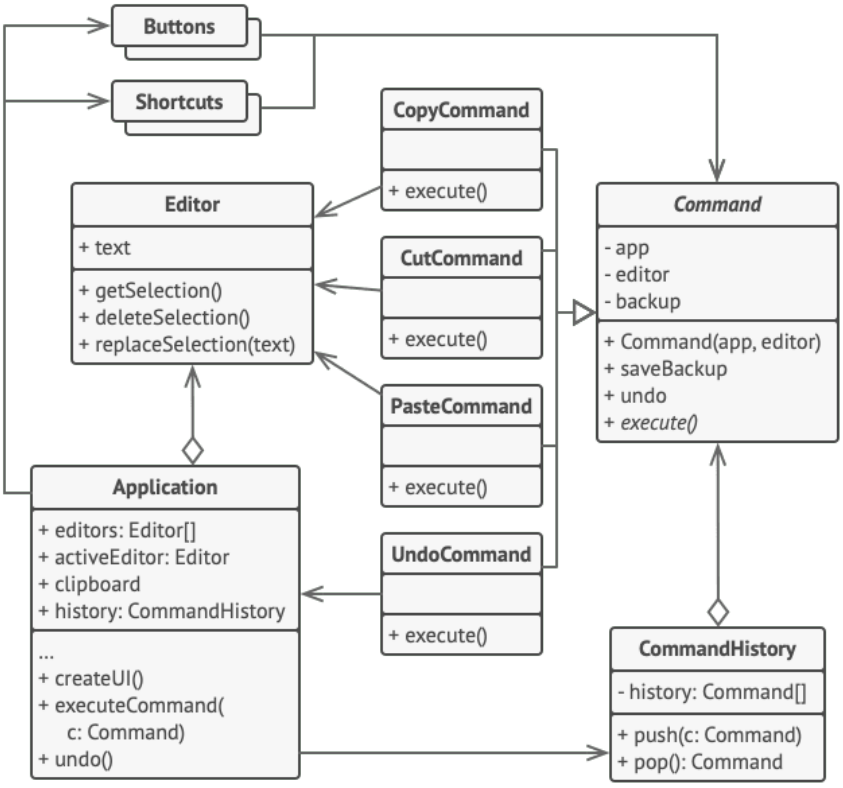
   Parameters required to execute a method on a receiving object can be declared as fields in the concrete command. You can make command objects immutable by only allowing the initialization of these fields via the constructor.

4. The Receiver class contains some business logic. Almost any object may act as a receiver. Most commands only handle the details of how a request is passed to the receiver, while the receiver itself does the actual work.

5. The Client creates and configures concrete command objects. The client must pass all of the request parameters, including a receiver instance, into the command's constructor. After that, the resulting command may be associated with one or multiple senders.

4.6.5 Pseudocode

In this example, the Command pattern helps to track the history of executed operations and makes it possible to revert an operation if needed.



Undoable operations in a text editor.

Commands which result in changing the state of the editor (e.g., cutting and pasting) make a backup copy of the editor's state before executing an operation associated with the command. After a command is executed, it's placed into the command history (a stack of command objects) along with the backup copy of the editor's state at that point. Later, if the user needs to revert an operation, the app can take the most recent command from the history, read the associated backup of the editor's state, and restore it.

The client code (GUI elements, command history, etc.) isn't coupled to concrete command classes because it works with commands via the command interface. This approach lets you introduce new commands into the app without breaking any existing code.

PSEUDO CODE

```
// The base command class defines the common interface for all
//   concrete commands.
abstract class Command is
  protected field app: Application
  protected field editor: Editor
  protected field backup: text

  constructor Command(app: Application, editor: Editor) is
    this.app = app
    this.editor = editor

  // Make a backup of the editor's state.
  method saveBackup() is
    backup = editor.text

  // Restore the editor's state.
  method undo() is
    editor.text = backup

  // The execution method is declared abstract to force all concrete commands to
  //   provide their own implementations. The method must return true or false
  //   depending on whether the command changes the editor's state.
  abstract method execute()


// The concrete commands go here.
class CopyCommand extends Command is
// The copy command isn't saved to the history since it doesn't change
//   the editor's state.
  method execute() is
    app.clipboard = editor.getSelection()
    return false


class CutCommand extends Command is
// The cut command does change the editor's state, therefore it must be saved
//   to the history. And it'll be saved as long as the method returns true.
  method execute() is
    saveBackup()
    app.clipboard = editor.getSelection()
    editor.deleteSelection()
    return true


class PasteCommand extends Command is
  method execute() is
    saveBackup()
    editor.replaceSelection(app.clipboard)
    return true

```


```
// The undo operation is also a command.
class UndoCommand extends Command is
  method execute() is
    app.undo()
    return false


// The global command history is just a stack.
class CommandHistory is
  private field history: array of Command

  // Last in ...
  method push(c: Command) is
    // Push the command to the end of the history array.

  // ... first out
  method pop():Command is
    // Get the most recent command from the history.


// The editor class has actual text editing operations. It plays the role of
//  a receiver: all commands end up delegating execution to the editor's methods.
class Editor is
  field text: string

  method getSelection() is
    // Return selected text.

  method deleteSelection() is
    // Delete selected text.

  method replaceSelection(text) is
    // Insert the clipboard's contents at the current position.


// The application class sets up object relations. It acts as a sender: when
//  something needs to be done, it creates a command object and executes it.
class Application is
  field clipboard: string
  field editors: array of Editors
  field activeEditor: Editor
  field history: CommandHistory

  // The code which assigns commands to UI objects may look like this.
  method createUI() is
    // ...
    copy = function() { executeCommand(
      new CopyCommand(this, activeEditor)) }
    copyButton.setCommand(copy)
    shortcuts.onKeyPress("Ctrl+C", copy)
```

PSEUDO CODE

```
    cut = function() { executeCommand(
      new CutCommand(this, activeEditor)) }

    cutButton.setCommand(cut)
    shortcuts.onKeyPress("Ctrl+X", cut)

    paste = function() { executeCommand(
      new PasteCommand(this, activeEditor)) }
    pasteButton.setCommand(paste)
    shortcuts.onKeyPress("Ctrl+V", paste)

    undo = function() { executeCommand(
      new UndoCommand(this, activeEditor)) }
    undoButton.setCommand(undo)
    shortcuts.onKeyPress("Ctrl+Z", undo)

// Execute a command and check whether it has to be added to the history.
method executeCommand(command) is
    if (command.execute)
        history.push(command)

// Take the most recent command from the history and run its undo method.
//   Note that we don't know the class of that command. But we don't have to,
//   since the command knows how to undo its own action.
method undo() is
    command = history.pop()
    if (command != null)
        command.undo()
```

4.6.6 Applicability

- Use the Command pattern when you want to parametrize objects with operations.

▷ The Command pattern can turn a specific method call into a stand-alone object. This change opens up a lot of interesting uses: you can pass commands as method arguments, store them inside other objects, switch linked commands at runtime, etc.

Here's an example: you're developing a GUI component such as a context menu, and you want your users to be able to configure menu items that trigger operations when an end user clicks an item.

- Use the Command pattern when you want to queue operations, schedule their execution, or execute them remotely.

▷ As with any other object, a command can be serialized, which means converting it to a string that can be easily written to a file or a database. Later, the string can be restored as the initial command object. Thus, you can delay and schedule command execution. But there's even more! In the same way, you can queue, log or send commands over the network.

- Use the Command pattern when you want to implement reversible operations.

▷ Although there are many ways to implement undo/redo, the Command pattern is perhaps the most popular of all.

To be able to revert operations, you need to implement the history of performed operations. The command history is a stack that contains all executed command objects along with related backups of the application's state.

This method has two drawbacks. First, it isn't that easy to save an application's state because some of it can be private. This problem can be mitigated with the Memento pattern.

Second, the state backups may consume quite a lot of RAM. Therefore, sometimes you can resort to an alternative implementation: instead of restoring the past state, the command performs the inverse operation. The reverse operation also has a price: it may turn out to be hard or even impossible to implement.

4.6.7 How to Implement

1. Declare the command interface with a single execution method.
2. Start extracting requests into concrete command classes that implement the command interface. Each class must have a set of fields for storing the request arguments along with a reference to the actual receiver object. All these values must be initialized via the command's constructor.
3. Identify classes that will act as senders. Add the fields for storing commands into these classes. Senders should communicate with their commands only via the command interface. Senders usually don't create command objects on their own, but rather get them from the client code.
4. Change the senders so they execute the command instead of sending a request to the receiver directly.
5. The client should initialize objects in the following order:
    - Create receivers.
    - Create commands, and associate them with receivers if needed.
    - Create senders, and associate them with specific commands.

4.6.8 Pros and Cons

+ Single Responsibility Principle. You can decouple classes that invoke operations from classes that perform these operations.

+ Open/Closed Principle. You can introduce new commands into the app without breaking existing client code.

+ You can implement undo/redo.

+ You can implement deferred execution of operations.

+ You can assemble a set of simple commands into a complex one.

- The code may become more complicated since you're introducing a whole new layer between senders and receivers.

4.6.9 Relations with Other Patterns

- Chain of Responsibility, Command, Mediator and Observer address various ways of connecting senders and receivers of requests:
  - Chain of Responsibility passes a request sequentially along a dynamic chain of potential receivers until one of them handles it.
  - Command establishes unidirectional connections between senders and receivers.
  - Mediator eliminates direct connections between senders and receivers, forcing them to communicate indirectly via a mediator object.
  - Observer lets receivers dynamically subscribe to and unsubscribe from receiving requests.

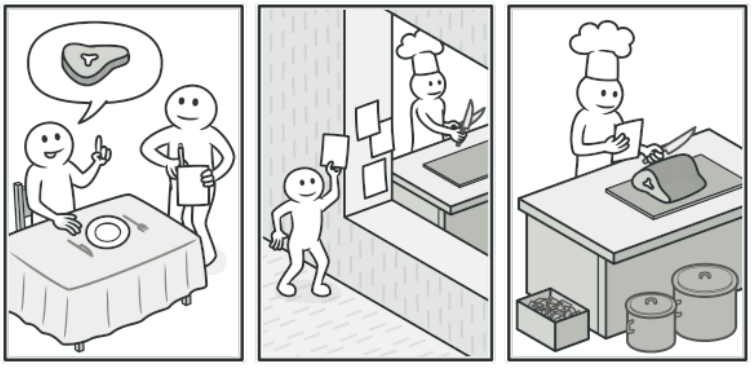
- Handlers in Chain of Responsibility can be implemented as Commands. In this case, you can execute a lot of different operations over the same context object, represented by a request.

  However, there's another approach, where the request itself is a Command object. In this case, you can execute the same operation in a series of different contexts linked into a chain.

- You can use Command and Memento together when implementing "undo". In this case, commands are responsible for performing various operations over a target object, while mementos save the state of that object just before a command gets executed.

- Command and Strategy may look similar because you can use both to parameterize an object with some action. However, they have very different intents.
  - You can use Command to convert any operation into an object. The operation's parameters become fields of that object. The conversion lets you defer execution of the operation, queue it, store the history of commands, send commands to remote services, etc.
  - On the other hand, Strategy usually describes different ways of doing the same thing, letting you swap these algorithms within a single context class.
- Prototype can help when you need to save copies of Commands into history.
- You can treat Visitor as a powerful version of the Command pattern. Its objects can execute operations over various objects of different classes.

4.6.10 Real-World Analogy



Making an order in a restaurant.

After a long walk through the city, you get to a nice restaurant and sit at the table by the window. A friendly waiter approaches you and quickly takes your order, writing it down on a piece of paper. The waiter goes to the kitchen and sticks the order on the wall. After a while, the order gets to the chef, who reads it and cooks the meal accordingly. The cook places the meal on a tray along with the order. The waiter discovers the tray, checks the order to make sure everything is as you wanted it, and brings everything to your table.

The paper order serves as a command. It remains in a queue until the chef is ready to serve it. The order contains all the relevant information required to cook the meal. It allows the chef to start cooking right away instead of running around clarifying the order details from you directly.

4.6.11 Examples

1. Structure Example

```java
package com.patterns.command;

public abstract class Command {
    protected Receiver receiver;

    public Command(Receiver receiver) {
        this.receiver = receiver;
    }

    public abstract void execute();
}
```

```java
package com.patterns.command.structure;

public class ConcreteCommand extends Command {
    public ConcreteCommand(Receiver receiver) {
        super(receiver);
    }

    @Override
    public void execute() {
        receiver.action();
    }
}
```

```java
package com.patterns.command.structure;

public class Receiver {
    public void action() {
        System.out.println("Called Receiver.action()");
    }
}
```

```java
package com.patterns.command.structure;

public class Invoker {
    private Command command;

    public void setCommand(Command command) {
        this.command = command;
    }

    public void executeCommand() {
        command.execute();
    }
}
```

```java
package com.patterns.command.structure;

public class App {
    public static void main(string[] args) {
        Receiver receiver = new Receiver();

        Command command = new ConcreteCommand(receiver);

        Invoker invoker = new Invoker();
        invoker.setCommand(command);
        invoker.executeCommand();
    }
}
```

2. Real-World Example

```java
package com.patterns.command.realworld;

public class Fan {
    public void startRotate() {
        System.out.println("Fan is rotating");
    }

    public void stopRotate() {
        System.out.println("Fan is not rotating");
    }
```

```
}
```

```
package com.patterns.command.realworld;

public class Light {
    public void turnOn() {
        System.out.println("Light is on");
    }

    public void turnOff() {
        System.out.println("Light is off");
    }
}
```

```
package com.patterns.command.realworld;

public class LightOnCommand implements Command {
    private Light light;

    public LightOnCommand(Light light) {
        this.light = light;
    }

    @Override
    public void execute() {
        this.light.turnOn();
    }
}
```

```
package com.patterns.command.realworld;

public interface Command {
    void execute();
}
```

```java
package com.patterns.command.realworld;

public class LightOffCommand implements Command {
    private Light light;

    public LightOffCommand(Light light) {
        this.light = light;
    }

    public void execute() {
        this.light.turnOff();
    }
}
```

```java
package com.patterns.command.realworld;

class FanOnCommand implements Command {
    private Fan fan;

    public FanOnCommand(Fan fan) {
        this.fan = fan;
    }

    public void execute() {
        this.fan.startRotate();
    }
}
```

```java
package com.patterns.command.realworld;

public class FanOffCommand implements Command {
    private Fan fan;

    public FanOffCommand(Fan fan) {
        this.fan = fan;
    }

    public void execute() {
        this.fan.stopRotate();
    }
}
```

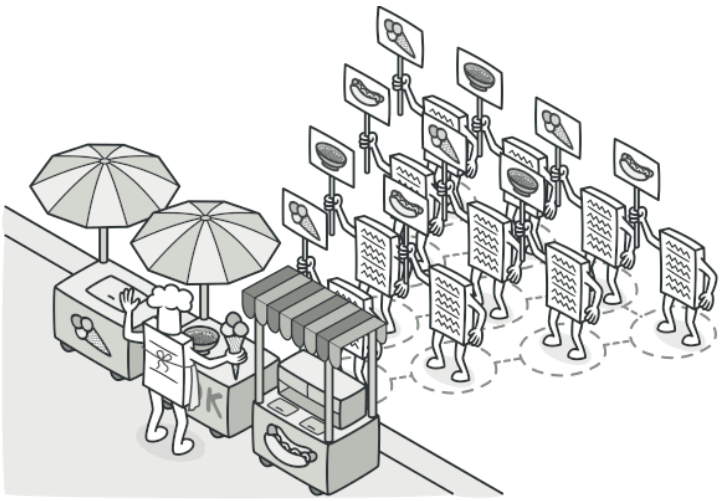
```java
package com.patterns.command.realworld;

public class Switch {
    private Command upCommand,
    private Command downCommand;

    public Switch(Command upCommand, Command downCommand) {
        this.upCommand = up;
        this.downCommand = down;
    }

    void flipUp() {
        this.upCommand.execute();
    }

    void flipDown() {
        this.downCommand.execute();
    }
}
```

```java
package com.patterns.command.realworld;

public class App {
    public void main(String[] args) {
        Light light = new Light();
        LightOnCommand lightOn = new LightOnCommand(light);
        LightOffCommand lightOff = new LightOffCommand(light);
        Switch lightSwitch = new Switch(lightOn, lightOff);
        lightSwitch.flipUp();
        lightSwitch.flipDown();

        Fan fan = new Fan();
        FanOnCommand fanOn = new FanOnCommand(fan);
        FanOffCommand fanOff = new FanOffCommand(fan);
        Switch fanSwitch = new Switch(fanOn, fanOff);
        fanSwitch.flipUp();
        fanSwitch.flipDown();
    }
}
```

4.7 Visitor Pattern

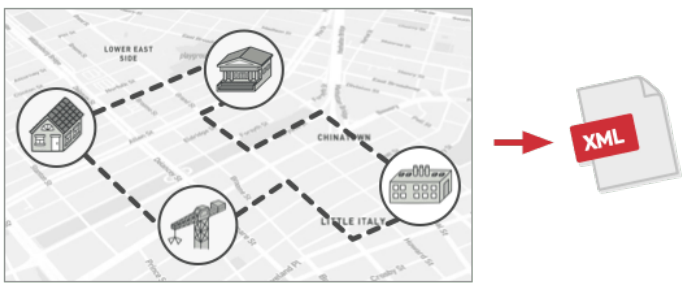
4.7.1 Intent

Visitor is a behavioral design pattern that lets you separate algorithms from the objects on which they operate.



4.7.2 Problem

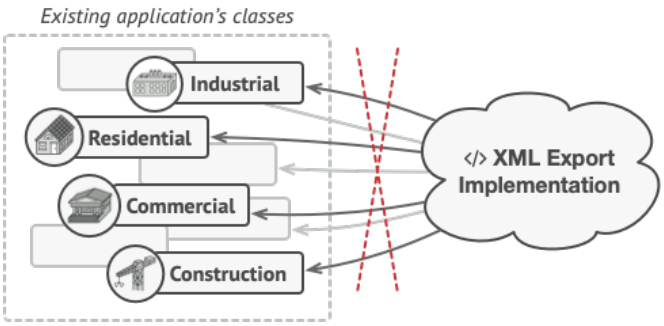
Imagine that your team develops an app which works with geographic information structured as one colossal graph. Each node of the graph may represent a complex entity such as a city, but also more granular things like industries, sightseeing areas, etc. The nodes are connected with others if there's a road between the real objects that they represent. Under the hood, each node type is represented by its own class, while each specific node is an object.



Exporting the graph into XML.

At some point, you got a task to implement exporting the graph into XML format. At first, the job seemed pretty straightforward. You planned to add an export method to each node class and then leverage recursion to go over each node of the graph, executing the export method. The solution was simple and elegant: thanks to polymorphism, you weren't coupling the code which called the export method to concrete classes of nodes.

Unfortunately, the system architect refused to allow you to alter existing node classes. He said that the code was already in production and he didn't want to risk breaking it because of a potential bug in your changes.



The XML export method had to be added into all node classes, which bore the risk of breaking the whole application if any bugs slipped through along with the change.

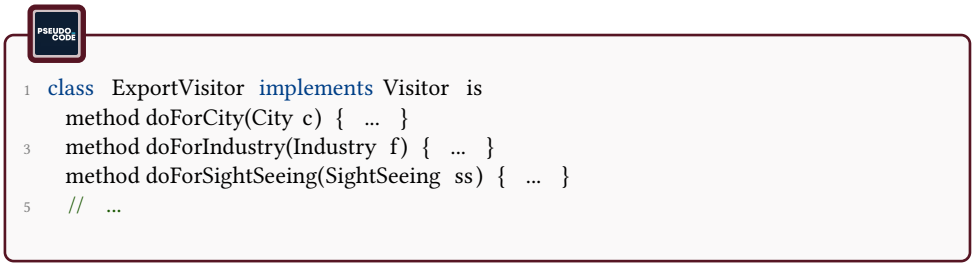
Besides, he questioned whether it makes sense to have the XML export code within the node classes. The primary job of these classes was to work with geodata. The XML export behavior would look alien there.

There was another reason for the refusal. It was highly likely that after this feature was implemented, someone from the marketing department would ask you to provide the ability to export into a different format, or request some other weird stuff. This would force you to change those precious and fragile classes again.

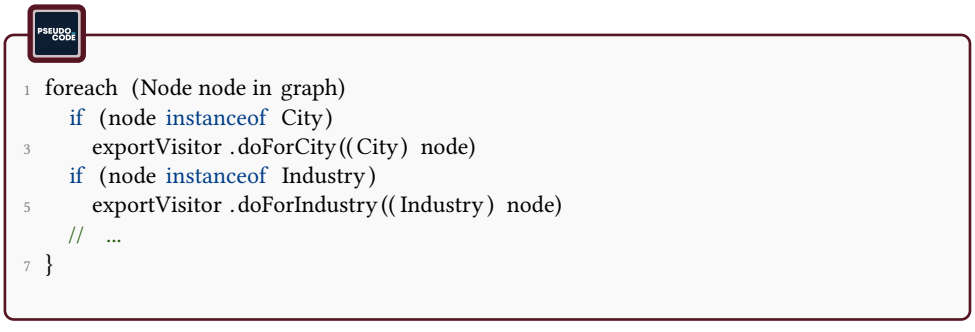
4.7.3 Solution

The Visitor pattern suggests that you place the new behavior into a separate class called visitor, instead of trying to integrate it into existing classes. The original object that had to perform the behavior is now passed to one of the visitor's methods as an argument, providing the method access to all necessary data contained within the object.

Now, what if that behavior can be executed over objects of different classes? For example, in our case with XML export, the actual implementation will probably be a little bit different across various node classes. Thus, the visitor class may define not one, but a set of methods, each of which could take arguments of different types, like this:



But how exactly would we call these methods, especially when dealing with the whole graph? These methods have different signatures, so we can't use polymorphism. To pick a proper visitor method that's able to process a given object, we'd need to check its class. Doesn't this sound like a nightmare?



You might ask, why don't we use method overloading? That's when you give all methods the same name, even if they support different sets of parameters. Unfortunately, even assuming that our programming language supports it at all (as Java and C# do), it won't help us. Since the exact class of a node object is unknown in advance, the overloading mechanism won't be able to determine the correct method to execute. It'll default to the method that takes an object of the base Node class.

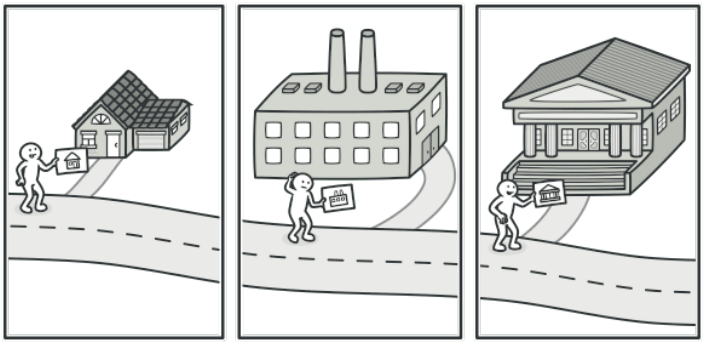
However, the Visitor pattern addresses this problem. It uses a technique called Double Dispatch, which helps to execute the proper method on an object without cumbersome conditionals. Instead of letting the client select a proper version of the method to call, how about we delegate this choice to objects we're passing to the visitor as an argument? Since the objects know their own classes, they'll be able to pick a proper method on the visitor less awkwardly. They "accept" a visitor and tell it what visiting method should be executed.

PSEUDO CODE

```
// Client code
foreach (Node node in graph)
  node.accept( exportVisitor )

// City
class City is
  method accept( Visitor v) is
    v.doForCity( this )
    // ...

// Industry
class Industry is
  method accept( Visitor v) is
    v.doForIndustry( this )
    // ...
```

I confess. We had to change the node classes after all. But at least the change is trivial and it lets us add further behaviors without altering the code once again. Now, if we extract a common interface for all visitors, all existing nodes can work with any visitor you introduce into the app. If you find yourself introducing a new behavior related to nodes, all you have to do is implement a new visitor class.

4.7.4 Real-World Analogy

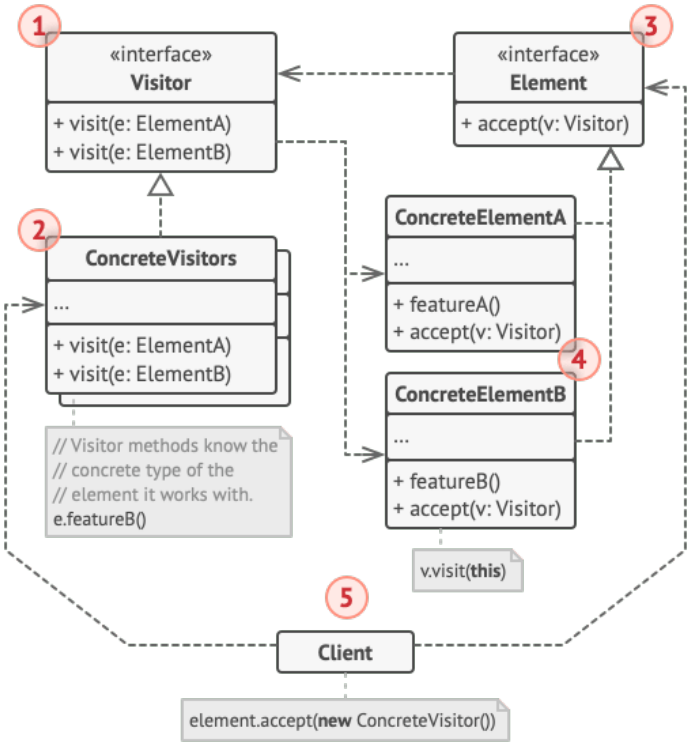


A good insurance agent is always ready to offer different policies to various types of organizations.

Imagine a seasoned insurance agent who's eager to get new customers. He can visit every building in a neighborhood, trying to sell insurance to everyone he meets. Depending on the type of organization that occupies the building, he can offer specialized insurance policies:

- If it's a residential building, he sells medical insurance.
- If it's a bank, he sells theft insurance.
- If it's a coffee shop, he sells fire and flood insurance.

4.7.5 Structure



1. The Visitor interface declares a set of visiting methods that can take concrete elements of an object structure as arguments. These methods may have the same names if the program is written in a language that supports overloading, but the type of their parameters must be different.

2. Each Concrete Visitor implements several versions of the same behaviors, tailored for different concrete element classes.

3. The Element interface declares a method for "accepting" visitors. This method should have one parameter declared with the type of the visitor interface.

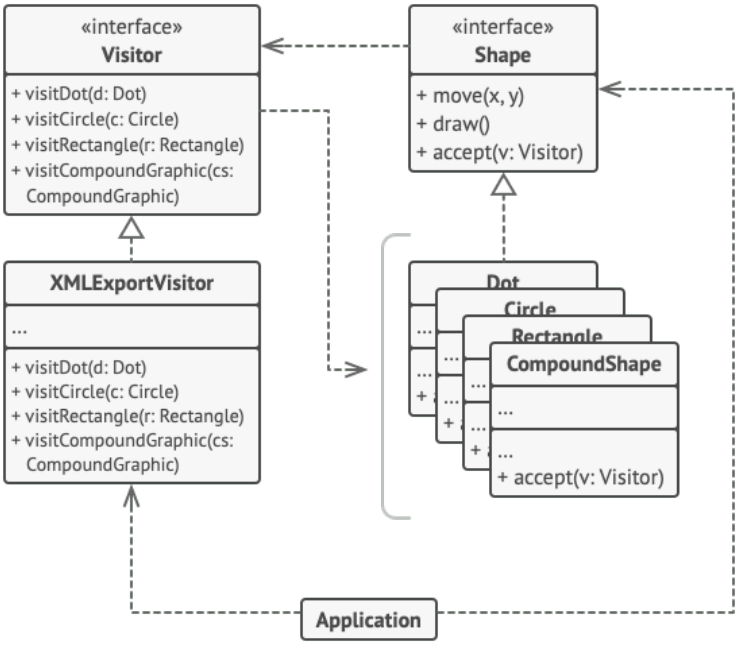
4. Each Concrete Element must implement the acceptance method. The purpose of this method is to redirect the call to the proper visitor's method corresponding to the current element class. Be aware that even if a base element class implements

this method, all subclasses must still override this method in their own classes and call the appropriate method on the visitor object.

5. The Client usually represents a collection or some other complex object (for example, a Composite tree). Usually, clients aren't aware of all the concrete element classes because they work with objects from that collection via some abstract interface.

4.7.6 Pseudocode

In this example, the Visitor pattern adds XML export support to the class hierarchy of geometric shapes.



Exporting various types of objects into XML format via a visitor object.

PSEUDO CODE

```
// The element interface declares an 'accept' method that takes
//   the base visitor interface as an argument.
interface Shape is
  method move(x, y)
  method draw()
  method accept(v: Visitor )

```


```
// Each concrete element class must implement the `accept` method in such a way
//   that it calls the visitor's method that corresponds to the element's class.
class Dot implements Shape is
  // ...

  // Note that we're calling `visitDot`, which matches the current class name.
  // This way we let the visitor know the class of the element it works with.
  method accept(v: Visitor) is
    v.visitDot(this)


class Circle implements Shape is
  // ...
  method accept(v: Visitor) is
    v.visitCircle(this)


class Rectangle implements Shape is
  // ...
  method accept(v: Visitor) is
    v.visitRectangle(this)


class CompoundShape implements Shape is
  // ...
  method accept(v: Visitor) is
    v.visitCompoundShape(this)


// The Visitor interface declares a set of visiting methods that correspond to
//   element classes. The signature of a visiting method lets the visitor identify
//   the exact class of the element that it's dealing with.
interface Visitor is
  method visitDot(d: Dot)
  method visitCircle(c: Circle)
  method visitRectangle(r: Rectangle)
  method visitCompoundShape(cs: CompoundShape)


// Concrete visitors implement several versions of the same algorithm,
//   which can work with all concrete element classes.
//
// You can experience the biggest benefit of the Visitor pattern when using it
//   with a complex object structure such as a Composite tree. In this case,
//   it might be helpful to store some intermediate state of the algorithm
//   while executing the visitor's methods over various objects of the structure.
class XMLExportVisitor implements Visitor is
  method visitDot(d: Dot) is
    // Export the dot's ID and center coordinates.
```

```
    method visitCircle(c: Circle) is
        // Export the circle's ID, center coordinates and radius.

    method visitRectangle(r: Rectangle) is
        // Export the rectangle's ID, left-top coordinates, width and height.

    method visitCompoundShape(cs: CompoundShape) is
        // Export the shape's ID as well as the list of its children's IDs.


// The client code can run visitor operations over any set of elements without
//  figuring out their concrete classes. The accept operation directs a call
//  to the appropriate operation in the visitor object.
class Application is
    field allShapes: array of Shapes

    method export() is
        exportVisitor = new XMLExportVisitor()

        foreach (shape in allShapes) do
            shape.accept(exportVisitor)
```

If you wonder why we need the accept method in this example, my article Visitor and Double Dispatch addresses this question in detail.

4.7.7 Applicability

- Use the Visitor when you need to perform an operation on all elements of a complex object structure (for example, an object tree).

▷ The Visitor pattern lets you execute an operation over a set of objects with different classes by having a visitor object implement several variants of the same operation, which correspond to all target classes.

- Use the Visitor to clean up the business logic of auxiliary behaviors.

▷ The pattern lets you make the primary classes of your app more focused on their main jobs by extracting all other behaviors into a set of visitor classes.

- Use the pattern when a behavior makes sense only in some classes of a class hierarchy, but not in others.

▷ You can extract this behavior into a separate visitor class and implement only those visiting methods that accept objects of relevant classes, leaving the rest empty.

4.7.8 How to Implement

1. Declare the visitor interface with a set of "visiting" methods, one per each concrete element class that exists in the program.

2. Declare the element interface. If you're working with an existing element class hierarchy, add the abstract "acceptance" method to the base class of the hierarchy. This method should accept a visitor object as an argument.

3. Implement the acceptance methods in all concrete element classes. These methods must simply redirect the call to a visiting method on the incoming visitor object which matches the class of the current element.

4. The element classes should only work with visitors via the visitor interface. Visitors, however, must be aware of all concrete element classes, referenced as parameter types of the visiting methods.

5. For each behavior that can't be implemented inside the element hierarchy, create a new concrete visitor class and implement all of the visiting methods.

   You might encounter a situation where the visitor will need access to some private members of the element class. In this case, you can either make these fields or methods public, violating the element's encapsulation, or nest the visitor class in the element class. The latter is only possible if you're lucky to work with a programming language that supports nested classes.

6. The client must create visitor objects and pass them into elements via "acceptance" methods.

4.7.9 Pros and Cons

+ Open/Closed Principle. You can introduce a new behavior that can work with objects of different classes without changing these classes.

+ Single Responsibility Principle. You can move multiple versions of the same behavior into the same class.

+ A visitor object can accumulate some useful information while working with various objects. This might be handy when you want to traverse some complex object structure, such as an object tree, and apply the visitor to each object of this structure.

- You need to update all visitors each time a class gets added to or removed from the element hierarchy.

- Visitors might lack the necessary access to the private fields and methods of the elements that they're supposed to work with.

4.7.10 Relations with Other Patterns

- You can treat Visitor as a powerful version of the Command pattern. Its objects can execute operations over various objects of different classes.
- You can use Visitor to execute an operation over an entire Composite tree.
- You can use Visitor along with Iterator to traverse a complex data structure and execute some operation over its elements, even if they all have different classes.

4.7.11 Examples

1. Without Visitor Pattern

```
public interface MailClient {
  void sendMail(String[] mailInfo);
  void receiveMail(String[] mailInfo);
  boolean configureForMac();
  boolean configureForWindows();
}
```

```
public class OperaMailClient implements MailClient {
  @Override
  public void sendMail(String[] mailInfo) {
    System.out.println("OperaMailClient: Sending mail");
  }

  @Override
  public void receiveMail(String[] mailInfo) {
    System.out.println("OperaMailClient: Receiving mail");
  }

  @Override
  public boolean configureForMac() {
    System.out.println("Configuration of Opera mail client for Mac complete");
    return true;
  }

  @Override
  public boolean configureForWindows() {
    System.out.println("Configuration of Opera mail client for Windows complete");
    return true;
  }
```

```
public class SquirrelMailClient implements MailClient {
  @Override
  public void sendMail(String[] mailInfo) {
    System.out.println(" SquirrelMailClient : Sending mail");
  }

  @Override
  public void receiveMail(String[] mailInfo) {
    System.out.println(" SquirrelMailClient : Receiving mail");
  }

  @Override
  public boolean configureForMac() {
    System.out.println("Configuration of Squirrel mail client for Mac complete");
    return true;
  }

  @Override
  public boolean configureForWindows() {
    System.out.println("Configuration of Squirrel mail client for Windows complete");
    return true;
  }
}
```

```
public class MailClientTest {
  public static void main(String[] args) throws Exception {
    testConfigureMailClientForDifferentEnvironments();
  }

  public void testConfigureMailClientForDifferentEnvironments() {
    MailClient operaMailClient = new OperaMailClient();
    operaMailClient.configureForMac();
    operaMailClient.configureForWindows();

    MailClient squirrelMailClient = new SquirrelMailClient();
    squirrelMailClient.configureForMac();
    squirrelMailClient.configureForWindows();
  }
}
```

2. Using Visitor Patterns

```java
package com.patterns.visitor.structure;

import com.patterns.visitor.visitors.MailClientVisitor;

public interface MailClient {
    void sendMail(String[] mailInfo);
    void receiveMail(String[] mailInfo);
    boolean accept(MailClientVisitor visitor);
}
```

```java
package com.patterns.visitor.structure;

import com.patterns.visitor.visitors.MailClientVisitor;

public class OperaMailClient implements MailClient {
    @Override
    public void sendMail(String[] mailInfo) {
        System.out.println("OperaMailClient: Sending mail");
    }

    @Override
    public void receiveMail(String[] mailInfo) {
        System.out.println("OperaMailClient: Receiving mail");
    }

    @Override
    public boolean accept(MailClientVisitor visitor) {
        visitor.visit(this);
        return true;
    }
}
```

```java
package com.patterns.visitor.structure;

import com.patterns.visitor.visitors.MailClientVisitor;

public class SquirrelMailClient implements MailClient {
    @Override
    public void sendMail(String[] mailInfo) {
```

```
        System.out.println(" SquirrelMailClient : Sending mail");
    }

    @Override
    public void receiveMail(String[] mailInfo) {
        System.out.println(" SquirrelMailClient : Receiving mail");
    }

    @Override
    public boolean accept(MailClientVisitor visitor) {
        visitor.visit(this);
        return true;
    }
}
```

```
package com.patterns.visitor.structure;

import com.patterns.visitor.visitors.MailClientVisitor;

public class ZimbraMailClient implements MailClient {
    @Override
    public void sendMail(String[] mailInfo) {
        System.out.println("ZimbraMailClient: Sending mail");
    }

    @Override
    public void receiveMail(String[] mailInfo) {
        System.out.println("ZimbraMailClient: Receiving mail");
    }

    @Override
    public boolean accept(MailClientVisitor visitor) {
        visitor.visit(this);
        return true;
    }
}
```

```
package com.patterns.visitor.visitors;

import com.patterns.visitor.structure.OperaMailClient;
import com.patterns.visitor.structure.SquirrelMailClient;
```

```
import com.patterns.visitor.structure.ZimbraMailClient;

public interface MailClientVisitor {
    void visit(OperaMailClient mailClient);
    void visit(SquirrelMailClient mailClient);
    void visit(ZimbraMailClient mailClient);
}
```

```
package com.patterns.visitor.visitors;

import com.patterns.visitor.structure.OperaMailClient;
import com.patterns.visitor.structure.SquirrelMailClient;
import com.patterns.visitor.structure.ZimbraMailClient;

public class WindowsMailClientVisitor implements MailClientVisitor {
    @Override
    public void visit(OperaMailClient mailClient) {
        System.out.println("Configuration of Opera mail client for Windows complete");
    }

    @Override
    public void visit(SquirrelMailClient mailClient) {
        System.out.println("Configuration of Squirrel mail client for Windows complete");
    }

    @Override
    public void visit(ZimbraMailClient mailClient) {
        System.out.println("Configuration of Zimbra mail client for Windows complete");
    }
}
```

```
package com.patterns.visitor.visitors;

import com.patterns.visitor.structure.OperaMailClient;
import com.patterns.visitor.structure.SquirrelMailClient;
import com.patterns.visitor.structure.ZimbraMailClient;

public class MacMailClientVisitor implements MailClientVisitor {
    @Override
    public void visit(OperaMailClient mailClient) {
        System.out.println("Configuration of Opera mail client for Mac complete");
```

```
    }

    @Override
    public void visit(SquirrelMailClient mailClient) {
        System.out.println("Configuration of Squirrel mail client for Mac complete");
    }

    @Override
    public void visit(ZimbraMailClient mailClient) {
        System.out.println("Configuration of Zimbra mail client for Mac complete");
    }
}
```

```
package com.patterns.visitor.visitors;

import com.patterns.visitor.structure.OperaMailClient;
import com.patterns.visitor.structure.SquirrelMailClient;
import com.patterns.visitor.structure.ZimbraMailClient;

public class LinuxMailClientVisitor implements MailClientVisitor {
    @Override
    public void visit(OperaMailClient mailClient) {
        System.out.println("Configuration of Opera mail client for Linux complete");
    }

    @Override
    public void visit(SquirrelMailClient mailClient) {
        System.out.println("Configuration of Squirrel mail client for Linux complete");
    }

    @Override
    public void visit(ZimbraMailClient mailClient) {
        System.out.println("Configuration of Zimbra mail client for Linux complete");
    }
}
```

```
package com.patterns.visitor.visitors;

import com.patterns.visitor.structure.OperaMailClient;
import com.patterns.visitor.structure.SquirrelMailClient;
import com.patterns.visitor.structure.ZimbraMailClient;
```

```
6
public class MailClientVisitorTest {
8   private MacMailClientVisitor macVisitor;
    private LinuxMailClientVisitor linuxVisitor;
10  private WindowsMailClientVisitor windowsVisitor;
    private OperaMailClient operaMailClient;
12  private SquirrelMailClient squirrelMailClient;
    private ZimbraMailClient zimbraMailClient;
14
    public void setup() {
16    macVisitor = new MacMailClientVisitor();
      linuxVisitor = new LinuxMailClientVisitor();
18    windowsVisitor = new WindowsMailClientVisitor();
      operaMailClient = new OperaMailClient();
20    squirrelMailClient = new SquirrelMailClient();
      zimbraMailClient = new ZimbraMailClient();
22  }

24  public void testOperaMailClient() throws Exception {
      System.out.println("--Testing Opera Mail Client for different environments--");
26    operaMailClient.accept(macVisitor);
      operaMailClient.accept(linuxVisitor);
28    operaMailClient.accept(windowsVisitor);
    }
30
    public void testSquirrelMailClient() throws Exception {
32    System.out.println("\n-Testing Squirrel Mail Client for different environments-");
      squirrelMailClient.accept(macVisitor);
34    squirrelMailClient.accept(linuxVisitor);
      squirrelMailClient.accept(windowsVisitor);
36  }

38  public void testZimbraMailClient() throws Exception {
      System.out.println("\n--Testing Zimbra Mail Client for different environments--");
40    zimbraMailClient.accept(macVisitor);
      zimbraMailClient.accept(linuxVisitor);
42    zimbraMailClient.accept(windowsVisitor);
    }
44
    public static void main(String[] args) {
46    setup();

48    testOperaMailClient();
      testSquirrelMailClient();
50    testZimbraMailClient()
    }
52 }
```

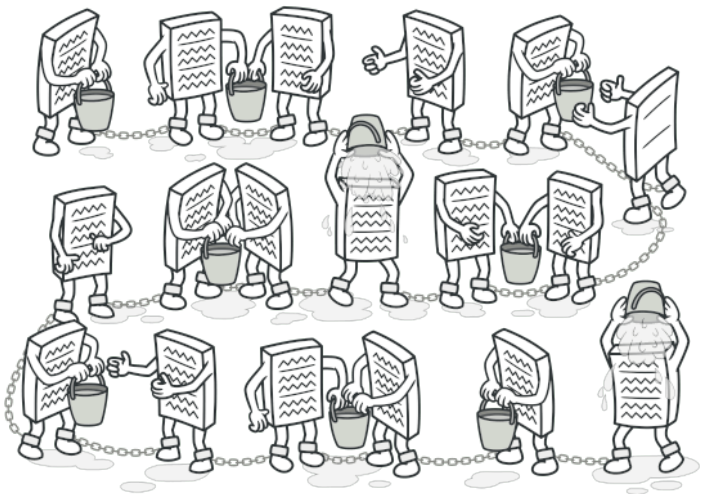
Command window

```
-----Testing Opera Mail Client for different environments-----
Configuration of Opera mail client for Mac complete
Configuration of Opera mail client for Linux complete
Configuration of Opera mail client for Windows complete

-----Testing Squirrel Mail Client for different environments-----
Configuration of Squirrel mail client for Mac complete
Configuration of Squirrel mail client for Linux complete
Configuration of Squirrel mail client for Windows complete

-----Testing Zimbra Mail Client for different environments-----
Configuration of Zimbra mail client for Mac complete
Configuration of Zimbra mail client for Linux complete
Configuration of Zimbra mail client for Windows complete
```

4.8 Chain Of Responsibility Pattern

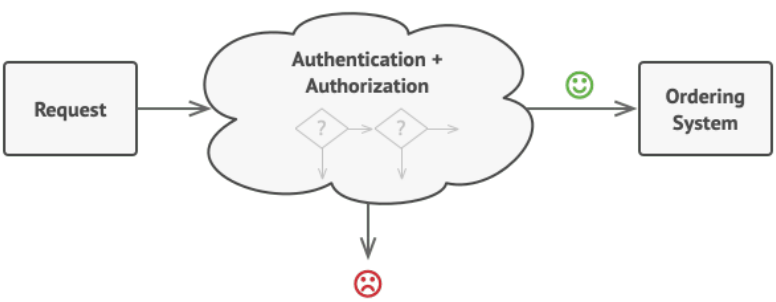
4.8.1 Intent

Chain of Responsibility is a behavioral design pattern that lets you pass requests along a chain of handlers. Upon receiving a request, each handler decides either to process the request or to pass it to the next handler in the chain.



4.8.2 Problem

Imagine that you're working on an online ordering system. You want to restrict access to the system so only authenticated users can create orders. Also, users who have administrative permissions must have full access to all orders.

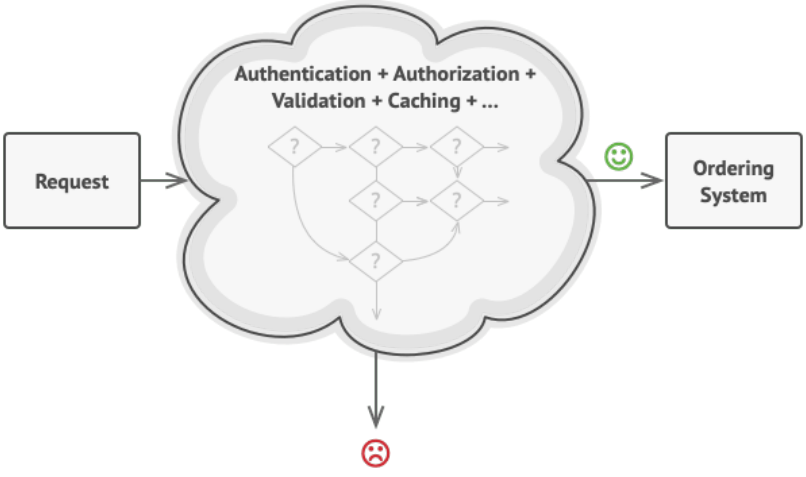


The request must pass a series of checks before the ordering system itself can handle it.

After a bit of planning, you realized that these checks must be performed sequentially. The application can attempt to authenticate a user to the system whenever it receives a request that contains the user's credentials. However, if those credentials aren't correct and authentication fails, there's no reason to proceed with any other checks.

During the next few months, you implemented several more of those sequential checks.

- One of your colleagues suggested that it's unsafe to pass raw data straight to the ordering system. So you added an extra validation step to sanitize the data in a request.
- Later, somebody noticed that the system is vulnerable to brute force password cracking. To negate this, you promptly added a check that filters repeated failed requests coming from the same IP address.
- Someone else suggested that you could speed up the system by returning cached results on repeated requests containing the same data. Hence, you added another check which lets the request pass through to the system only if there's no suitable cached response.



The bigger the code grew, the messier it became.

The code of the checks, which had already looked like a mess, became more and more bloated as you added each new feature. Changing one check sometimes affected the others. Worst of all, when you tried to reuse the checks to protect other components of the system, you had to duplicate some of the code since those components required some of the checks, but not all of them.

The system became very hard to comprehend and expensive to maintain. You struggled with the code for a while, until one day you decided to refactor the whole thing.

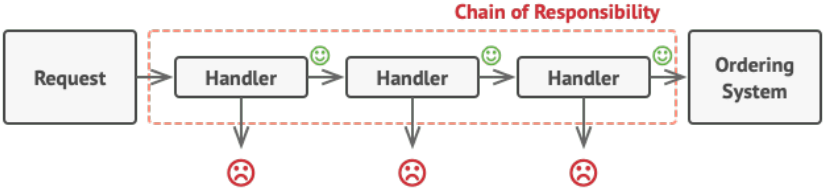
4.8.3 Solution

Like many other behavioral design patterns, the Chain of Responsibility relies on transforming particular behaviors into stand-alone objects called handlers. In our case, each check should be extracted to its own class with a single method that performs the check. The request, along with its data, is passed to this method as an argument.

The pattern suggests that you link these handlers into a chain. Each linked handler has a field for storing a reference to the next handler in the chain. In addition to processing a request, handlers pass the request further along the chain. The request travels along the chain until all handlers have had a chance to process it.

Here's the best part: a handler can decide not to pass the request further down the chain and effectively stop any further processing.

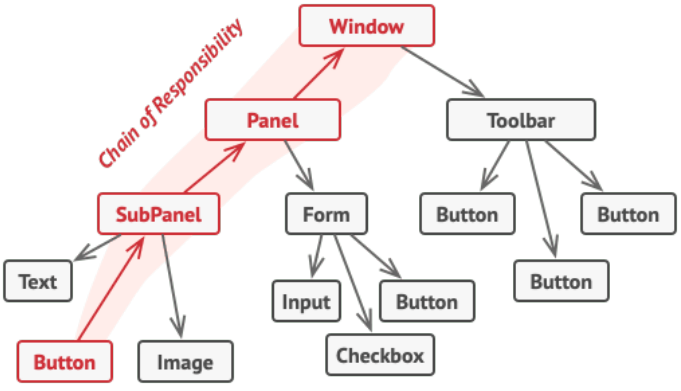
In our example with ordering systems, a handler performs the processing and then decides whether to pass the request further down the chain. Assuming the request contains the right data, all the handlers can execute their primary behavior, whether it's authentication checks or caching.



Handlers are lined up one by one, forming a chain.

However, there's a slightly different approach (and it's a bit more canonical) in which, upon receiving a request, a handler decides whether it can process it. If it can, it doesn't pass the request any further. So it's either only one handler that processes the request or none at all. This approach is very common when dealing with events in stacks of elements within a graphical user interface.

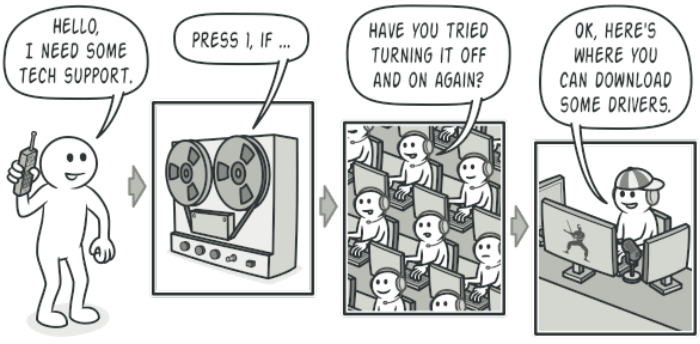
For instance, when a user clicks a button, the event propagates through the chain of GUI elements that starts with the button, goes along its containers (like forms or panels), and ends up with the main application window. The event is processed by the first element in the chain that's capable of handling it. This example is also noteworthy because it shows that a chain can always be extracted from an object tree.



A chain can be formed from a branch of an object tree.

It's crucial that all handler classes implement the same interface. Each concrete handler should only care about the following one having the execute method. This way you can compose chains at runtime, using various handlers without coupling your code to their concrete classes.

4.8.4 Real-World Analogy



A call to tech support can go through multiple operators.

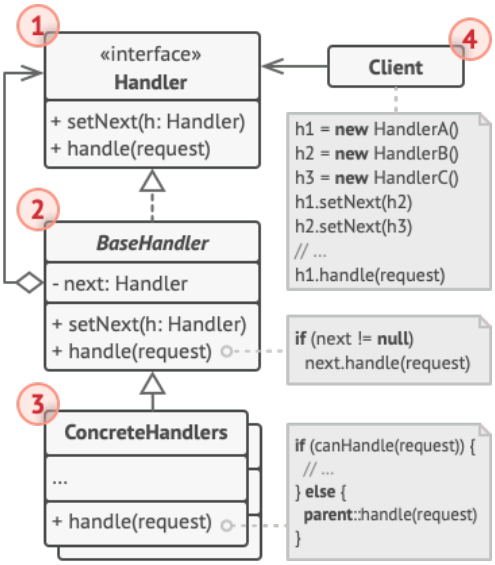
You've just bought and installed a new piece of hardware on your computer. Since you're a geek, the computer has several operating systems installed. You try to boot all of them to see whether the hardware is supported. Windows detects and enables the hardware automatically. However, your beloved Linux refuses to work with the new hardware. With a small flicker of hope, you decide to call the tech-support phone number written on the box.

The first thing you hear is the robotic voice of the autoresponder. It suggests nine popular solutions to various problems, none of which are relevant to your case. After a while, the robot connects you to a live operator.

Alas, the operator isn't able to suggest anything specific either. He keeps quoting lengthy excerpts from the manual, refusing to listen to your comments. After hearing the phrase "have you tried turning the computer off and on again?" for the 10th time, you demand to be connected to a proper engineer.

Eventually, the operator passes your call to one of the engineers, who had probably longed for a live human chat for hours as he sat in his lonely server room in the dark basement of some office building. The engineer tells you where to download proper drivers for your new hardware and how to install them on Linux. Finally, the solution! You end the call, bursting with joy.

4.8.5 Structure



1. The Handler declares the interface, common for all concrete handlers. It usually contains just a single method for handling requests, but sometimes it may also have another method for setting the next handler on the chain.

2. The Base Handler is an optional class where you can put the boilerplate code that's common to all handler classes.

   Usually, this class defines a field for storing a reference to the next handler. The clients can build a chain by passing a handler to the constructor or setter of the previous handler. The class may also implement the default handling behavior: it can pass execution to the next handler after checking for its existence.

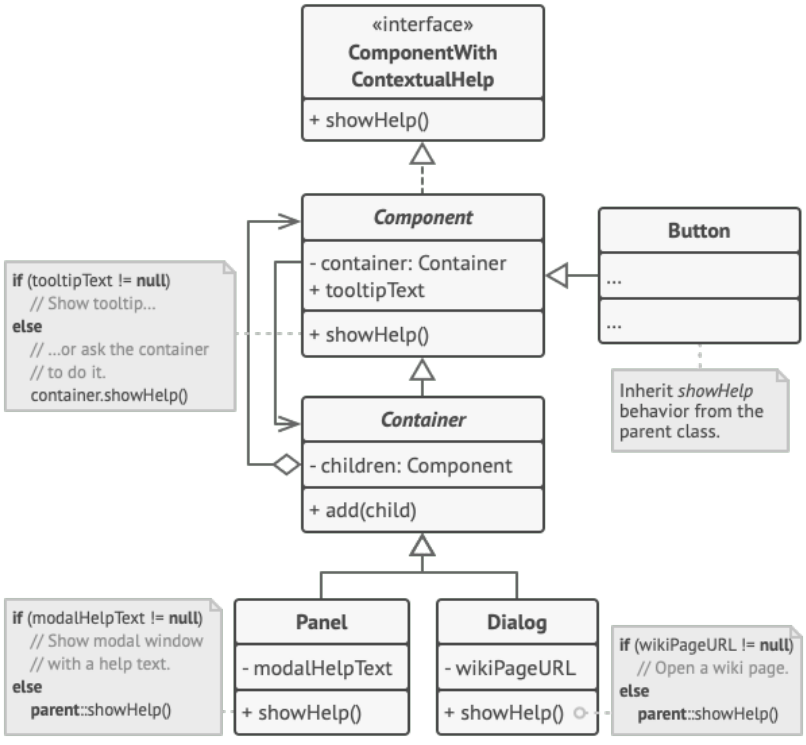
3. Concrete Handlers contain the actual code for processing requests. Upon receiving a request, each handler must decide whether to process it and, additionally, whether to pass it along the chain.

Handlers are usually self-contained and immutable, accepting all necessary data just once via the constructor.

4. The Client may compose chains just once or compose them dynamically, depending on the application's logic. Note that a request can be sent to any handler in the chain—it doesn't have to be the first one.

4.8.6 Pseudocode

In this example, the Chain of Responsibility pattern is responsible for displaying contextual help information for active GUI elements.

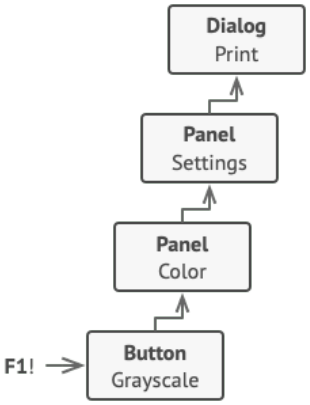


The GUI classes are built with the Composite pattern. Each element is linked to its container element. At any point, you can build a chain of elements that starts with the element itself and goes through all of its container elements.

The application's GUI is usually structured as an object tree. For example, the Dialog class, which renders the main window of the app, would be the root of the object tree. The dialog contains Panels, which might contain other panels or simple low-level elements like Buttons and TextFields.

A simple component can show brief contextual tooltips, as long as the component has some help text assigned. But more complex components define their own way

of showing contextual help, such as showing an excerpt from the manual or opening a page in a browser.



That's how a help request traverses GUI objects.

When a user points the mouse cursor at an element and presses the F1 key, the application detects the component under the pointer and sends it a help request. The request bubbles up through all the element's containers until it reaches the element that's capable of displaying the help information.

PSEUDO CODE

```
// The handler interface declares a method for executing a request.
interface ComponentWithContextualHelp is
  method showHelp()


// The base class for simple components.
abstract class Component implements ComponentWithContextualHelp is
  field tooltipText : string

  // The component's container acts as the next link in the chain of handlers.
  protected field container : Container

  // The component shows a tooltip if there's help text assigned to it.
  //  Otherwise it forwards the call to the container, if it exists.
  method showHelp() is
    if (tooltipText != null)
      // Show tooltip.
    else
      container.showHelp()


// Containers can contain both simple components and other containers
```


```
// as children. The chain relationships are established here.
// The class inherits showHelp behavior from its parent.
abstract class Container extends Component is
  protected field children: array of Component

  method add(child) is
    children.add(child)
    child.container = this


// Primitive components may be fine with default help implementation...
class Button extends Component is
  // ...


// But complex components may override the default implementation.
// If the help text can't be provided in a new way, the component
// can always call the base implementation (see Component class).
class Panel extends Container is
  field modalHelpText: string

  method showHelp() is
    if (modalHelpText != null)
      // Show a modal window with the help text.
    else
      super.showHelp()


// ... same as above ...
class Dialog extends Container is
  field wikiPageURL: string

  method showHelp() is
    if (wikiPageURL != null)
      // Open the wiki help page.
    else
      super.showHelp()


// Client code.
class Application is
  // Every application configures the chain differently.
  method createUI() is
    dialog = new Dialog("Budget Reports")
    dialog.wikiPageURL = "http://..."

    panel = new Panel(0, 0, 400, 800)
    panel.modalHelpText = "This panel does ..."

    ok = new Button(250, 760, 50, 20, "OK")
    ok.tooltipText = "This is an OK button that ..."
```

PSEUDO CODE

```
74
        cancel = new Button(320, 760, 50, 20, "Cancel")
76
        // ...
78
        panel.add(ok)
80      panel.add(cancel)

82      dialog.add(panel)

84    // Imagine what happens here.
      method onF1KeyPress() is
86      component = this.getComponentAtMouseCoords()
        component.showHelp()
```

4.8.7 Applicability

- Use the Chain of Responsibility pattern when your program is expected to process different kinds of requests in various ways, but the exact types of requests and their sequences are unknown beforehand.

▷ The pattern lets you link several handlers into one chain and, upon receiving a request, “ask” each handler whether it can process it. This way all handlers get a chance to process the request.

- Use the pattern when it’s essential to execute several handlers in a particular order.

▷ Since you can link the handlers in the chain in any order, all requests will get through the chain exactly as you planned.

- Use the CoR pattern when the set of handlers and their order are supposed to change at runtime.

▷ If you provide setters for a reference field inside the handler classes, you’ll be able to insert, remove or reorder handlers dynamically.

4.8.8 How to Implement

1. Declare the handler interface and describe the signature of a method for handling requests.

   Decide how the client will pass the request data into the method. The most flexible way is to convert the request into an object and pass it to the handling method as an argument.

2. To eliminate duplicate boilerplate code in concrete handlers, it might be worth creating an abstract base handler class, derived from the handler interface.

   This class should have a field for storing a reference to the next handler in the chain. Consider making the class immutable. However, if you plan to modify chains at runtime, you need to define a setter for altering the value of the reference field.

   You can also implement the convenient default behavior for the handling method, which is to forward the request to the next object unless there's none left. Concrete handlers will be able to use this behavior by calling the parent method.

3. One by one create concrete handler subclasses and implement their handling methods. Each handler should make two decisions when receiving a request:

   - Whether it'll process the request.
   - Whether it'll pass the request along the chain.

4. The client may either assemble chains on its own or receive pre-built chains from other objects. In the latter case, you must implement some factory classes to build chains according to the configuration or environment settings.

5. The client may trigger any handler in the chain, not just the first one. The request will be passed along the chain until some handler refuses to pass it further or until it reaches the end of the chain.

6. Due to the dynamic nature of the chain, the client should be ready to handle the following scenarios:

   - The chain may consist of a single link.
   - Some requests may not reach the end of the chain.
   - Others may reach the end of the chain unhandled.

4.8.9 Pros and Cons

+ You can control the order of request handling.

+ Single Responsibility Principle. You can decouple classes that invoke operations from classes that perform operations.

+ Open/Closed Principle. You can introduce new handlers into the app without breaking the existing client code.

- Some requests may end up unhandled.

4.8.10 Relations with Other Patterns

- Chain of Responsibility, Command, Mediator and Observer address various ways of connecting senders and receivers of requests:
  - Chain of Responsibility passes a request sequentially along a dynamic chain of potential receivers until one of them handles it.
  - Command establishes unidirectional connections between senders and receivers.
  - Mediator eliminates direct connections between senders and receivers, forcing them to communicate indirectly via a mediator object.
  - Observer lets receivers dynamically subscribe to and unsubscribe from receiving requests.
- Chain of Responsibility is often used in conjunction with Composite. In this case, when a leaf component gets a request, it may pass it through the chain of all of the parent components down to the root of the object tree.
- Handlers in Chain of Responsibility can be implemented as Commands. In this case, you can execute a lot of different operations over the same context object, represented by a request.

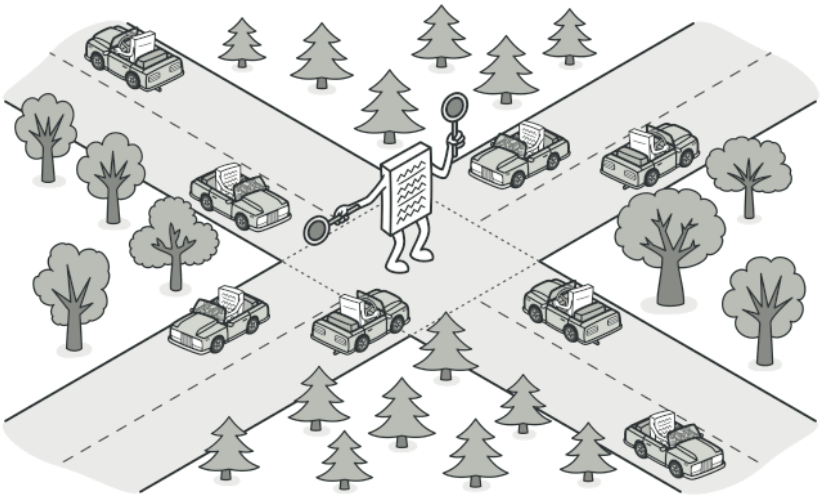
  However, there's another approach, where the request itself is a Command object. In this case, you can execute the same operation in a series of different contexts linked into a chain.
- Chain of Responsibility and Decorator have very similar class structures. Both patterns rely on recursive composition to pass the execution through a series of objects. However, there are several crucial differences.

  The CoR handlers can execute arbitrary operations independently of each other. They can also stop passing the request further at any point. On the other hand, various Decorators can extend the object's behavior while keeping it consistent with the base interface. In addition, decorators aren't allowed to break the flow of the request.

4.9 Mediator Pattern

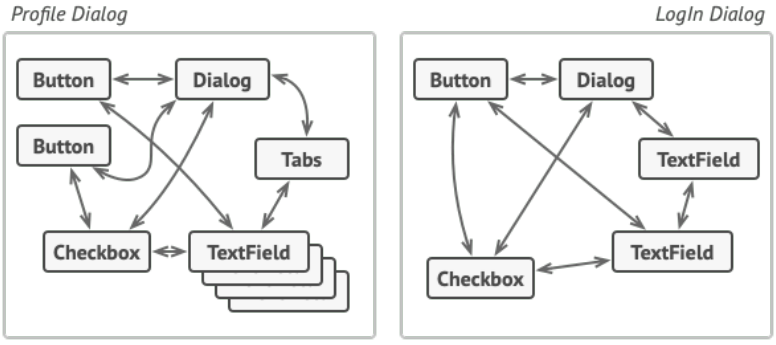
4.9.1 Intent

Mediator is a behavioral design pattern that lets you reduce chaotic dependencies between objects. The pattern restricts direct communications between the objects and forces them to collaborate only via a mediator object.



4.9.2 Problem

Say you have a dialog for creating and editing customer profiles. It consists of various form controls such as text fields, checkboxes, buttons, etc.



Relations between elements of the user interface can become chaotic as the application evolves.

Some of the form elements may interact with others. For instance, selecting the "I have a dog" checkbox may reveal a hidden text field for entering the dog's name. Another example is the submit button that has to validate values of all fields before saving the data.

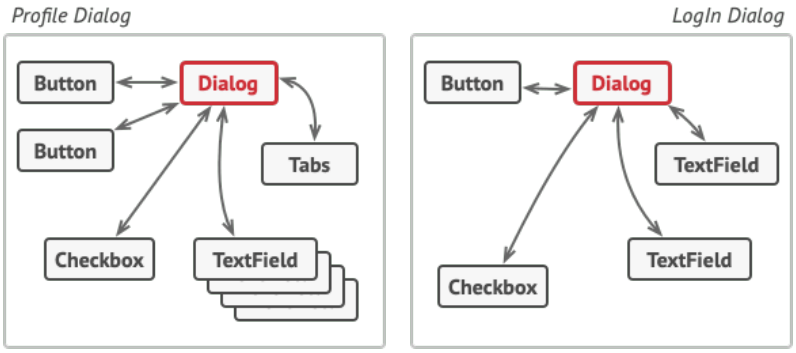
Elements can have lots of relations with other elements. Hence, changes to some elements may affect the others.

By having this logic implemented directly inside the code of the form elements you make these elements' classes much harder to reuse in other forms of the app. For example, you won't be able to use that checkbox class inside another form, because it's coupled to the dog's text field. You can use either all the classes involved in rendering the profile form, or none at all.

4.9.3 Solution

The Mediator pattern suggests that you should cease all direct communication between the components which you want to make independent of each other. Instead, these components must collaborate indirectly, by calling a special mediator object that redirects the calls to appropriate components. As a result, the components depend only on a single mediator class instead of being coupled to dozens of their colleagues.

In our example with the profile editing form, the dialog class itself may act as the mediator. Most likely, the dialog class is already aware of all of its sub-elements, so you won't even need to introduce new dependencies into this class.



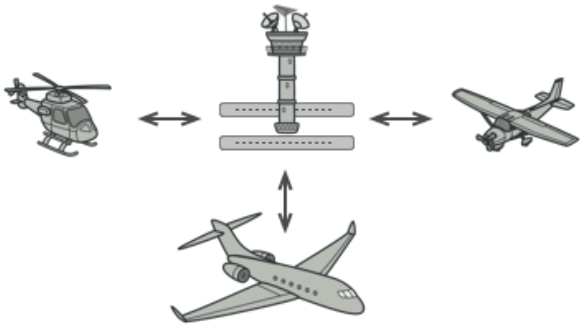
UI elements should communicate indirectly, via the mediator object.

The most significant change happens to the actual form elements. Let's consider the submit button. Previously, each time a user clicked the button, it had to validate the values of all individual form elements. Now its single job is to notify the dialog about the click. Upon receiving this notification, the dialog itself performs the validations or passes the task to the individual elements. Thus, instead of being tied to a dozen form elements, the button is only dependent on the dialog class.

You can go further and make the dependency even looser by extracting the common interface for all types of dialogs. The interface would declare the notification method which all form elements can use to notify the dialog about events happening to those elements. Thus, our submit button should now be able to work with any dialog that implements that interface.

This way, the Mediator pattern lets you encapsulate a complex web of relations between various objects inside a single mediator object. The fewer dependencies a class has, the easier it becomes to modify, extend or reuse that class.

4.9.4 Real-World Analogy

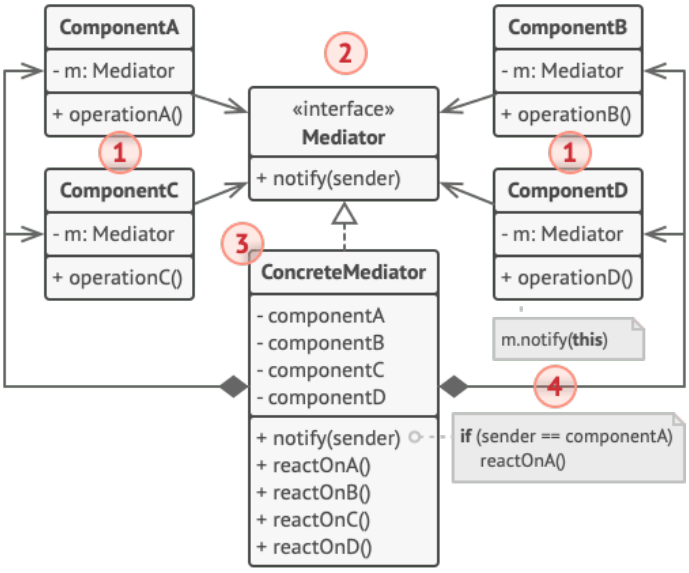


Aircraft pilots don't talk to each other directly when deciding who gets to land their plane next. All communication goes through the control tower.

Pilots of aircraft that approach or depart the airport control area don't communicate directly with each other. Instead, they speak to an air traffic controller, who sits in a tall tower somewhere near the airstrip. Without the air traffic controller, pilots would need to be aware of every plane in the vicinity of the airport, discussing landing priorities with a committee of dozens of other pilots. That would probably skyrocket the airplane crash statistics.

The tower doesn't need to control the whole flight. It exists only to enforce constraints in the terminal area because the number of involved actors there might be overwhelming to a pilot.

4.9.5 Structure



1. Components are various classes that contain some business logic. Each component has a reference to a mediator, declared with the type of the mediator interface. The component isn't aware of the actual class of the mediator, so you can reuse the component in other programs by linking it to a different mediator.

2. The Mediator interface declares methods of communication with components, which usually include just a single notification method. Components may pass any context as arguments of this method, including their own objects, but only in such a way that no coupling occurs between a receiving component and the sender's class.

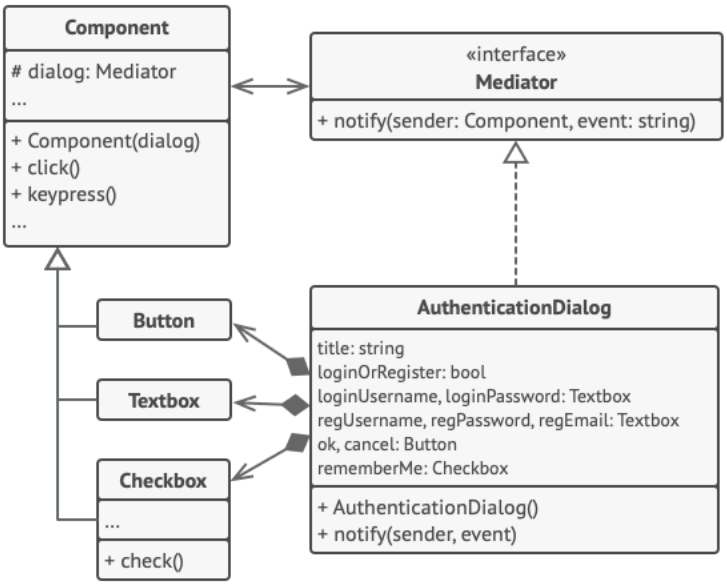
3. Concrete Mediators encapsulate relations between various components. Concrete mediators often keep references to all components they manage and sometimes even manage their lifecycle.

4. Components must not be aware of other components. If something important happens within or to a component, it must only notify the mediator. When the mediator receives the notification, it can easily identify the sender, which might be just enough to decide what component should be triggered in return.

   From a component's perspective, it all looks like a total black box. The sender doesn't know who'll end up handling its request, and the receiver doesn't know who sent the request in the first place.

4.9.6 Pseudocode

In this example, the Mediator pattern helps you eliminate mutual dependencies between various UI classes: buttons, checkboxes and text labels.



Structure of the UI dialog classes.

An element, triggered by a user, doesn't communicate with other elements directly, even if it looks like it's supposed to. Instead, the element only needs to let its mediator know about the event, passing any contextual info along with that notification.

In this example, the whole authentication dialog acts as the mediator. It knows how concrete elements are supposed to collaborate and facilitates their indirect communication. Upon receiving a notification about an event, the dialog decides what element should address the event and redirects the call accordingly.

PSEUDO CODE

```
// The mediator interface declares a method used by components to notify
//   the mediator about various events. The mediator may react to these events
//   and pass the execution to other components.
interface Mediator is
  method notify(sender: Component, event: string)


// The concrete mediator class. The intertwined web of connections between
```

```
// individual components has been untangled and moved into the mediator.
class AuthenticationDialog implements Mediator is
    private field title : string
    private field loginOrRegisterChkBx: Checkbox
    private field loginUsername: Checkbox
    private field loginPassword: Textbox
    private field registrationUsername : Textbox
    private field registrationPassword : Textbox
    private field registrationEmail : Textbox
    private field okBtn: Button
    private field cancelBtn: Button

    constructor AuthenticationDialog () is
    // Create all component objects by passing the current
    //     mediator into their constructors to establish links.

    // When something happens with a component, it notifies the mediator.
    //  Upon receiving a notification , the mediator may do something on
    //  its own or pass the request to another component.
    method notify(sender, event) is
        if (sender == loginOrRegisterChkBx and event == "check")
            if (loginOrRegisterChkBx.checked)
                title = "Log in"
                // 1. Show login form components.
                // 2. Hide registration form components.
            else
                title = "Register"
                // 1. Show registration form components.
                // 2. Hide login form components

        if (sender == okBtn && event == "click")
            if (loginOrRegister.checked)
                // Try to find a user using login credentials.
                if (!found)
                    // Show an error message above the login field.
            else
                // 1. Create a user account using data from the registration fields.
                // 2. Log that user in.
                // ...


// Components communicate with a mediator using the mediator interface.
//  Thanks to that, you can use the same components in other contexts by
//  linking them with different mediator objects.
class Component is
    field dialog: Mediator

    constructor Component(dialog) is
        this.dialog = dialog

    method click() is
```

```
        dialog.notify(this, "click")

    method keypress() is
        dialog.notify(this, "keypress")


// Concrete components don't talk to each other. They have only one
//  communication channel, which is sending notifications to the mediator.
class Button extends Component is
    //  ...


class Textbox extends Component is
    //  ...


class Checkbox extends Component is
    method check() is
        dialog.notify(this, "check")

    //  ...
```

4.9.7 Applicability

- Use the Mediator pattern when it's hard to change some of the classes because they are tightly coupled to a bunch of other classes.

▷ The pattern lets you extract all the relationships between classes into a separate class, isolating any changes to a specific component from the rest of the components.

- Use the pattern when you can't reuse a component in a different program because it's too dependent on other components.

▷ After you apply the Mediator, individual components become unaware of the other components. They could still communicate with each other, albeit indirectly, through a mediator object. To reuse a component in a different app, you need to provide it with a new mediator class.

- Use the Mediator when you find yourself creating tons of component subclasses just to reuse some basic behavior in various contexts.

▷ Since all relations between components are contained within the mediator, it's easy to define entirely new ways for these components to collaborate by introducing new mediator classes, without having to change the components themselves.

4.9.8 How to Implement

1. Identify a group of tightly coupled classes which would benefit from being more independent (e.g., for easier maintenance or simpler reuse of these classes).

2. Declare the mediator interface and describe the desired communication protocol between mediators and various components. In most cases, a single method for receiving notifications from components is sufficient.

   This interface is crucial when you want to reuse component classes in different contexts. As long as the component works with its mediator via the generic interface, you can link the component with a different implementation of the mediator.

3. Implement the concrete mediator class. Consider storing references to all components inside the mediator. This way, you could call any component from the mediator's methods.

4. You can go even further and make the mediator responsible for the creation and destruction of component objects. After this, the mediator may resemble a Factory or a Facade.

5. Components should store a reference to the mediator object. The connection is usually established in the component's constructor, where a mediator object is passed as an argument.

6. Change the components' code so that they call the mediator's notification method instead of methods on other components. Extract the code that involves calling other components into the mediator class. Execute this code whenever the mediator receives notifications from that component.

4.9.9 Pros and Cons

+ Single Responsibility Principle. You can extract the communications between various components into a single place, making it easier to comprehend and maintain.

+ Open/Closed Principle. You can introduce new mediators without having to change the actual components.

+ You can reduce coupling between various components of a program.

+ You can reuse individual components more easily.

- Over time a mediator can evolve into a **God Object**.

4.9.10 Relations with Other Patterns

- Chain of Responsibility, Command, Mediator and Observer address various ways of connecting senders and receivers of requests:
  - Chain of Responsibility passes a request sequentially along a dynamic chain of potential receivers until one of them handles it.
  - Command establishes unidirectional connections between senders and receivers.
  - Mediator eliminates direct connections between senders and receivers, forcing them to communicate indirectly via a mediator object.
  - Observer lets receivers dynamically subscribe to and unsubscribe from receiving requests.
- Facade and Mediator have similar jobs: they try to organize collaboration between lots of tightly coupled classes.
  - Facade defines a simplified interface to a subsystem of objects, but it doesn't introduce any new functionality. The subsystem itself is unaware of the facade. Objects within the subsystem can communicate directly.
  - Mediator centralizes communication between components of the system. The components only know about the mediator object and don't communicate directly.
- The difference between Mediator and Observer is often elusive. In most cases, you can implement either of these patterns; but sometimes you can apply both simultaneously. Let's see how we can do that.

  The primary goal of Mediator is to eliminate mutual dependencies among a set of system components. Instead, these components become dependent on a single mediator object. The goal of Observer is to establish dynamic one-way connections between objects, where some objects act as subordinates of others.

  There's a popular implementation of the Mediator pattern that relies on Observer. The mediator object plays the role of publisher, and the components act as subscribers which subscribe to and unsubscribe from the mediator's events. When Mediator is implemented this way, it may look very similar to Observer.

  When you're confused, remember that you can implement the Mediator pattern in other ways. For example, you can permanently link all the components to the same mediator object. This implementation won't resemble Observer but will still be an instance of the Mediator pattern.

  Now imagine a program where all components have become publishers, allowing dynamic connections between each other. There won't be a centralized mediator object, only a distributed set of observers.

Part VI Java Generics

Part VII Java Functional Programming

Part VIII Java Concurrency

Part IX Java GUI

Part X References