Design Patterns

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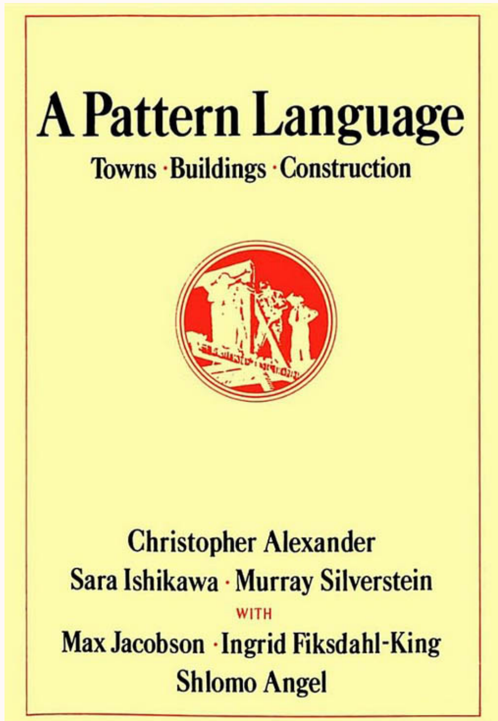
Reference

- Gamma, Erich, et al. "Design Patterns: Elements of Reusable Object-Oriented Software." (1994).
- Source Making
- Refactoring Guru

Introduction

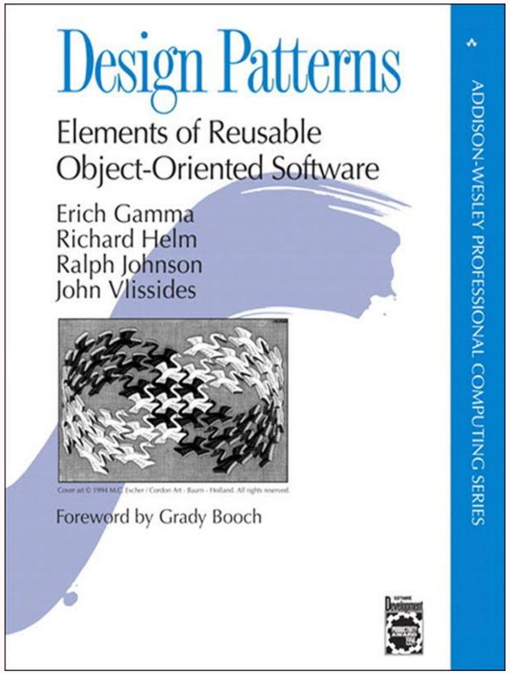
Patterns

Patterns originated as an **architectural** concept by Christopher **Alexander** (1977/78).



(Software) Design Patterns

Design patterns gained popularity in computer science after the book **"Design Patterns: Elements of Reusable Object-Oriented Software"** was published in **1994** by the so-called **"Gang of Four"**.



Design Pattern

A **general**, **reusable** solution to a **commonly** occurring problem within a given **context** in software design.

It is **not** a **finished design** that can be transformed directly into source code.

It is a **description** or **template** for **how** to **solve** a problem that can be **used** in **many** different situations.

GoF Patterns

The twenty-three design patterns described by the Gang of Four:

Creational	Structural	Behavioral
Abstract Factory	**Adapter**	Chain of Responsibility
Builder	Bridge	**Command**
Factory Method	**Composite**	Interpreter
Prototype	**Decorator**	Iterator
Singleton	Facade	Mediator
	Flyweight	Memento
	Proxy	**Observer**
		State
		Strategy
		Template Method
		Visitor

Documentation

The documentation for a design pattern describes the context in which the pattern is used, the forces within the context that the pattern seeks to resolve, and the suggested solution.

Pattern Name	Classification
Intent	Collaboration
Also Known As	**Consequences**
Motivation	**Implementation**
Applicability	Sample Code
Structure	Known Uses
Participants	Related Patterns

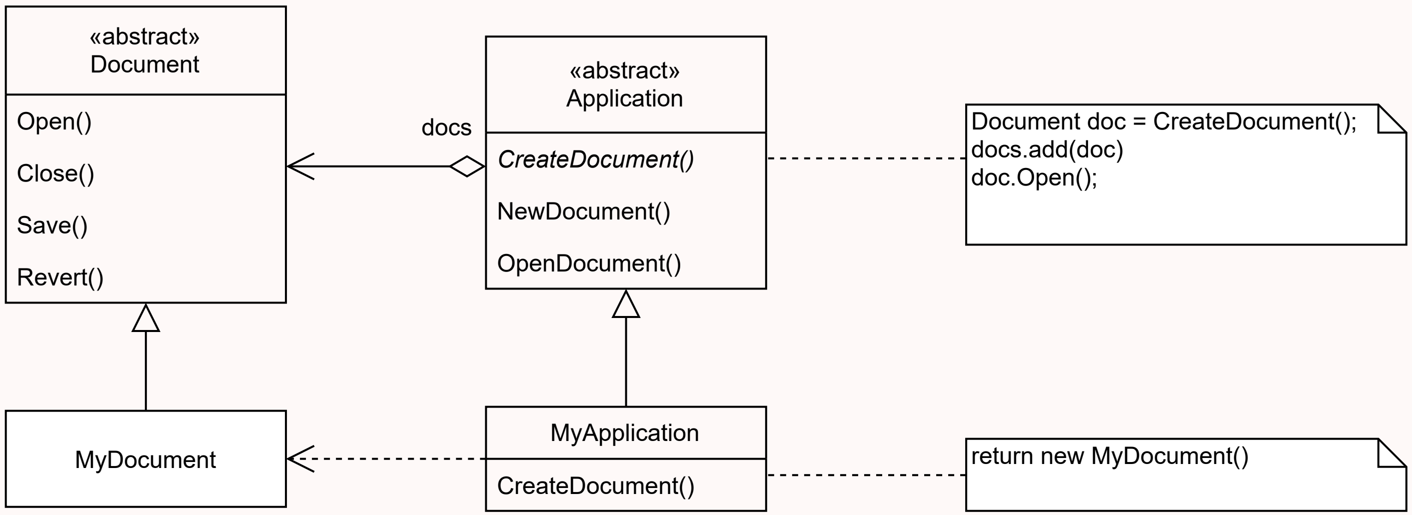
Factory Method

Factory Method

> *"Define an interface for creating an object, but let sub-classes decide which class to instantiate."*

Motivation

A framework for applications that can present multiple documents to the user.



Applicability

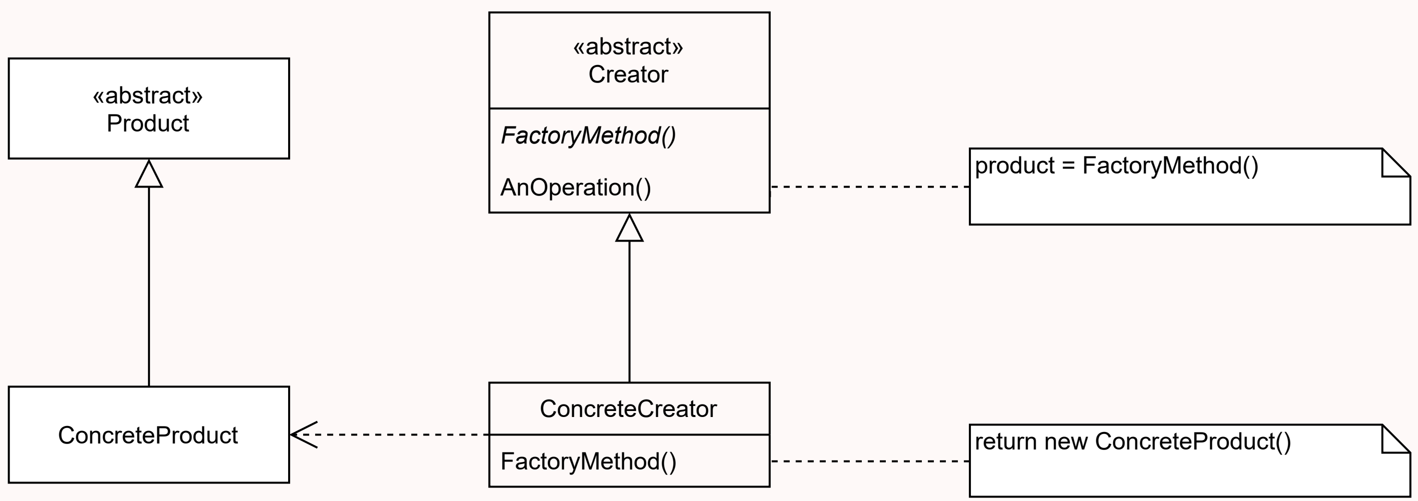
Use the **factory method** pattern when:

- a class can't anticipate the class of objects it must create.
- a class wants the subclasses to specify the objects it creates.
- classes delegate responsibility to one of several helper classes, and you want to localize the knowledge of which helper subclass is the delegate.

Consequences

Factory methods eliminate the need to bind application-specific classes into your code. The code only needs to deal with the Product *interface*; therefore it can work with any user-defined ConcreteProduct classes.

Structure


«abstract»
Product
ConcreteProduct
«abstract»
Creator
FactoryMethod()
AnOperation()
ConcreteCreator
FactoryMethod()
product = FactoryMethod()
return new ConcreteProduct()

Variations

- **Creator** might **not be abstract** and provide a **default implementation** for the **FactoryMethod**.
- **Factory Method** might take a **parameter** specifying the **type of product** to create.
- Using **Generics/Templates** to avoid *subclassing* the **Creator**.

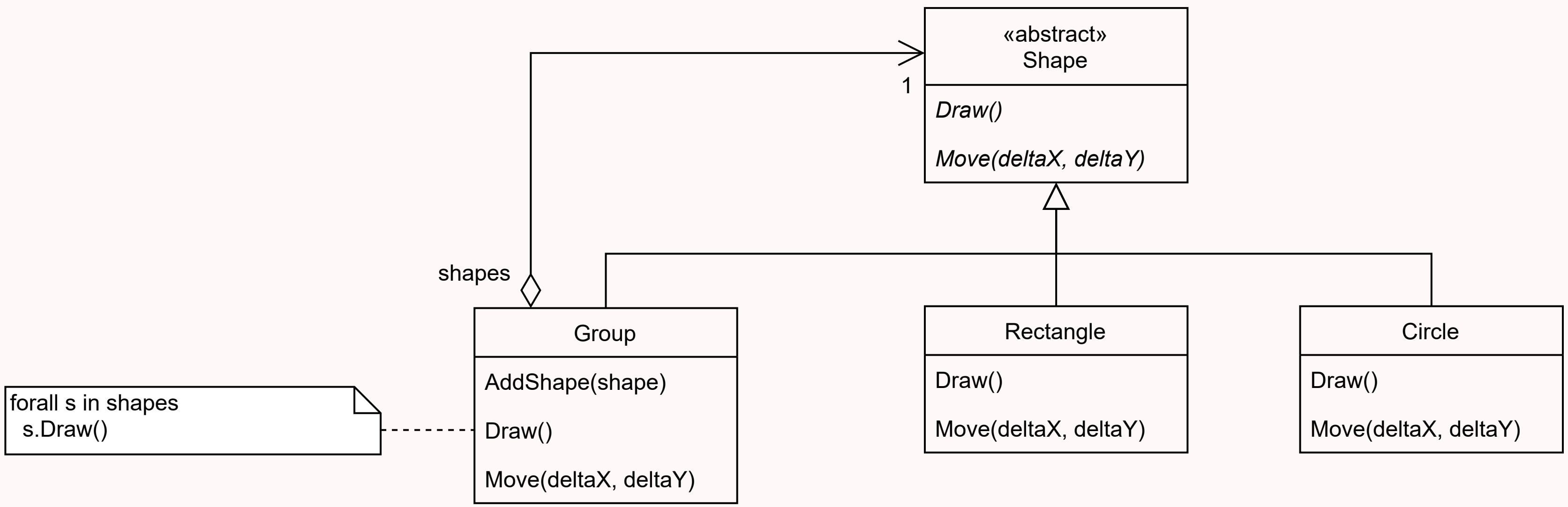
Composite

Composite

> *"Compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions uniformly."*

Motivation

A graphics application where shapes can be composed into groups.



Applicability

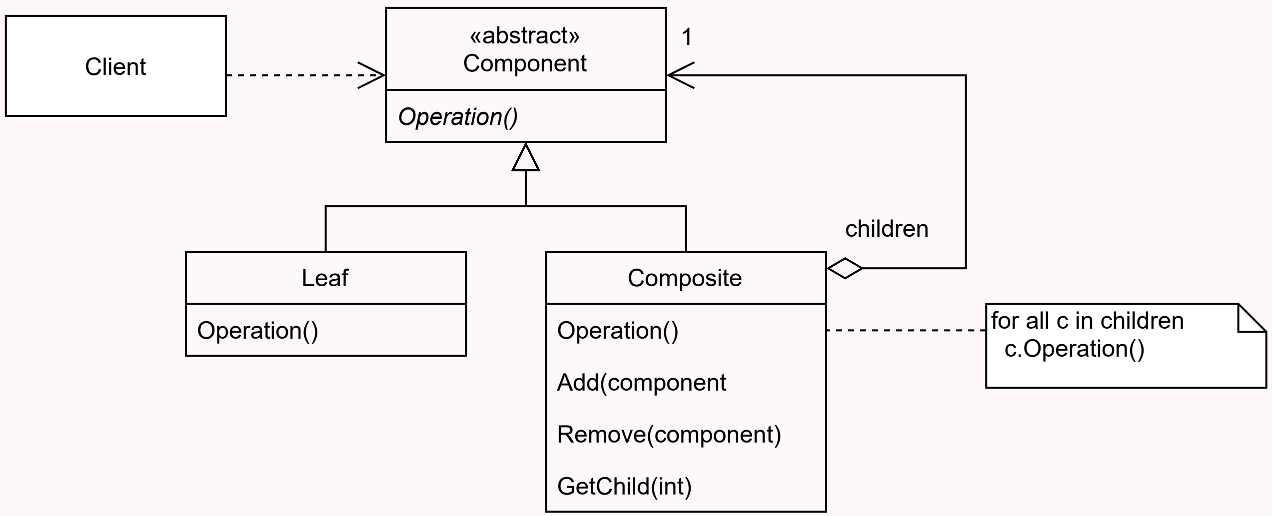
Use the **composite** pattern when:

- you want to represent part-whole hierarchies of objects.
- you want clients to be able to ignore the difference between compositions of objects and individual objects.

Consequences

- Primitive objects can be composed into more complex objects.
- Clients can be kept simple.
- Easier to add new types of components.

Structure



Client
«abstract»
Component
Operation()
1
children
Leaf
Operation()
Composite
Operation()
Add(component
Remove(component)
GetChild(int)
for all c in children
c.Operation()

Variations

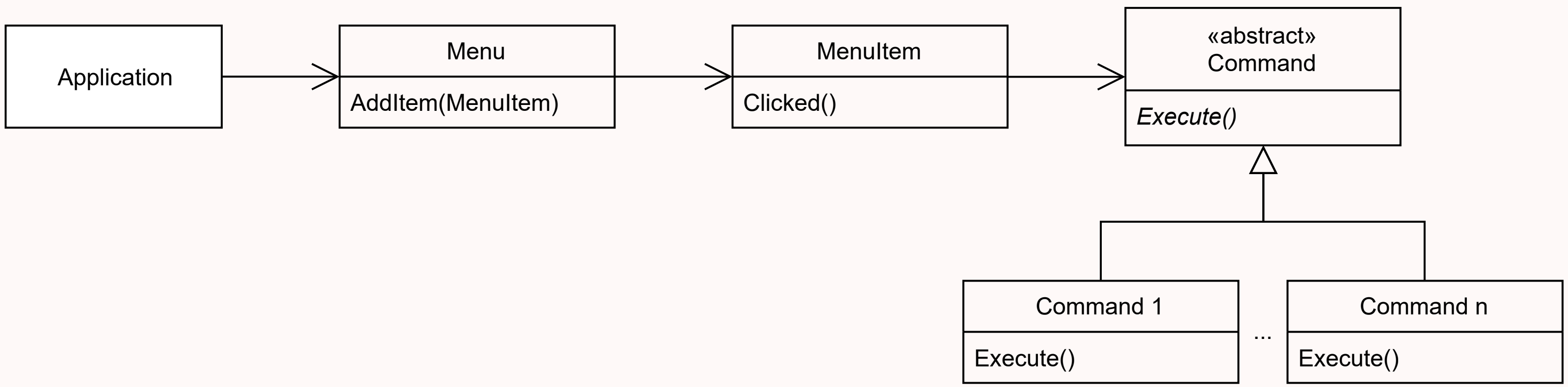
- Maintaining **references** from **child** components to their **parents**.
- **Sharing** components.
- Child **ordering**.
- **Caching** to improve performance.

Command

Command

> *"Encapsulate a request as an object thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operations."*

Motivation



Applicability

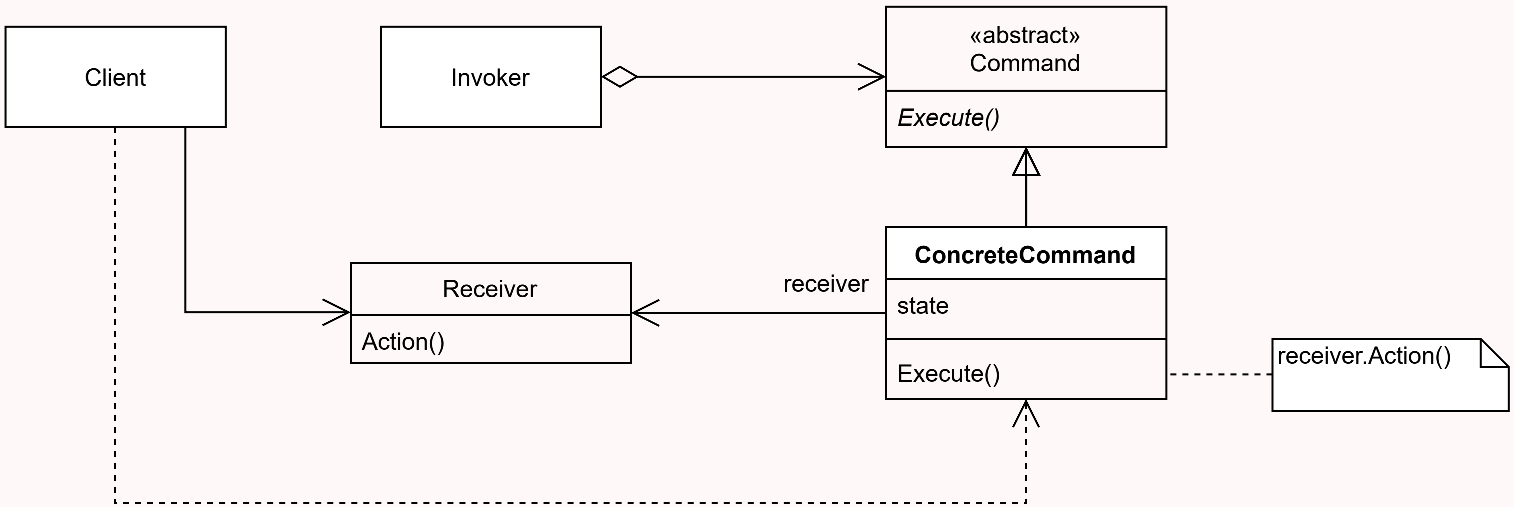
Use the **command** pattern when:

- **parameterize** objects by an action to perform.
- **specify**, **queue**, and **execute** requests at different times.
- support **undo/redo** operations.
- support **logging** changes so they can be reapplied.
- **structure** a system around **high-level** operations built on **primitive** operations.

Consequences

- Decouples the object that invokes the operation from the one that knows how to perform it.
- Commands can be extended and manipulated like any other object.
- You can create **Composite** commands.
- It's easy to add new commands.

Structure


Client
Invoker
«abstract»
Command
Execute()
ConcreteCommand
state
Execute()
receiver
Receiver
Action()
receiver.Action()

Variations

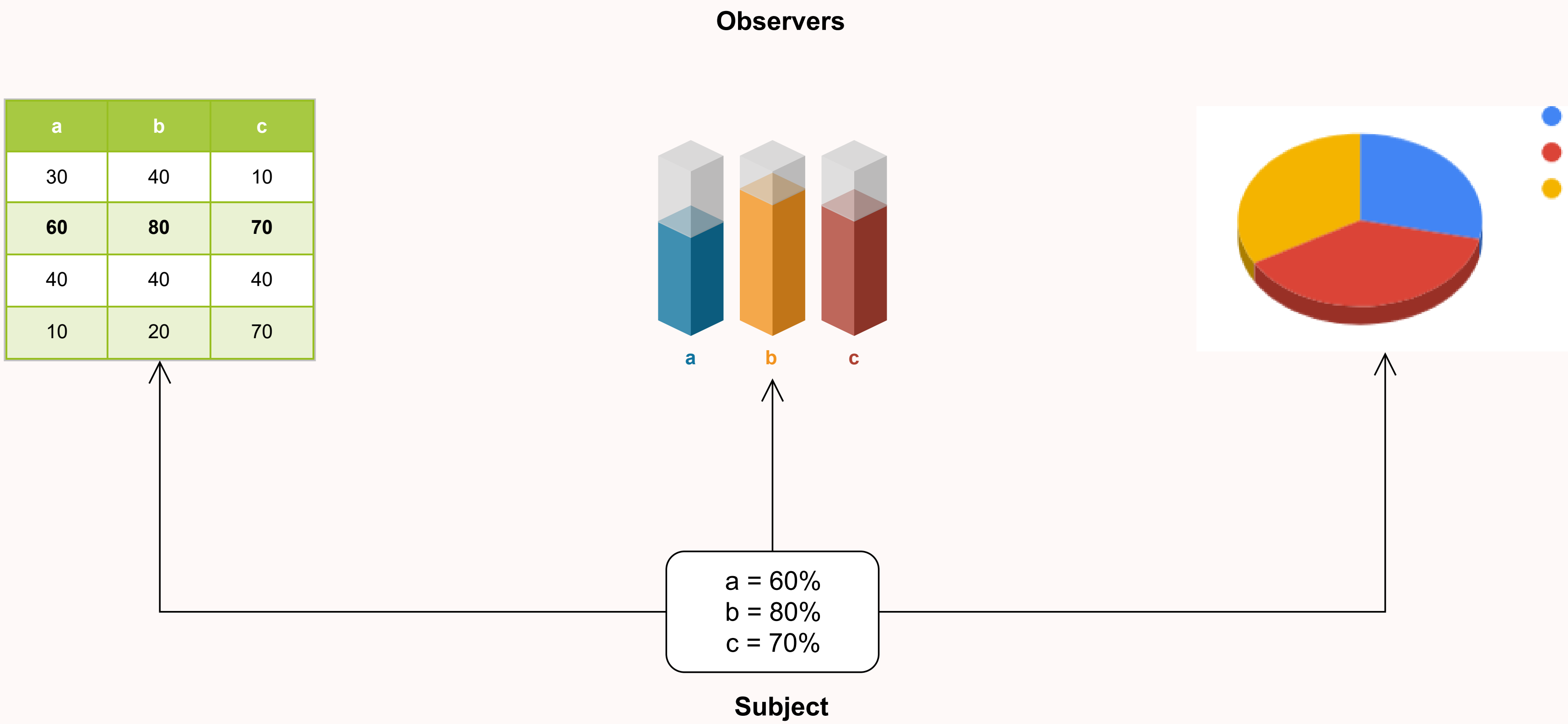
- Commands only **delegating** to Receiver actions or doing **all the work** by themselves.
- Support **undo/redo** instead of only action.
- Avoiding **error accumulation** in undo operations.

Observer

Observer

> *"Define a one-to-many dependency between objects so that when one object changes status all its dependents are notified and updated automatically."*

Motivation



Applicability

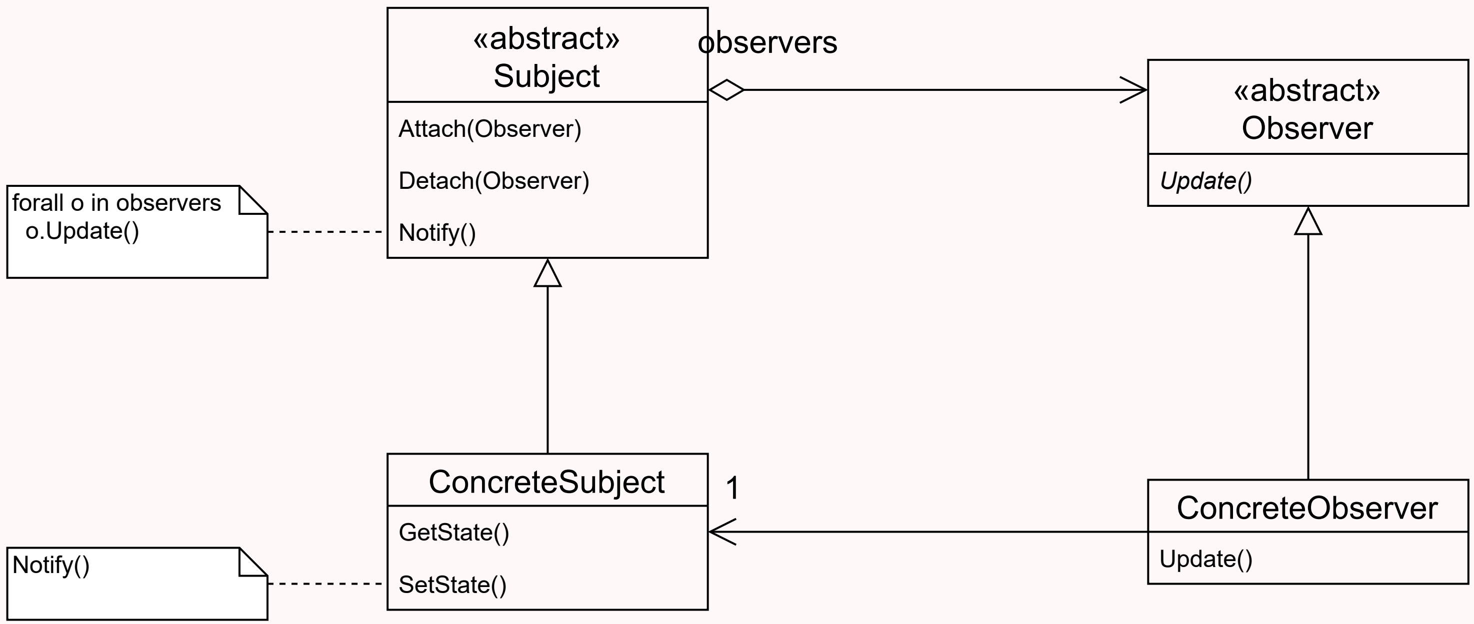
Use the **observer** pattern when:

- When an abstraction has two aspects one dependent on the other.
- When a change to one object requires changing others.
- When an object should be able to notify other objects without making assumptions about who those objects are.

Consequences

- Abstract coupling between subject and observer.
- Support for broadcast communication.
- Unexpected updates.

Structure



«abstract»
Subject
Attach(Observer)
Detach(Observer)
Notify()
observers
«abstract»
Observer
Update()
forall o in observers
o.Update()
ConcreteSubject
GetState()
SetState()
1
ConcreteObserver
Update()
Notify()

Variations

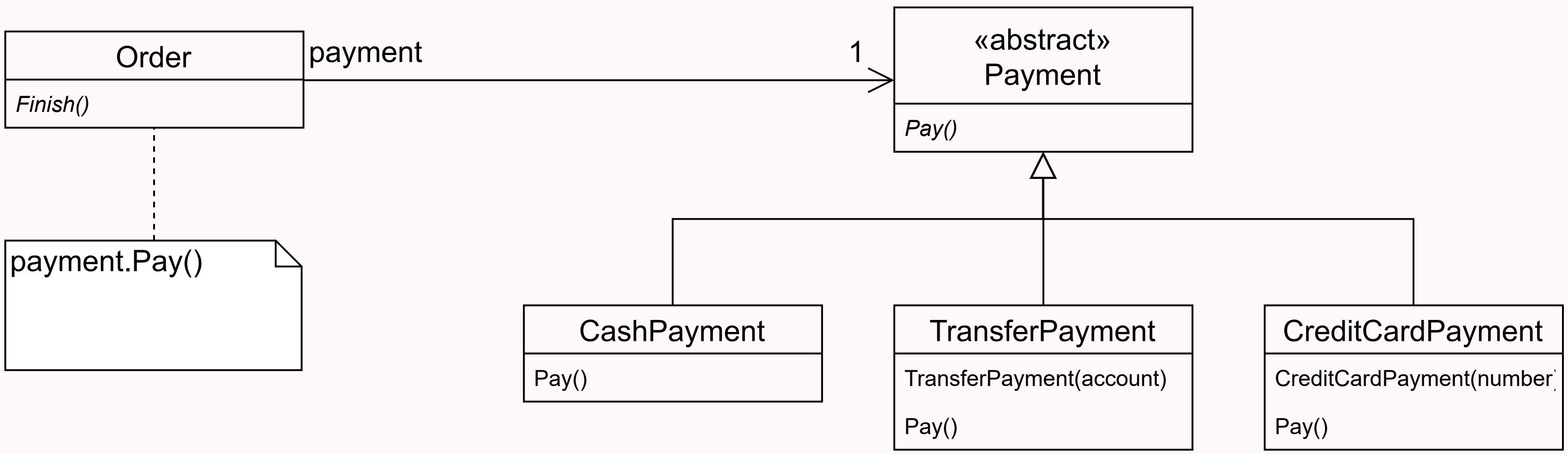
- Observing more than one subject.
- Who triggers the update (client or subject)?
- Push and pull models.
- Specifying "events of interest" explicitly.

Strategy

Strategy

> *"Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary depending from clients that use it."*

Motivation



Applicability

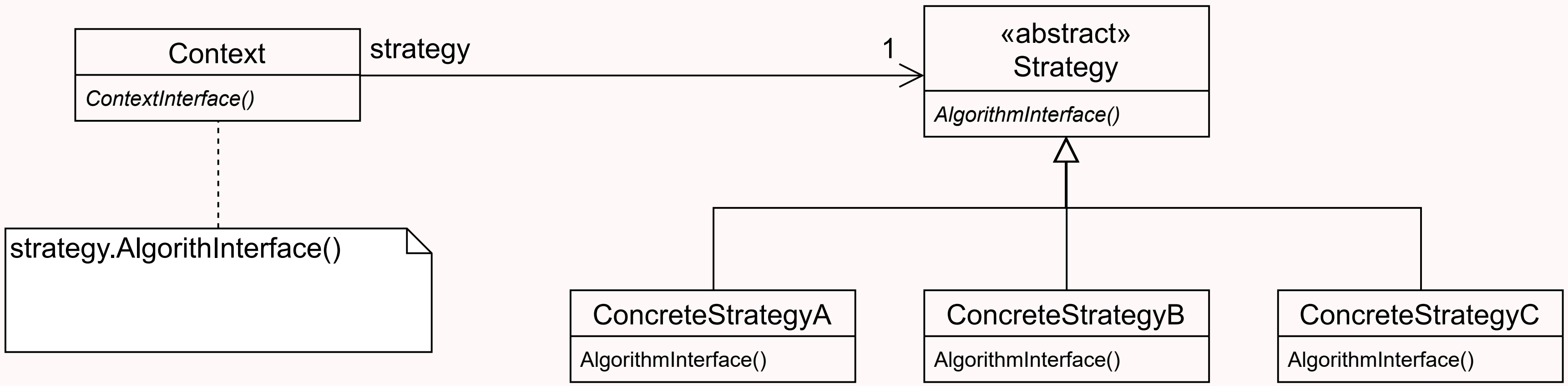
Use the **strategy** pattern when:

- many related classes differ only in their behavior.
- you need different variants of an algorithm.
- an algorithm uses data that clients should not know about.
- a class defines many behaviors that appear in multiple conditional statements.

Consequences

- An alternative to subclassing.
- Eliminates conditional statements.
- Provides different implementations.
- Clients must be aware of different strategies.

Structure


Context
ContextInterface()
strategy
1
«abstract»
Strategy
AlgorithmInterface()
strategy.AlgorithInterface()
ConcreteStrategyA
AlgorithmInterface()
ConcreteStrategyB
AlgorithmInterface()
ConcreteStrategyC
AlgorithmInterface()

Variations

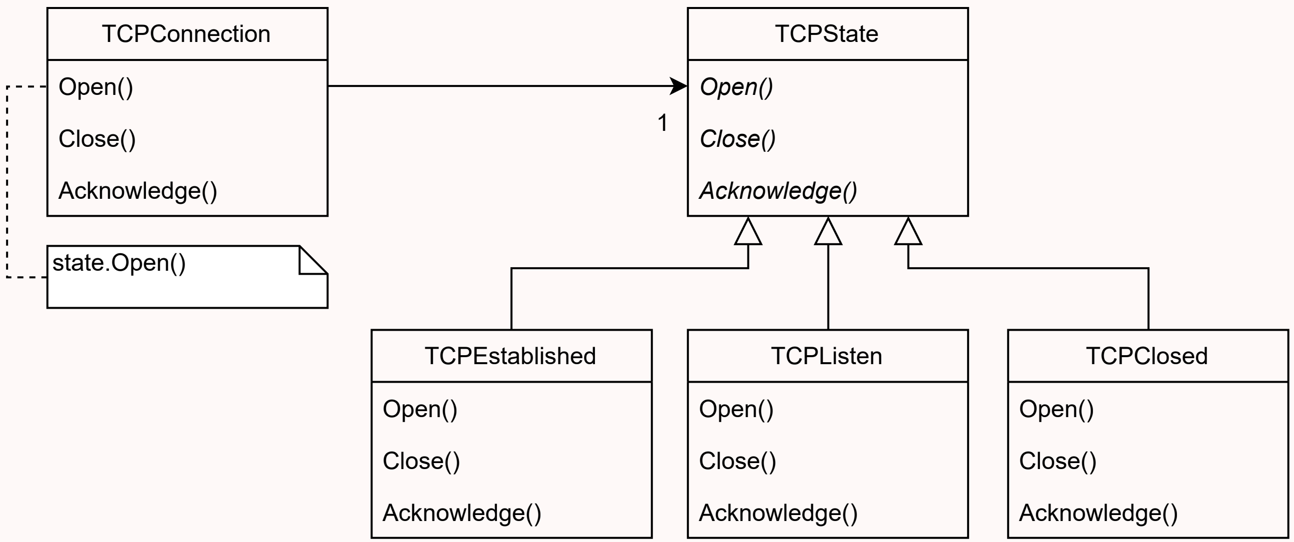
- Strategy and Context must have well defined interfaces for exchanging any needed data.
- Strategy can be optional if context has default behavior.

State

State

> *"Allow an object to alter its behavior when its internal state changes. The object will appear to change its class."*

Motivation



Applicability

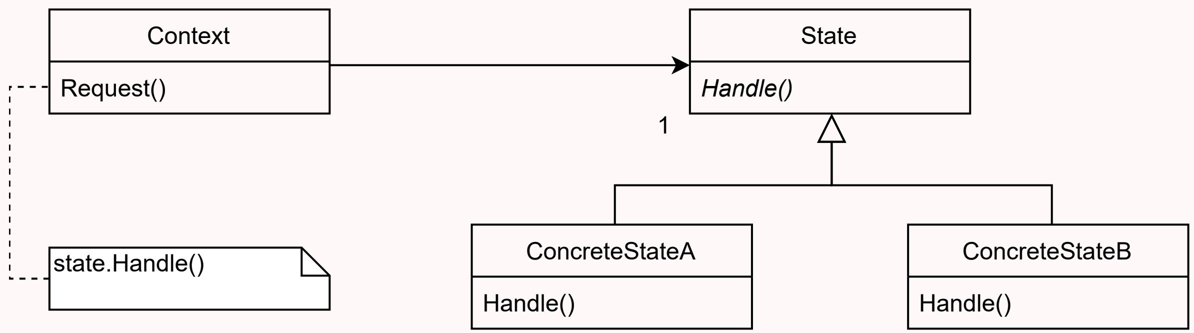
Use the **state** pattern when:

- an object behavior depends on its state, and it must change that state in run-time.
- operations have large, multipart conditional statements that depend on one or more enumerated constants.

Consequences

- Localizes and partitions behavior for different states.
- Makes state transitions explicit.

Structure


Context
Request()
State
Handle()
1
state.Handle()
ConcreteStateA
Handle()
ConcreteStateB
Handle()

Variations

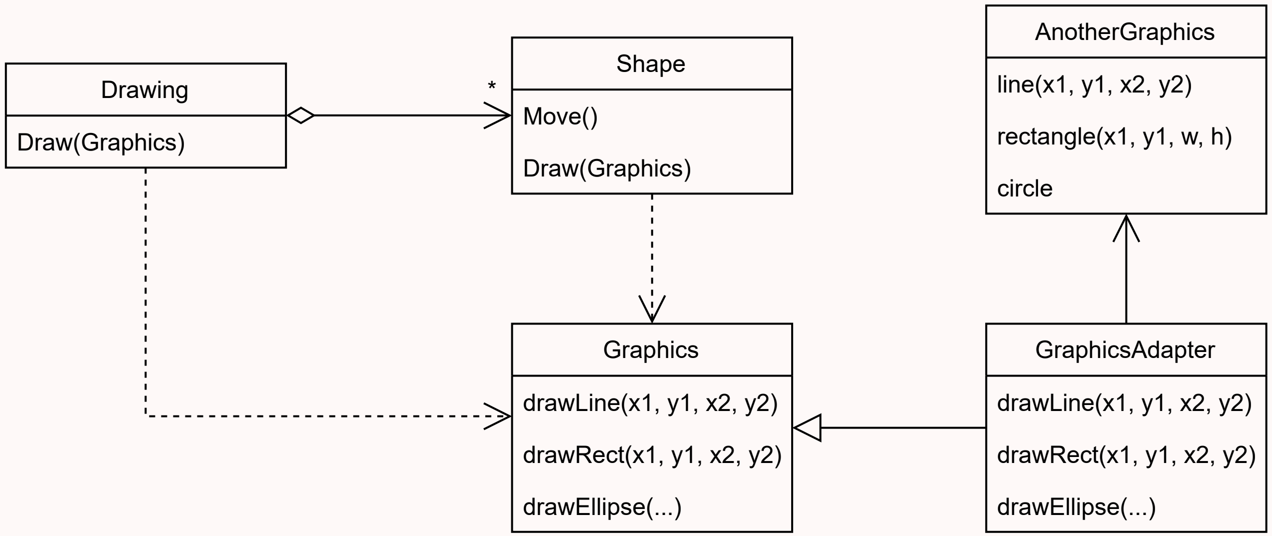
- Who defines the criteria for state transitions? More flexible solution is to let the states define the transitions.
- When are state objects created and destroyed? Easier to create and destroy when state changes. Better to only create them once and never destroy them.

Adapter

Adapter

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

Motivation

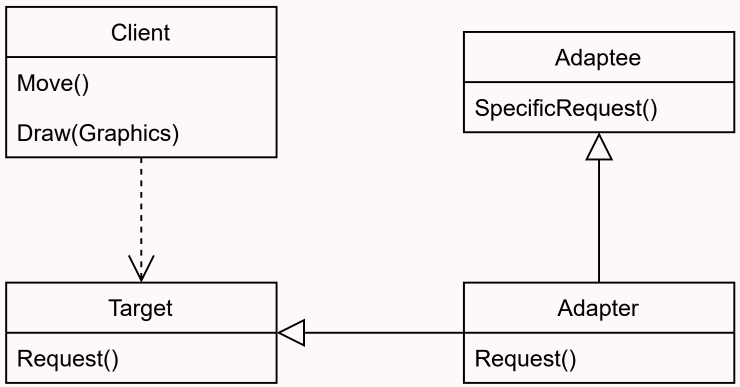


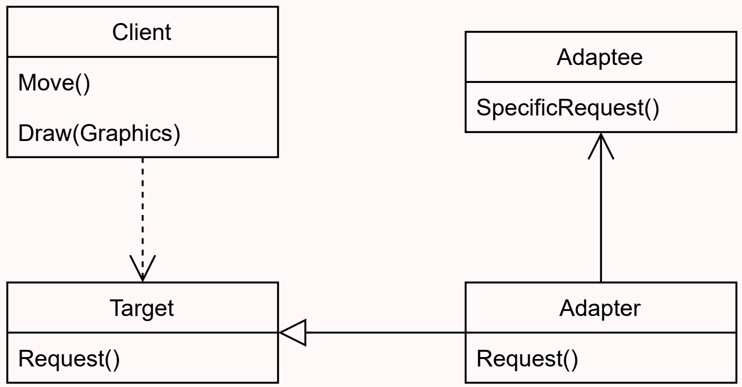
Applicability

Use the **adapter** pattern when:

- you want to use an existing class, and the interface does not match the one you need.
- you want to create a reusable class that work with unforseen classes.

Structure





Two different alternatives:

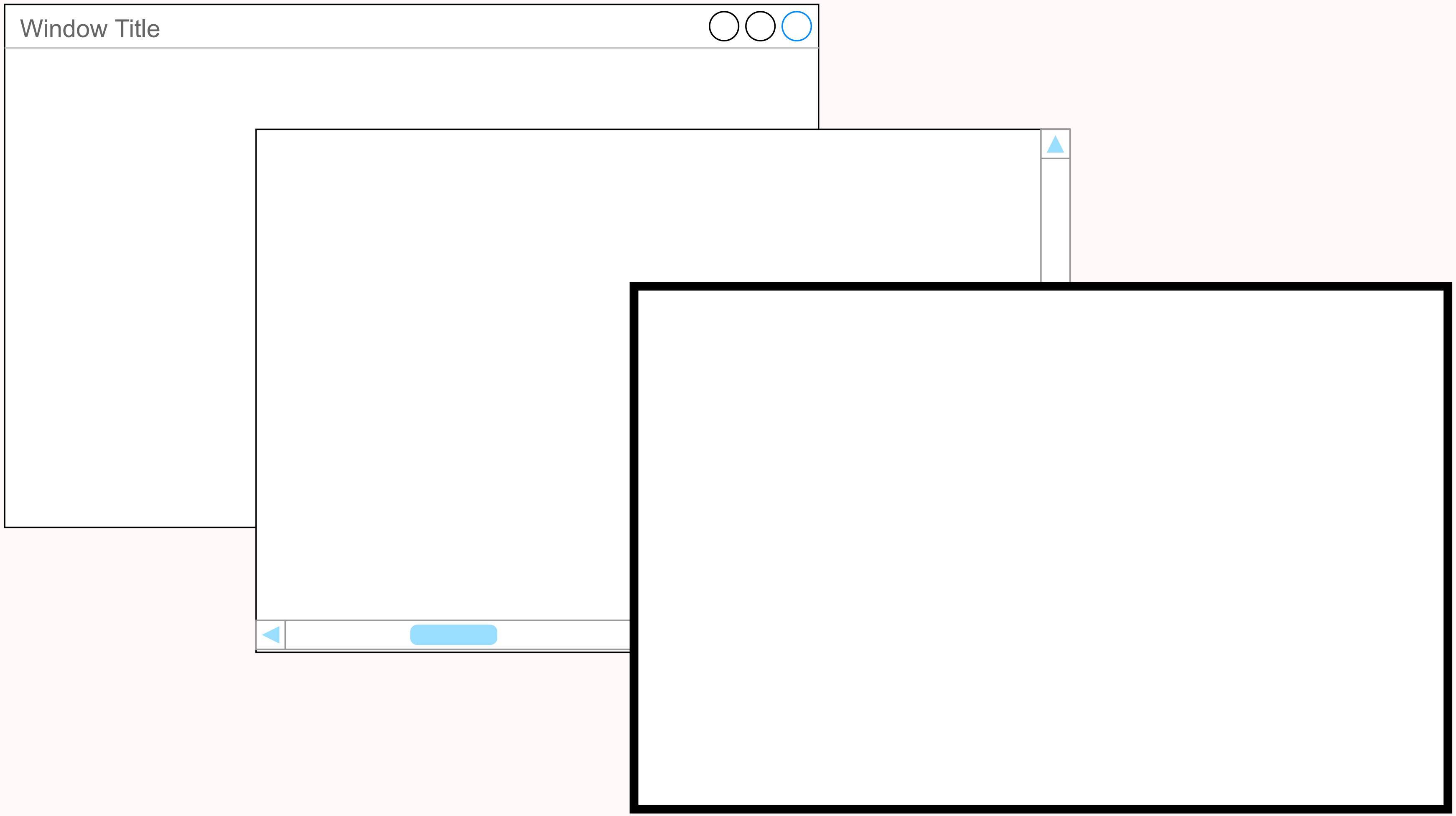
- **Class adapter**: Using multiple inheritance (if available).
- **Object adapter**: Using composition.

Decorator

Decorator

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

Motivation



Applicability

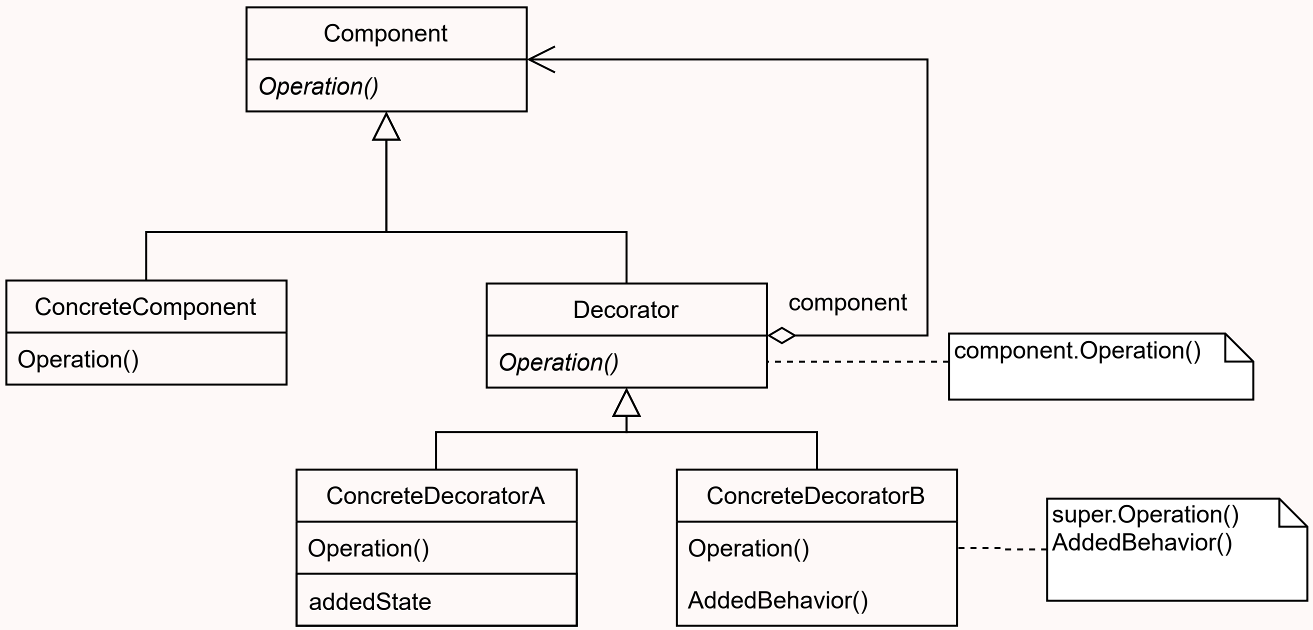
Use the **decorator** pattern when:

- to add responsibilities for **individual** objects dynamically and transparently.
- for responsibilities that can be withdrawn.
- when extension by subclassing is impractical (many different combinations → explosion of subclasses).

Consequences

- More flexible than static inheritance.
- Avoids classes with too many features and responsibilities.
- Lots of little objects.

Structure



> *"Changing the object guts (Strategy) versus changing the object skin (Decorator)".*

Singleton

Singleton

> *"Ensure a class only has one instance and provide a global point to acess it."*

Applicability

Use the **singleton** pattern when:

- there must be exactly one instance of a class.
- when the sole instance must be extensible by subclassing.

Consequences

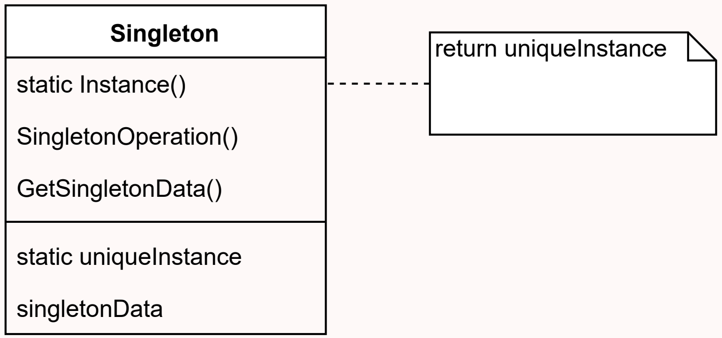
The **singleton** pattern is considered an anti-pattern:

- The assumption that there will ever be only one instance is often broken during a project's lifetime.
- Makes it very difficult to test code.
- Difficult to implement correctly when taking multi-threading into account.

What to use instead

- Instantiate a single instance and propagate it to places that use the object as a parameter.

Structure



Variations

When to create the unique instance?

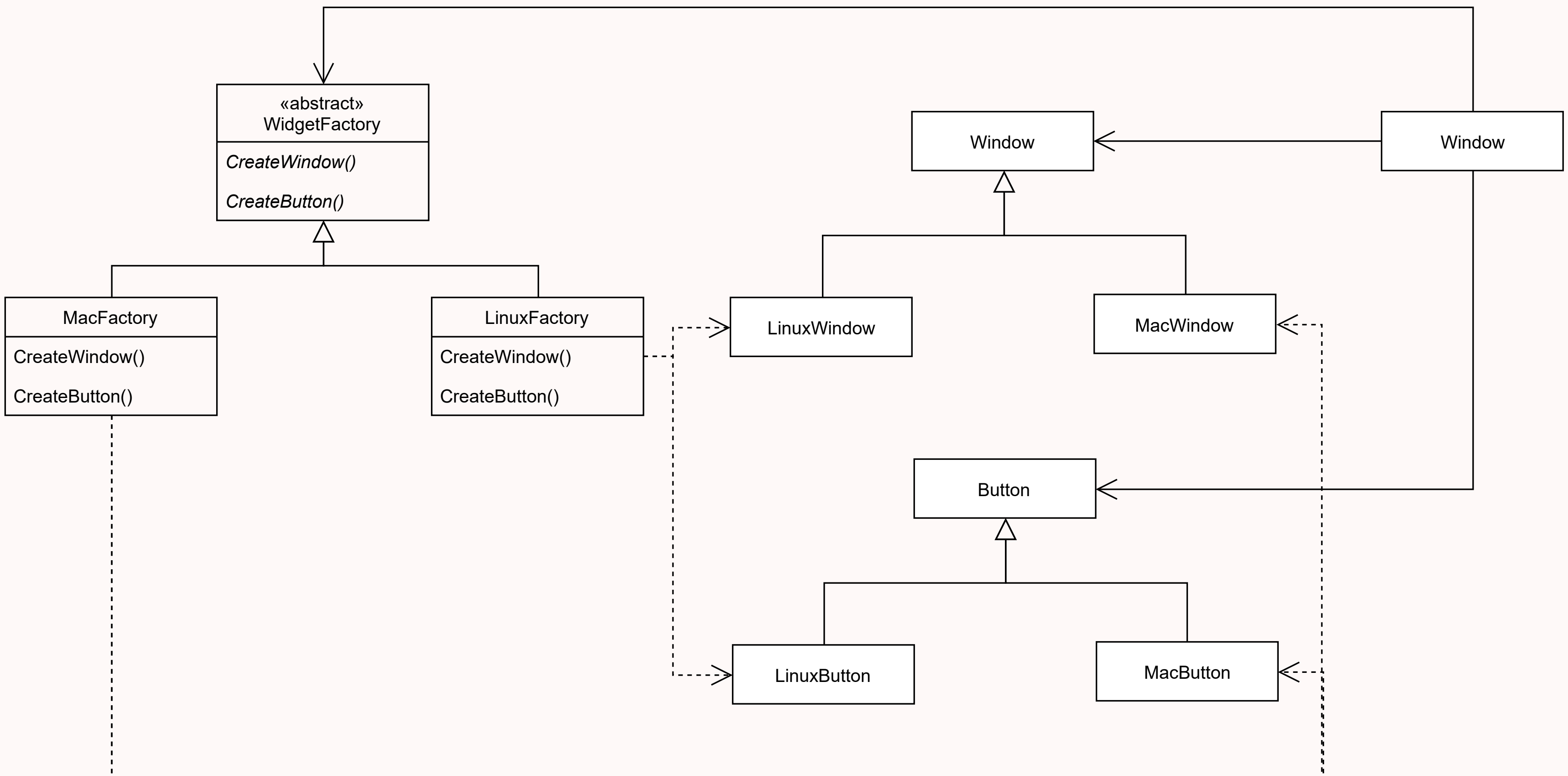
- At application start.
- When instance() is called for the first time.

Abstract-Factory

Abstract-Factory

> *"Provide an interface for creating families of related or dependent objects without specifying the concrete classes."*

Motivation



Applicability

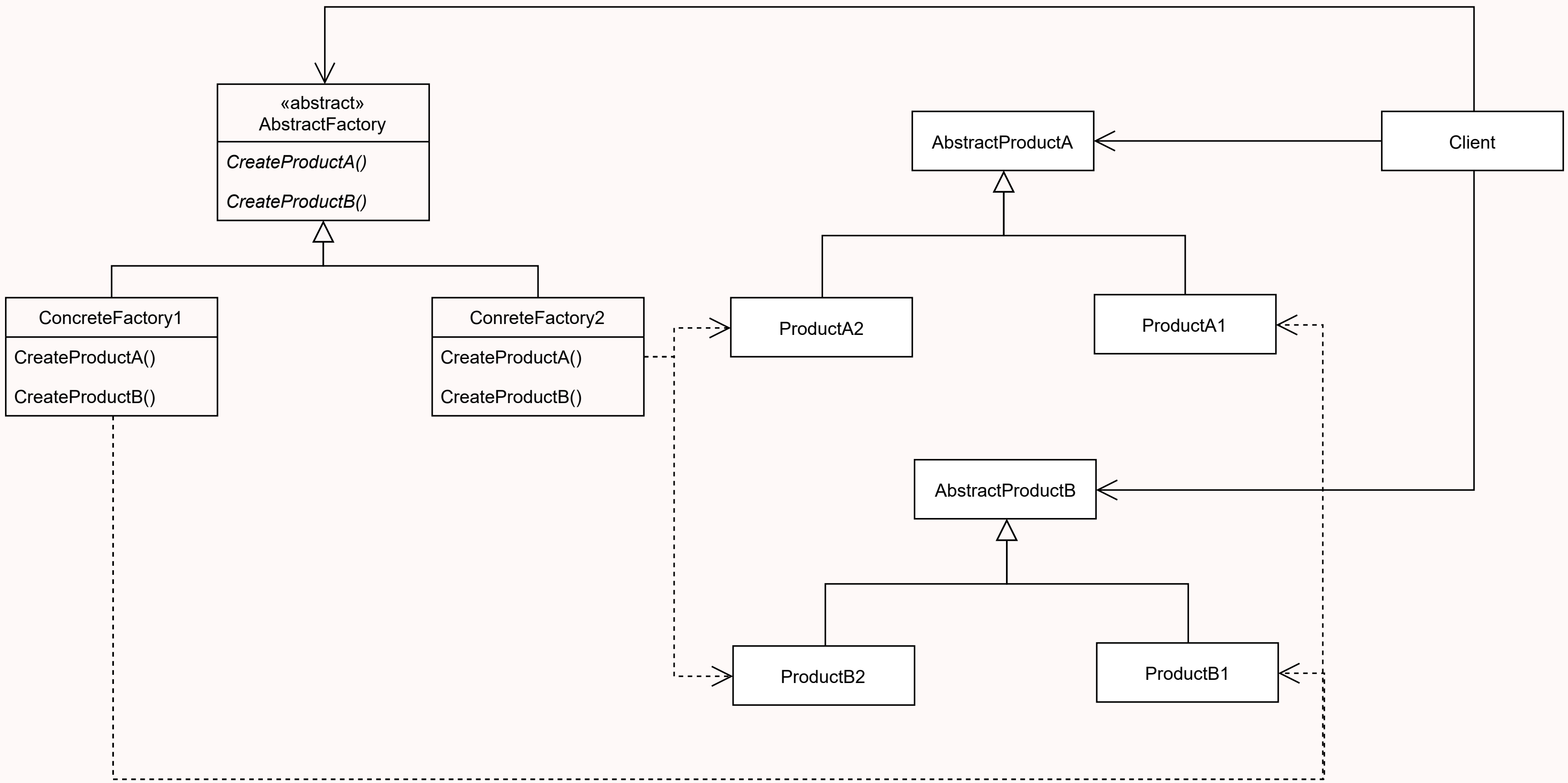
Use the **abstract factory** pattern when:

- a system should be independent from how its products are created, composed and represented.
- a system should be configurable with one or more families of products.
- a family of products is designed to work together and you need to reinforce this constraint.

Consequences

- It isolates concrete classes.
- It makes exchanging product families easy.
- It promotes consistency among products.
- Supporting new types of products is difficult.

Structure



«abstract»
AbstractFactory
CreateProductA()
CreateProductB()
ConcreteFactory1
CreateProductA()
CreateProductB()
ConreteFactory2
CreateProductA()
CreateProductB()
AbstractProductA
Client
ProductA2
ProductA1
AbstractProductB
ProductB2
ProductB1

Architectural Patterns

Architectural Patterns

An **Architectural style** is responsible for how we should organize our code (monolithic, pipes and filters, plugins, microservices, ...).

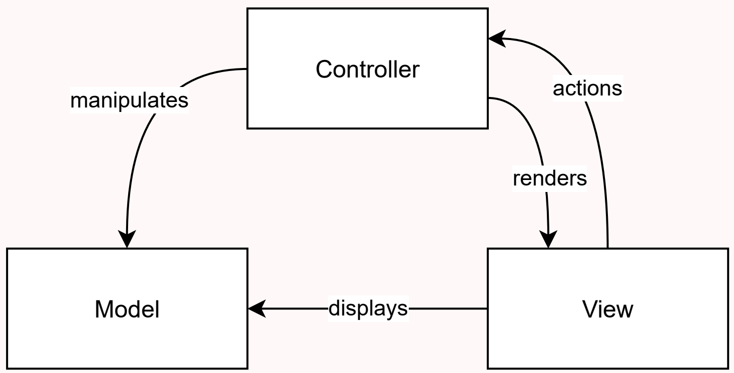
Architectural patterns are patterns that deal with the architectural style of software.

Some examples:

- Model-View-Controller (commonly used in GUIs)
- Pipe-Filter (pipes guide data from filter to filter)
- Broker (message queues e.g. RabbitMQ)
- ...

Model-View-Controller (MVC)

An architectural pattern commonly used for developing user interfaces that divides an application into **three** parts.



- The **model** only represents the **data**.
- The **view displays** the **model** data, and sends user **actions** to the **controller**.
- The **controller** provides **model** data to the **view**, and **interprets** user **actions**.

MVC Variants

There are several variants to the MVC pattern and even the MVC hasn't got a single interpretation:

- **HMVC** - Hierarchical Model-View-Controller: Each visual component has its own MVC model.
- **MVVM** - Model-View-ViewModel: Uses a ViewModel as a binder between the model and the view.
- **MVP** - Model-View-Presenter: The Presenter sits in the middle of the View and the Model mediating the actions between them.