C# Design Patterns Demystified: Upgrade your skill to senior development

**What are design patterns and what problems solve?**

Design patterns are reusable and generalizable solutions to common problems that software developers encounter when designing and building software applications.

They are established best practices that have evolved over time and have been identified as effective solutions to recurring design and architectural challenges in software development.

Design patterns provide a common vocabulary and framework for developers to communicate and share their knowledge about how to solve specific problems in a structured and maintainable way, addressing a variety of issues and problems in software development, including:

**Code Reusability:** Design patterns promote the reuse of proven, well-tested design and coding techniques, this can lead to more efficient development processes and less duplication of effort.

**Scalability:** They help in designing systems that can easily adapt and scale to changing requirements, whether it's adding new features or handling increased user loads.

**Maintainability:** Design patterns encourage clean and modular code, making it easier to maintain and extend software over time.

This can reduce the cost of maintenance and decrease the likelihood of introducing bugs.

**Flexibility:** Design patterns allow for flexibility in system design; developers can modify or extend existing patterns to fit specific project requirements without completely redesigning the entire system.

**Communication:** Design patterns provide a common language for developers to discuss and document solutions to common problems; this improves collaboration and knowledge sharing among team members.

**Performance:** While not all design patterns directly address performance concerns, some can help optimize code for better runtime efficiency.

**Separation of Concerns:** Many design patterns promote the separation of different concerns within an application, such as separating user interface logic from business logic, this separation improves code organization and maintainability.

**Testability:** Patterns that encourage loose coupling and modularity often make it easier to write unit tests and perform testing in isolation.

There are numerous design patterns, which are typically categorized into three main groups:

**Creational Patterns:** These patterns focus on object creation mechanisms, trying to create objects in a manner suitable to the situation.

Examples include the Singleton, Factory Method, and Abstract Factory patterns.

**Structural Patterns:** Structural patterns deal with object composition, helping to form relationships between objects to create larger, more complex structures.

Examples include the Adapter, Decorator, and Composite patterns.

**Behavioral Patterns:** Behavioral patterns are concerned with how objects interact and communicate with one another.

They help define the responsibilities of objects and how they collaborate.

Examples include the Observer, Strategy, and Command patterns.

By applying these design patterns appropriately, developers can make their software more maintainable, scalable, and adaptable while solving common design challenges effectively.

However, it's essential to use design patterns judiciously and not overcomplicate a solution by applying patterns unnecessarily.

The choice of a design pattern should always align with the specific needs and constraints of the project.

**SOLID principles.**

The SOLID principles were formulated in the early 2000s and deal with defining a certain style in software development.

If the programmer adopts certain practices, they will be able to write code that is clearer, more maintainable, modular, and testable.

These principles were formulated to address architectural issues in the development of larger projects that need to be maintained over time.

SOLID is an acronym and defines 5 important principles:

(S) Single Responsibility Principle (SRP)

(O) Open-Closed Principle (OCP)

(L) Liskov Substitution Principle (LSP)

(I) Interface Segregation Principle (ISP)

(D) Dependency Inversion Principle (DIP)

**Single responsability principle (SRP)**

This principle states that each object should have a single responsibility, dealing with a specific, singular task.

For example, if we have a bulletin board class, it should be responsible for post management, including creation, modification, and deletion, but not, for instance, for saving those posts.

The responsibility of the bulletin board class is therefore to handle posts, while the saving task would be delegated to another class.

This separation is important because, if we were to change the way posts are saved, such as switching from a database to a text file in the file system or the cloud, we would be forced to modify the bulletin board class, this would go against another principle we'll discuss, the Open-Closed Principle.

The goal is to write code that minimizes impact: if we need to modify the logic of post writing, we'll only need to modify the class responsible for that, such as, for example, a Feed class, which would be responsible solely for post management.

public class Feed

{

private readonly List<string> Posts = new List<string>();

private static int Count = 0;

public void AddPost(string Text)

{

Posts.Add($"{++Count}: {Text}");

}

public void RemovePost(int index)

{

Posts.RemoveAt(index);

}

public override string ToString()

{

StringBuilder sb = new StringBuilder();

Posts.ForEach(x => sb.Append(x));

return sb.ToString();

}

}

We might be tempted to add a "save" method to the class to save the posts, but this would violate the Single Responsibility Principle, therefore, we delegate the sole responsibility of saving the posts to a new manager:

public class SavingManager

{

public void Save(Feed feed, string fileName, bool overwrite = false)

{

if (overwrite || !File.Exists(fileName))

{

File.WriteAllText(fileName, feed.ToString());

}

}

}

So we can use the "feed" object and later save it using the following code.

It becomes evident that the creation and deletion of feeds, as well as their saving, are different activities delegated to different objects:

Feed feed = new Feed();

feed.AddPost($"This is the first post {Environment.NewLine}");

feed.AddPost($"This is the second post {Environment.NewLine}");

SavingManager savingManager = new SavingManager();

savingManager.Save(feed, @"C:\feed.txt");

**Open close principle (OCP).**

This principle dictates that well-structured code should always allow for the extension of its functionality while simultaneously preventing the modification of existing classes.

This is done so that the addition of new features happens through new modules, rather than by modifying existing ones, which would have significant impacts on the already written code.

Let's take an example: suppose we need to implement different types of invoices, each of which gives rise to a specific discount.

At first glance, we could write the following code, using enumeration to distinguish between the types and using an "if" statement to apply a specific discount based on the type:

public class Invoice

{

public double GetInvoiceDiscount(double amount, InvoiceType invoiceType)

{

double finalAmount = 0;

if (invoiceType == InvoiceType.FinalInvoice)

{

finalAmount = amount - 100;

}

else if (invoiceType == InvoiceType.ProposedInvoice)

{

finalAmount = amount - 50;

}

return finalAmount;

}

}

public enum InvoiceType

{

FinalInvoice,

ProposedInvoice

};

However, this code has a problem: it violates the Open-Closed Principle, because if in the future we need to add a new type of invoice, we will have to modify this class by adding a new "if" statement.

The solution is to create a base class that implements default behavior that can be overridden in the classes that inherit from it.

public class Invoice

{

public virtual double GetInvoiceDiscount(double amount)

{

return amount - 10;

}

}

Then, we proceed to have our concrete classes inherit from the interface, implementing the specific discount logic based on the type of invoice.

We will create a concrete class for each invoice type:

public class FinalInvoice : Invoice

{

public override double GetInvoiceDiscount(double amount)

{

return base.GetInvoiceDiscount(amount) - 50;

}

}

public class ProposedInvoice : Invoice

{

public override double GetInvoiceDiscount(double amount)

{

return base.GetInvoiceDiscount(amount) - 30;

}

}

This way, if we want to add a new invoice type, we will create a new concrete class, just like we did with FinalInvoice or ProposedInvoice.

In other words, we will simply add a new module without modifying an existing one.

The code that now adheres to the Open-Closed Principle can be used as follows:

Invoice finalInvoice = new FinalInvoice();

Invoice proposedInvoice = new ProposedInvoice();

double finalInvoiceAmount = finalInvoice.GetInvoiceDiscount(20000);

double proposedInvoiceAmount = proposedInvoice.GetInvoiceDiscount(20000);

**Liskov sobstitution principle**

This principle dictates that derived classes should be able to extend their base classes without modifying their behavior, meaning that derived classes should be substitutable for their base types.

Let's look at an example of a violation of this principle to better understand the concept.

Suppose you have a base class Animal:

public class Animal

{

public virtual void MakeSound()

{

Console.WriteLine("An animal makes a sound.");

}

}

Now, you create two derived classes, Dog and Cat, which inherit from the Animal class:

public class Dog : Animal

{

public override void MakeSound()

{

Console.WriteLine("A dog barks.");

}

}

public class Cat : Animal

{

public override void MakeSound()

{

Console.WriteLine("A cat meows.");

}

}

Suppose we introduce a new derived class called Fish that inherits from the Animal class:

public class Fish : Animal

{

// This class does not override the MakeSound method becouse Fish doesn't make sound

}

In this case, SilentAnimal is derived from Animal but does not override the MakeSound() method, which means it inherits the default behavior from the base class.

Now, let's see how this violates the Liskov Substitution Principle:

Animal myPet3 = new Fish();

myPet3.MakeSound(); // Output: An animal makes a sound.

In this example, we have created an instance of SilentAnimal and assigned it to a variable of type Animal.

When we call MakeSound() on myPet3, we get "An animal makes a sound," which is the default behavior inherited from the Animal base class, but this is wrong because the derived class contradicts the behavior of the base class

To implement a Fish class that adheres to the Liskov Substitution Principle you can override the MakeSound() method to provide a silent behavior, which is typically represented by an empty or minimal sound.

Here's how you can implement a Fish class:

public class Fish : Animal

{

public override void MakeSound()

{

// This class does not override the MakeSound method becouse Fish doesn't make sound

Console.WriteLine("A fish doesn't make sound");

}

}

**Interface segregation principle (ISP)**

The Interface Segregation Principle states that no client should be forced to implement large interfaces with numerous methods; a component should be scalable and, as such, should implement only the methods it needs by inheriting simple interfaces.

Let's take an example: suppose we need to implement a multifunction printer that can print, scan, and fax documents, if we build it this way, it consumes an interface with many heterogeneous methods:

class MultifunctionalPrinter : IMachine

{

public void fax(Document document)

{

}

public void Print(Document document)

{

}

public void Scan(Document document)

{

}

}

This is the interface implemented by the class above:

public interface IMachine

{

void Print(Document document);

void fax(Document document);

void Scan(Document document);

}

It's evident that the interface above is not generic and does not abstract, as if you wanted to implement a simple printer that only prints or a simple scanner, etc., and if we make our classes implement the same interface, we would be forced to implement unnecessary methods declared in the interface.

The solution is to break down the interface with many methods into multiple simple interfaces.

Afterward, the component can inherit from more than one interface (a class supports the ability to inherit from multiple interfaces in .NET, which is not possible when it tries to inherit from multiple classes).

public interface IPrinter

{

void Print(Document document);

}

public interface IScanner

{

void Scan(Document document);

}

public interface IFax

{

void Fax(Document document);

}

So, our simple printer will implement only the "print" method using the IPrint interface:

class Printer : IPrinter

{

public void Print(Document document)

{

}

}

While the multifunction printer can inherit from multiple interfaces.

class MultifunctionalPrinter : IPrinter, IScanner, IFax

{

public void Fax(Document document)

{

}

public void Scan(Document document)

{

}

public void Print(Document document)

{

}

}

**Dependency inversion principle (DIP)**

The Dependency Inversion Principle states that a high-level module should not depend on a low-level module, but both should depend on an abstraction.

An abstraction should not depend on details, and details should not depend on an abstraction.

In other words, the interaction between classes should occur through abstract classes or interfaces.

Let's see an example.

Suppose we want to implement a class that allows us to log errors:

class ExceptionLogger

{

private ILogger logger;

public ExceptionLogger(ILogger logger)

{

this.logger = logger;

}

public void LogException(Exception ex)

{

logger.LogMessage(ex.Message);

}

}

As we can see, the class is associated with an interface of type ILogger and not directly with a Logger object.

This association is referred to as loose coupling, as opposed to tight coupling where objects are strongly dependent on each other.

The ILogger interface is defined as follows:

public interface ILogger

{

void LogMessage(string message);

}

Weak coupling allows us to delegate the concrete implementation of how to log the message to a third class, so that the logic of the third class is completely independent of the described implementation context.

For example, we could decide to save messages to a database rather than a file like this:

class DbLogger : ILogger

{

public void LogMessage(string message)

{

//here saving logic on DB

}

}

class FileLogger : ILogger

{

public void LogMessage(string message)

{

//here saving logic on file

}

}

The client that instantiates the ExceptionLogger object to save the exception can decide whether to save errors to a database or a file like this:

ExceptionLogger el = new ExceptionLogger(new DbLogger());

//or

//ExceptionLogger el = new ExceptionLogger(new FileLogger());

try

{

//here some code...

}

catch (Exception ex)

{

el.LogException(ex);

}

Notice how we pass a concrete object, DbLogger, that implements the Ilogger interface to the ExceptionLogger constructor.

Therefore, the LogException method will use the logic defined in the DbLogger class to save the message to the database.

If we had passed an instance of FileLogger to our constructor, the message would be stored in a file.

This change has minimal impact on the overall logic, which remains almost identical in both cases.

If we needed to add a third error storage method, we would simply add a new concrete class that implements Ilogger, following the Open-Closed Principle.

In other words, we have created code that is open to future changes without impacting existing code.

**How design patterns follow SOLID principles?**

Design patterns and SOLID principles are complementary concepts in software engineering. SOLID is an acronym that represents a set of five principles aimed at promoting clean, maintainable, and flexible software design.

These principles guide developers in creating software that is easier to understand, extend, and maintain.

Design patterns, on the other hand, provide proven solutions to common design challenges.

Let's see how design patterns align with the SOLID principles:

**Single Responsibility Principle (SRP):**

This principle states that a class should have only one reason to change.

Design patterns often help in achieving SRP by promoting separation of concerns.

For example, the Observer pattern separates the subject (which changes) from the observers (which react to changes), thereby adhering to SRP.

**Open/Closed Principle (OCP):**

The OCP encourages software entities to be open for extension but closed for modification.

Many design patterns, such as the Strategy and Decorator patterns, follow this principle.

They allow you to add new behavior or features to a system without changing existing code.

**Liskov Substitution Principle (LSP):**

This principle states that objects of a derived class should be substitutable for objects of the base class without affecting the correctness of the program.

Some design patterns, like the Factory Method and Abstract Factory patterns, support the LSP by providing a way to create objects without specifying their concrete classes, thus ensuring that derived classes can be used interchangeably with their base class.

**Interface Segregation Principle (ISP):**

ISP suggests that clients should not be forced to depend on interfaces they don't use.

Design patterns like the Adapter and Bridge patterns can help adhere to ISP by allowing clients to interact with specific interfaces that are tailored to their needs rather than having a monolithic interface with unnecessary methods.

**Dependency Inversion Principle (DIP):**

DIP advocates that high-level modules should not depend on low-level modules but instead both should depend on abstractions.

Design patterns like the Dependency Injection (DI) pattern and the Observer pattern with the use of interfaces help achieve this principle by promoting the use of abstractions (interfaces or abstract classes) to decouple high-level and low-level modules.

In summary, design patterns can be seen as practical implementations of SOLID principles.

By applying design patterns in your software design, you are more likely to adhere to these principles, resulting in code that is modular, maintainable, and easier to extend without causing widespread changes.

Design patterns help to guide you in making design decisions that align with SOLID principles and promote good software design practices.

However, it's essential to understand both the principles and the patterns thoroughly and apply them judiciously to meet the specific needs of your project.

**Creational patterns.**

Creational design patterns are a category of design patterns that deal with object creation mechanisms, providing various ways to create objects while abstracting the instantiation process.

These patterns help manage object creation by controlling which classes to instantiate, how to instantiate them, and where to instantiate them.

Creational patterns aim to make a system more flexible, extensible, and independent of the specific classes it uses for object creation.

**Singleton Pattern**

The Singleton pattern is a creational design pattern that restricts the instantiation of a class to only one instance and provides a global point of access to that instance.

It is used to ensure that there is only one instance of a particular class in an application, and that instance can be easily accessed from anywhere in the codebase.

This is one example:

public sealed class Singleton

{

private static Singleton instance;

private static readonly object lockObject = new object();

private Singleton()

{

// Private constructor to prevent the creation of external instances.

}

public static Singleton Instance

{

get

{

if (instance == null)

{

lock (lockObject)

{

if (instance == null)

{

instance = new Singleton();

}

}

}

return instance;

}

}

// Other methods and properties of the Singleton class can be added here.

}

In this example:

The Singleton class has a private constructor, which means that instances of this class cannot be created directly from the outside.

The static variable instance keeps track of the single instance of the Singleton class. It is initialized as null initially.

The static property Instance is the access point to get the Singleton instance. If instance is null, a new Singleton object is created within a synchronized block to avoid concurrency issues.

The synchronized block ensures that only one thread at a time can create the Singleton instance and that the instance is created only when necessary.

Now you can use the Singleton in your code like this:

Singleton singleton1 = Singleton.Instance;

Singleton singleton2 = Singleton.Instance;

// The two variables singleton1 and singleton2 share the same Singleton instance.

Console.WriteLine(singleton1 == singleton2); // Should be "True".

When you call Singleton.Instance, it will always return the same shared instance of the Singleton class, regardless of how many times it is called.

This is useful for maintaining shared state or ensuring that there is only one instance of a class that manages, for example, database connections or application settings.

Here is a concrete example of using the Singleton pattern in a C# application to create a database connection manager:

public class DatabaseConnection

{

private static DatabaseConnection instance;

private string connectionString;

// Private constructor to avoid creating external instances.

private DatabaseConnection()

{

// Initialize the database connection string.

connectionString = “Server=example.com;Database=mydb;User=myuser;Password=mypassword;";

}

// Properties to access the Singleton instance.

public static DatabaseConnection Instance

{

get

{

if (instance == null)

{

instance = new DatabaseConnection();

}

return instance;

}

}

// Method for opening a database connection.

public void OpenConnection()

{

Console.WriteLine("Open database connection: " + connectionString);

// Here you can implement the code to open the database connection.

}

// Method for closing the database connection.

public void CloseConnection()

{

Console.WriteLine("Database connection closed: " + connectionString);

// Here you can implement the code to close the database connection.

}

}

you can use the DatabaseConnection in your code like this:

// Get the singleton instance of the database connection manager.

DatabaseConnection dbConnection = DatabaseConnection.Instance;

// Open and close the database connection.

dbConnection.OpenConnection();

dbConnection.CloseConnection();

// Verify that the singleton instances are the same.

DatabaseConnection dbConnection2 = DatabaseConnection.Instance;

Console.WriteLine(dbConnection == dbConnection2); // Should print "True".

In this example, DatabaseConnection is a Singleton class that manages the database connection.

The Singleton instance is accessible through the static property Instance.

You can open and close the database connection using the OpenConnection and CloseConnection methods. Being a Singleton class, the operations of opening and closing the connection are performed on the same instance throughout the application, ensuring that multiple connections to the database are not opened.

Here is another concrete example of Singleton represented by the general setting options for managing an application:

public class AppSettings

{

private Dictionary<string, string> settings;

// Instantiate the Singleton when the class is loaded.

private static readonly AppSettings instance = new AppSettings();

// Private constructor to avoid creating external instances.

private AppSettings()

{

// Initialize settings with default values.

settings = new Dictionary<string, string>

{

{ "BackgroundColor", "White" },

{ "FontColor", "Black" },

{ "FontSize", "12pt" }

};

}

// Property for accessing the Singleton instance.

public static AppSettings Instance

{

get { return instance; }

}

// Method to get the value of a specific setting.

public string GetSetting(string key)

{

if (settings.ContainsKey(key))

{

return settings[key];

}

else

{

return null;// Return null if the key does not exist.

}

}

// Method for setting the value of a specific setting.

public void SetSetting(string key, string value)

{

if (settings.ContainsKey(key))

{

settings[key] = value;

}

else

{

settings.Add(key, value);

}

}

}

It's interesting to note that the appsetting instance is obtained when the instance is loaded, which has a drawback - the instance will occupy memory for the entire lifetime of the application, and there's no way to finalize it.

You can use Appsettings in your code like this:

// Get the Singleton instance of the application settings.

AppSettings appSettings = AppSettings.Instance;

// Read and change settings.

Console.WriteLine("Background Color: " + appSettings.GetSetting("BackgroundColor"));

Console.WriteLine("Font Color: " + appSettings.GetSetting("FontColor"));

// Changing the setting.

appSettings.SetSetting("BackgroundColor", "Blue");

Console.WriteLine("Updated Background Color: " + appSettings.GetSetting("BackgroundColor"));

// Check that changes are reflected everywhere.

AppSettings appSettings2 = AppSettings.Instance;

Console.WriteLine("Background Color in Another Instance: " + appSettings2.GetSetting("BackgroundColor"));

// The Singleton instance is the same for appSettings and appSettings2.

Console.WriteLine(appSettings == appSettings2); // Should print "True".

In this example, AppSettings is a Singleton class that manages application settings.

There is only one instance of AppSettings, accessible through the static property Instance.

You can read and modify settings through the GetSetting and SetSetting methods.

Changes made to settings through one instance are reflected in all other instances since they share the same Singleton instance.

**State**

The State Pattern is a behavioral design pattern that allows an object to alter its behavior when its internal state changes.

The pattern achieves this by defining a set of state classes that encapsulate the behavior associated with different states and allowing the context (the object whose behavior changes) to switch between these states seamlessly.

Here's a breakdown of the key components of the State Pattern:

**Context**: This is the object that maintains a reference to the current state object and delegates the behavior to that state object.

The context can change its state by transitioning to a different state object.

**State**: This is an interface or an abstract class that defines a set of methods that represent the different states the context can be in.

Each concrete state class implements these methods to provide specific behavior for that state.

**Concrete State**: These are the classes that implement the State interface or inherit from the State abstract class. Each concrete state class defines the behavior associated with a particular state of the context.

Now, let's see an example of the State Pattern in C#:

Suppose we are building a simple audio player that can be in different playback states: Playing, Paused, and Stopped. We'll use the State Pattern to manage these states.

// State interface

public interface IState

{

void Play();

void Pause();

void Stop();

}

// Concrete State classes

public class PlayingState : IState

{

public void Play()

{

Console.WriteLine("Already playing.");

}

public void Pause()

{

Console.WriteLine("Pausing the playback.");

}

public void Stop()

{

Console.WriteLine("Stopping the playback.");

}

}

public class PausedState : IState

{

public void Play()

{

Console.WriteLine("Resuming the playback.");

}

public void Pause()

{

Console.WriteLine("Already paused.");

}

public void Stop()

{

Console.WriteLine("Stopping the playback.");

}

}

public class StoppedState : IState

{

public void Play()

{

Console.WriteLine("Starting playback.");

}

public void Pause()

{

Console.WriteLine("Cannot pause, the player is stopped.");

}

public void Stop()

{

Console.WriteLine("Already stopped.");

}

}

// Context class

public class AudioPlayer

{

private IState currentState;

public AudioPlayer()

{

currentState = new StoppedState(); // Initial state is Stopped

}

public void ChangeState(IState newState)

{

currentState = newState;

}

public void Play()

{

currentState.Play();

}

public void Pause()

{

currentState.Pause();

}

public void Stop()

{

currentState.Stop();

}

}

Now you can use your state pattern in your client application like that:

AudioPlayer player = new AudioPlayer();

player.Play(); // Output: Starting playback.

player.Pause(); // Output: Cannot pause, the player is stopped.

player.Stop(); // Output: Already stopped.

player.Play(); // Output: Starting playback.

player.Pause(); // Output: Pausing the playback.

In this example, we have the AudioPlayer context class that can be in different states (Playing, Paused, Stopped).

The IState interface defines the methods that represent the possible actions the player can take in each state.

The concrete state classes (PlayingState, PausedState, and StoppedState) implement these methods to provide specific behavior for each state.

By changing the state of the AudioPlayer using the ChangeState method, we can control its behavior based on its current state.

This is the essence of the State Pattern, where the behavior of an object changes based on its internal state.

Let’s see another example: a traffic light implementation.

A traffic light can be in several states: Red, Yellow, and Green.

// State interface

public interface ITrafficLightState

{

void Handle(TrafficLight trafficLight);

}

// Concrete State classes

public class RedState : ITrafficLightState

{

public void Handle(TrafficLight trafficLight)

{

Console.WriteLine("Traffic light is red. Stop!");

Thread.Sleep(2000); // Simulate red light duration

trafficLight.ChangeState(new GreenState());

}

}

public class YellowState : ITrafficLightState

{

public void Handle(TrafficLight trafficLight)

{

Console.WriteLine("Traffic light is yellow. Prepare to stop.");

Thread.Sleep(1000); // Simulate yellow light duration

trafficLight.ChangeState(new RedState());

}

}

public class GreenState : ITrafficLightState

{

public void Handle(TrafficLight trafficLight)

{

Console.WriteLine("Traffic light is green. Go!");

Thread.Sleep(2000); // Simulate green light duration

trafficLight.ChangeState(new YellowState());

}

}

// Context class

public class TrafficLight

{

private ITrafficLightState currentState;

public TrafficLight()

{

currentState = new RedState(); // Initial state is Red

}

public void ChangeState(ITrafficLightState newState)

{

currentState = newState;

}

public void Request()

{

currentState.Handle(this);

}

}

And here the code to simulate the change of traffic light’s state:

TrafficLight trafficLight = new TrafficLight();

for (int i = 0; i < 5; i++)

{

trafficLight.Request();

}

In this example, we have a TrafficLight context class that can be in three states: RedState, YellowState, and GreenState.

Each state implements the ITrafficLightState interface and defines the behavior associated with that state.

The TrafficLight class uses the State Pattern to change its state based on the current state of the traffic light.

In the Main method, we create a TrafficLight object and simulate the behavior of a traffic light by repeatedly calling the Request method.

The traffic light transitions between red, yellow, and green states based on the specified durations, simulating a real-world traffic light.

**Strategy**

The Strategy Pattern is a behavioral design pattern that defines a family of algorithms, encapsulates each one, and makes them interchangeable.

It allows you to select an algorithm at runtime based on the context or the specific requirements of a task.

This pattern promotes the principle of "composition over inheritance" by favoring object composition over static inheritance.

Here's how the Strategy Pattern works:

Define a family of algorithms (strategies) that perform a specific task.

Create an interface or an abstract class that declares a method to execute the strategy.

Implement concrete strategy classes that provide different implementations of the strategy interface.

In the context class, maintain a reference to the strategy interface and use it to execute the selected strategy.

Here's a simple example of the Strategy Pattern in C#:

Suppose you are building a payment processing system where you can apply different payment methods (e.g., credit card, PayPal, Bitcoin) to make payments.

You want to make the payment method interchangeable at runtime.

Define the strategy interface:

public interface IPaymentStrategy

{

void ProcessPayment(double amount);

}

Implement concrete strategy classes for different payment methods:

public class CreditCardPayment : IPaymentStrategy

{

public void ProcessPayment(double amount)

{

Console.WriteLine($"Paid {amount:C} using Credit Card.");

// Add logic to process payment via credit card here

}

}

public class PayPalPayment : IPaymentStrategy

{

public void ProcessPayment(double amount)

{

Console.WriteLine($"Paid {amount:C} using PayPal.");

// Add logic to process payment via PayPal here

}

}

public class BitcoinPayment : IPaymentStrategy

{

public void ProcessPayment(double amount)

{

Console.WriteLine($"Paid {amount:C} using Bitcoin.");

// Add logic to process payment via Bitcoin here

}

}

Create a context class that allows you to change the payment strategy:

public class ShoppingCart

{

private IPaymentStrategy paymentStrategy;

public ShoppingCart(IPaymentStrategy strategy)

{

this.paymentStrategy = strategy;

}

public void Checkout(double totalAmount)

{

paymentStrategy.ProcessPayment(totalAmount);

}

public void SetPaymentStrategy(IPaymentStrategy strategy)

{

this.paymentStrategy = strategy;

}

}

Now, you can use the Strategy Pattern in your client:

var cart = new ShoppingCart(new CreditCardPayment());

// Make a payment

cart.Checkout(100.00);

// Change the payment method to PayPal

cart.SetPaymentStrategy(new PayPalPayment());

// Make another payment with the new payment method (PayPal)

cart.Checkout(50.00);

// Change the payment method to Bitcoin

cart.SetPaymentStrategy(new BitcoinPayment());

// Make another payment with the new payment method (Bitcoin)

cart.Checkout(200.00);

**Template method.**

The Template Method Pattern is used in object-oriented programming to define the skeleton or outline of an algorithm in a method, while allowing some of the steps within the algorithm to be implemented by subclasses.

This pattern promotes code reusability and helps in defining a common structure for a set of related algorithms.

Here's how the Template Method Pattern works:

A superclass (or abstract class) defines a template method that outlines the steps of an algorithm but leaves certain steps to be implemented by concrete subclasses.

This template method is often declared as final to prevent subclasses from altering the algorithm's structure.

The template method consists of a series of method calls, which are either abstract or concrete methods.

The abstract methods are placeholders for the steps that subclasses need to implement, while the concrete methods provide default or shared behavior that can be reused by all subclasses.

Subclasses inherit from the superclass and provide concrete implementations for the abstract methods, customizing the algorithm to their specific needs.

They can also choose to override any of the concrete methods to tailor the behavior as required.

When a client code interacts with the template method, it uses the method provided by the superclass.

This ensures that the algorithm's structure remains consistent across different subclasses while allowing for customization of specific steps.

Benefits of the Template Method Pattern are:

**Code Reusability:** The common steps of an algorithm are implemented in the template method, promoting code reuse among subclasses.

**Consistency:** The pattern enforces a consistent structure for related algorithms, making the code easier to understand and maintain.

**Customization:** Subclasses can customize specific steps of the algorithm while keeping the overall structure intact.

**Reduced Duplication:** The pattern reduces code duplication by encapsulating shared behavior in the superclass.

**Extension without Modification:** You can add new subclasses with different implementations without modifying the existing code in the superclass.

Example use cases for the Template Method Pattern include implementing sorting algorithms (where the comparison and swapping steps are customized by subclasses), document processing (where different document types may have unique processing steps), and game frameworks (where game loops or player actions may vary but share common structures).

Here's an example of the Template Method Pattern in C#. In this example, we'll create a template for building different types of sandwiches:

// Abstract class defining the template method

abstract class Sandwich

{

public void MakeSandwich()

{

PrepareBread();

AddIngredients();

AddCondiments();

WrapSandwich();

}

protected abstract void PrepareBread();

protected abstract void AddIngredients();

protected abstract void AddCondiments();

protected virtual void WrapSandwich()

{

Console.WriteLine("Wrap the sandwich in paper.");

}

}

// Concrete subclass 1 for creating a BLT sandwich

class BLTSandwich : Sandwich

{

protected override void PrepareBread()

{

Console.WriteLine("Prepare white bread for BLT.");

}

protected override void AddIngredients()

{

Console.WriteLine("Add bacon, lettuce, and tomato.");

}

protected override void AddCondiments()

{

Console.WriteLine("Add mayonnaise and mustard.");

}

}

// Concrete subclass 2 for creating a Veggie sandwich

class VeggieSandwich : Sandwich

{

protected override void PrepareBread()

{

Console.WriteLine("Prepare whole wheat bread for Veggie sandwich.");

}

protected override void AddIngredients()

{

Console.WriteLine("Add lettuce, tomato, cucumber, and bell peppers.");

}

protected override void AddCondiments()

{

Console.WriteLine("Add hummus and balsamic dressing.");

}

protected override void WrapSandwich()

{

Console.WriteLine("Wrap the Veggie sandwich in foil.");

}

}

You can use Template method pattern in your code like this:

Console.WriteLine("Making a BLT Sandwich:");

Sandwich bltSandwich = new BLTSandwich();

bltSandwich.MakeSandwich();

Console.WriteLine("\nMaking a Veggie Sandwich:");

Sandwich veggieSandwich = new VeggieSandwich();

veggieSandwich.MakeSandwich();

In this C# example:

Sandwich is an abstract class that defines the template method MakeSandwich().

It also declares three abstract methods PrepareBread(), AddIngredients(), and AddCondiments(), which must be implemented by concrete subclasses.

It also provides a default implementation for the WrapSandwich() method, which can be overridden by subclasses.

BLTSandwich and VeggieSandwich are concrete subclasses that inherit from Sandwich.

They provide specific implementations for the abstract methods to create different types of sandwiches.

The VeggieSandwich class overrides the WrapSandwich() method to customize the wrapping behavior.

In the Main method, we create instances of BLTSandwich and VeggieSandwich and then make sandwiches using the MakeSandwich() method.

The template method ensures that the sandwich-making process follows a consistent structure, with bread preparation, ingredient addition, and condiment application, while allowing for customization in each sandwich type.

When you run this C# code, you will see output demonstrating the use of the Template Method Pattern to create different types of sandwiches with a shared preparation process but varying ingredients and wrapping.

**Visitor Pattern.**

The Visitor pattern is used in object-oriented programming to separate the algorithm from the structure of an object.

It allows you to add new operations or behaviors to a set of objects without modifying their class definitions.

The primary purpose of the Visitor pattern is to achieve the following goals:

**Separation of Concerns:** The Visitor pattern separates the behavior (or algorithm) from the elements (or objects) that it operates on.

This separation makes it easier to add new behaviors to a set of objects without modifying their classes, which can be especially useful when working with classes that you don't have control over or that are part of a complex inheritance hierarchy.

**Open-Closed Principle:** The pattern adheres to the open-closed principle, which states that software entities (classes, modules, functions, etc.) should be open for extension but closed for modification. With the Visitor pattern, you can introduce new behaviors (visitor implementations) without altering the existing codebase.

**Double Dispatch:** The Visitor pattern allows for double dispatch, which is a mechanism that enables the selection of a specific method or operation based on both the type of the object being visited and the type of the visitor.

This enables more flexible and dynamic behavior selection.

Common scenarios where the Visitor pattern is useful include:

When you have a complex object structure with various classes, and you want to perform different operations on these objects without modifying their class hierarchy.

When you need to add new behaviors or operations to a set of classes without altering their source code, especially in situations where you can't modify the existing classes.

When you want to achieve dynamic dispatch based on both the type of the object being visited and the type of the visitor.

In essence, the Visitor pattern provides a way to achieve polymorphism in situations where traditional inheritance and method overriding may not be the most suitable solution.

It allows you to extend the functionality of classes in a more modular and maintainable manner.

However, it does introduce some complexity and can make the code harder to understand if not used judiciously, so it should be applied with care.

// Define the abstract Element class that will be visited by the Visitor.

abstract class Element

{

public abstract void Accept(IVisitor visitor);

}

// Concrete TextElement class representing text content.

class TextElement : Element

{

public string Text { get; set; }

public override void Accept(IVisitor visitor)

{

visitor.VisitTextElement(this);

}

}

// Concrete HyperlinkElement class representing hyperlinks.

class HyperlinkElement : Element

{

public string Url { get; set; }

public string Text { get; set; }

public override void Accept(IVisitor visitor)

{

visitor.VisitHyperlinkElement(this);

}

}

// Define the Visitor interface.

interface IVisitor

{

void VisitTextElement(TextElement textElement);

void VisitHyperlinkElement(HyperlinkElement hyperlinkElement);

}

// Concrete implementation of HTML generation visitor.

class HtmlVisitor : IVisitor

{

public void VisitTextElement(TextElement textElement)

{

Console.WriteLine($"<p>{textElement.Text}</p>");

}

public void VisitHyperlinkElement(HyperlinkElement hyperlinkElement)

{

Console.WriteLine($"<a href=\"{hyperlinkElement.Url}\">{hyperlinkElement.Text}</a>");

}

}

// Concrete implementation of plain text generation visitor.

class PlainTextVisitor : IVisitor

{

public void VisitTextElement(TextElement textElement)

{

Console.WriteLine(textElement.Text);

}

public void VisitHyperlinkElement(HyperlinkElement hyperlinkElement)

{

Console.WriteLine($"{hyperlinkElement.Text} ({hyperlinkElement.Url})");

}

}

You can use Visitor pattern in your code like this:

// Create a list of elements in a document.

List<Element> elements = new List<Element>

{

new TextElement { Text = "This is a paragraph of text." },

new HyperlinkElement { Url = "https://www.example.com", Text = "Visit Example.com" }

};

// Create visitors (HTML and plain text) and apply them to the elements.

IVisitor htmlVisitor = new HtmlVisitor();

IVisitor plainTextVisitor = new PlainTextVisitor();

Console.WriteLine("HTML Output:");

foreach (var element in elements)

{

element.Accept(htmlVisitor);

}

Console.WriteLine("\nPlain Text Output:");

foreach (var element in elements)

{

element.Accept(plainTextVisitor);

}

In this example:

We define two concrete element classes: TextElement representing text content and HyperlinkElement representing hyperlinks.

Both classes inherit from the abstract Element class and implement the Accept method.

We define an IVisitor interface with methods for visiting each type of element (e.g., VisitTextElement and VisitHyperlinkElement).

We implement two concrete visitor classes: HtmlVisitor for generating HTML output and PlainTextVisitor for generating plain text output.

Both visitors implement the IVisitor interface and define how to process each type of element.

In the Main method, we create a list of elements in a document and two visitors.

We then iterate through the elements, applying each visitor, which generates the desired output format based on the type of element.

This example demonstrates how the Visitor pattern allows you to separate the behavior (output generation) from the structure of the document elements, enabling you to add new output formats (visitors) without modifying the element classes.