Design Patterns

Design patterns help programmers in many ways; as these patterns make programmes more understandable, easily adaptable across other systems, easier to upgrade, etc. They are basically blueprints for common programming problems.

- Creational

These patterns are for creating flexible, efficient objects.

  - Builder
    - To create complex object piecewise & succinity

To create an object with too many specifications can be done by using parameters for every specification. Yet, implementing like this is costful since there can be many unused parameters. Instead of using parameters we can use ‘builder’s. They are simply helper functions for other vicinities of an object. Sometimes a ‘director’ is needed for directing building steps.

Example: There can be many options for a car (color, park censors, cruise control, speed limiter, etc.).

```
class Car():
    def __init__(self) -> None:
        self.options = []

    def add(self, option) -> None:
        self.options.append(option)

class Builder():
    def __init__(self) -> None:
        self.car=Car()

    def option_A(self) -> None:
        self.car.add("option_A")
        print("Car has option A")

    def option_B(self) -> None:
        self.car.add("option_B")
        print("Car has option B")

    def option_C(self) -> None:
        self.car.add("option_C")
        print("Car has option C")
```

  - Factory
    - To create wholesale objects unlike builder

While the builder method works from piece by piece to form an object, the factory method works as constructing objects from one source (class). Subclasses help us to define the factory method to create an instance of the appropriate product.

Example: Most cars are created by factories.

```
#Define a Factory class
```

```
class Creator():
    def factory_method(self):
        pass

    def operation(self):
        product = self.factory_method()
        if product:
            product.operation()

#Define Factory subclasses
class ConcreteCreator_1(Creator):
    def factory_method(self):
        return Car_1()

class ConcreteCreator_2(Creator):
    def factory_method(self):
        return Car_2()

#Define a Car class
class Car():
    def operation(self):
        pass

#Define Car subclasses
class Car_1(Car):
    def operation(self):
        print("Producing Car_1")

class Car_2(Car):
    def operation(self):
        print("Producing Car_2")
```

- Prototype
  - To create new object cheaply

Instead of creating a new object from ground-up, copying an already existing object is simpler and faster (with proper background).

Example: With prototype class an object can be instantiated, registered, and cloned (if object exists).

```
class Prototype:
    def __init__(self):
        self.objects = {}

    def register_object(self, name, obj):
```

```
        self.objects[name] = obj

    def unregister_object(self, name):
        del self.objects[name]

    def clone(self, name, **kwargs):
        obj = self.objects.get(name)
        if obj:
            cloned_obj = obj.clone(**kwargs)
            return cloned_obj
        else:
            raise ValueError(f"Object with name '{name}' does not
exist.")

class ConcreteObject:
    def __init__(self, x, y, color):
        self.x = x
        self.y = y
        self.color = color

    def clone(self, **kwargs):
        x = kwargs.get('x', self.x)
        y = kwargs.get('y', self.y)
        color = kwargs.get('color', self.color)
        obj = self.__class__(x, y, color)
        return obj
```

- Singleton
  - To create one and only on instance of class

There can be only one instance of a class. This can be implemented by checking if there exists that class before adding a new class.

Example:

```
class Singleton:
   _instance = None

   @staticmethod
   def get_instance():
       if Singleton._instance is None:
           Singleton._instance = Singleton()
       return Singleton._instance

   def __init__(self):
```

```
        if Singleton._instance is not None:
            raise Exception("This class is a Singleton!")
```

- Structural

These patterns are for constructing a system; using objects and classes, maintaining flexibility and efficiency.

  - Adapter
    - To get the interface you want from interface you have

Objects we have and objects that are wanted from us (by somebody else, or by another program) can be in different forms. To solve this we use adapters, we alter objects for expectations.

There are two main ways to implement this: Object Composition, inheriting interface of one object while wrapping other object (can be implemented in all programming languages); Inheritance, inheriting interface of both objects (programming language must support multiple inheritance).

Example:

```
class Target:
    def request(self) -> str:
        return "Target: The default target's behavior."


class Adaptee:
    def specific_request(self) -> str:
        return ".eetpadA eht fo roivaheb laicepS"


class Adapter(Target):
    #This is an example of object composition.
    #To adapt with inheritance we take Adaptee as an argument, and we
will not need an initiator (constructor).
    def __init__(self, adaptee: Adaptee) -> None:
        self.adaptee = adaptee

    def request(self) -> str:
        return f"Adapter: (TRANSLATED)
{self.adaptee.specific_request()[::-1]}"


def client_code(target: Target) -> None:
    #Client code is crucial (requests can change) but the target
interface must be met.
    try:
        print(target.request(), end="")
    except AttributeError as error:
```

```
        print(f"Error: {error}")
```

- Bridge
  - To separate the interface from implementation

This 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. For an object (circle) ‘abstraction’ includes initiators of the object (radius, location, etc.), ‘implementation’ includes more intricate options of the object (color, fullness of inside, etc.); and the bridge method builds a bridge between these two hierarchies.

Example:

```
# Implementing the Abstraction class
class Shape:
    def __init__(self, color):
        self.color = color

    def draw(self):
        pass

# Implementing the Concrete Implementor classes
class RedColor:
    def fill_color(self):
        return "Red"

class BlueColor:
    def fill_color(self):
        return "Blue"

# Implementing the Refined Abstraction classes
class Circle(Shape):
    def draw(self):
        return f"Drawing Circle with {self.color.fill_color()} color"

class Square(Shape):
    def draw(self):
        return f"Drawing Square with {self.color.fill_color()} color"
```

- Composite
  - To treat individual & group of objects uniformly

This 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. Working with this method only makes sense if the core model of the app is representable as a tree.

Example: A component is an object structured as a tree. Composite and Leaf classes build this object.

```
# Base class for components
class Component:
    def operation(self):
        pass

# Leaf component
class Leaf(Component):
    def operation(self):
        print("Leaf operation")

# Composite component
class Composite(Component):
    def __init__(self):
        self._children = []

    def add(self, component):
        self._children.append(component)

    def remove(self, component):
        self._children.remove(component)

    def operation(self):
        print("Composite operation")
        for child in self._children:
            child.operation()
```

- Decorator
  - To facilitate the additional functionality to objects

This 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. Instead of creating new subclasses for different combinations of classes, create composition/aggregation (Aggregation: object A contains objects B; B can live without A. Composition: object A consists of objects B; A manages life cycle of B; B can't live without A.) links between classes.

Example:

```
# Define the base component interface
class Component:
    def operation(self):
        pass

# Concrete component
class ConcreteComponent(Component):
    def operation(self):
        print("Performing the operation in the concrete component.")
```

```
# Base decorator class
class Decorator(Component):
    def __init__(self, component):
        self.component = component

    def operation(self):
        self.component.operation()

# Concrete decorator class
class ConcreteDecoratorA(Decorator):
    def operation(self):
        super().operation()
        self.additional_operation()

    def additional_operation(self):
        print("Adding additional operation in ConcreteDecoratorA.")

# Another concrete decorator class
class ConcreteDecoratorB(Decorator):
    def operation(self):
        super().operation()
        self.additional_operation()

    def additional_operation(self):
        print("Adding additional operation in ConcreteDecoratorB.")
```

- Facade
  - To provide unified interface by hiding system complexities

This is a structural design pattern that provides a simplified interface to a library, a framework, or any other complex set of classes.

Example: To hide complex subclasses write a simple interface.

```
# Subsystem 1
class Subsystem1:
    def method1(self):
        print("Subsystem 1: Method 1")

    def method2(self):
        print("Subsystem 1: Method 2")


# Subsystem 2
```

```
class Subsystem2:
    def method1(self):
        print("Subsystem 2: Method 1")

    def method2(self):
        print("Subsystem 2: Method 2")


# Facade
class Facade:
    def __init__(self):
        self.subsystem1 = Subsystem1()
        self.subsystem2 = Subsystem2()

    def operation(self):
        self.subsystem1.method1()
        self.subsystem1.method2()
        self.subsystem2.method1()
        self.subsystem2.method2()
```

- Flyweight
  - To avoid redundancy when storing data

This is a structural design pattern that lets you fit more objects into the available amount of memory by sharing common parts of state between multiple objects instead of keeping all of the data in each object. When objects share similar parts keep their shared data in the same memory location for memory efficiency, yet this memory efficiency gets traded with increasing CPU cycles.

Example:

```
class Flyweight:
#keeps data. by default initialized to shared data, it can be changed
to unique data.
    def __init__(self, shared_state):
        self.shared_state = shared_state

    def operation(self, unique_state):
        print(f"Flyweight: shared state({self.shared_state}) and unique
state({unique_state})")

class FlyweightFactory:
#creates new objects.
    def __init__(self):
        self.flyweights = {}

    def get_flyweight(self, shared_state):
```

```
        if shared_state not in self.flyweights:
            self.flyweights[shared_state] = Flyweight(shared_state)
        return self.flyweights[shared_state]
```

- Proxy
  - An interface for accessing a particular resource

This 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. This is needed because real objects can not always be present and yet it may get called any time. Initializing an object after a call can be impossible since there can be private classes, functions; and it would be slow. Therefore, we will initialize a proxy object that is a placeholder of the real object; do the updates, read necessary data from this proxy object.

Example: An image database with proxy object implementation

```
# Subject interface
class Image:
    def display(self):
        pass

# Real Subject class
class RealImage(Image):
    def __init__(self, filename):
        self._filename = filename
        self.load_from_disk()

    def load_from_disk(self):
        print(f"Loading image: {self._filename}")

    def display(self):
        print(f"Displaying image: {self._filename}")

# Proxy class
class ProxyImage(Image):
    def __init__(self, filename):
        self._filename = filename
        self._real_image = None

    def display(self):
        if self._real_image is None:
            self._real_image = RealImage(self._filename)
        self._real_image.display()
```

- Behavioural

These patterns are for assigning responsibilities and communicating effectively between objects.

- Chain of Responsibility
  - To handle the request by more than one object

This 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. This works when there are multiple security levels in a project such as an e-commerce website with users: buyer, seller, admin there should be different levels of authorization.

Example: There is a Handler class with subclasses A, B, C which can have requests and successors.

```
class Handler:
    def __init__(self, successor=None):
        self._successor = successor

    def handle_request(self, request):
        pass

class ConcreteHandlerA(Handler):
    def handle_request(self, request):
        if request == 'A':
            print("ConcreteHandlerA handles the request.")
        elif self._successor is not None:
            self._successor.handle_request(request)

class ConcreteHandlerB(Handler):
    def handle_request(self, request):
        if request == 'B':
            print("ConcreteHandlerB handles the request.")
        elif self._successor is not None:
            self._successor.handle_request(request)

class ConcreteHandlerC(Handler):
    def handle_request(self, request):
        if request == 'C':
            print("ConcreteHandlerC handles the request.")
        elif self._successor is not None:
            self._successor.handle_request(request)
```

- Command
  - To decouple the sender & receiver

This 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. This method does not help with writing an uncomplicated code since we need to write every layer for both sender and receiver.

Example:

```python
# Receiver class
class Light:
    def turn_on(self):
        print("Light is on.")

    def turn_off(self):
        print("Light is off.")

# Command interface
class Command:
    def execute(self):
        pass

# Concrete command classes
class TurnOnCommand(Command):
    def __init__(self, light):
        self.light = light

    def execute(self):
        self.light.turn_on()

class TurnOffCommand(Command):
    def __init__(self, light):
        self.light = light

    def execute(self):
        self.light.turn_off()

# Invoker class (sender interface)
class RemoteControl:
    def __init__(self):
        self.command = None

    def set_command(self, command):
        self.command = command

    def press_button(self): #executes command
        if self.command is not None:
            self.command.execute()
        else:
            print("No command is set.")
```

- Interpreter
  - To process structured text data

This is a behavioral design pattern that defines a way to evaluate or interpret sentences in a language. It provides a way to represent and evaluate grammar or language rules. The pattern is commonly used in the field of programming languages, compilers, and natural language processing.

Example:

```
# Abstract Expression
class Expression:
    def interpret(self, context):
        pass

# Terminal Expression
class Number(Expression):
    def __init__(self, value):
        self.value = value

    def interpret(self, context):
        return self.value

# Terminal Expression
class Plus(Expression):
    def __init__(self, left, right):
        self.left = left
        self.right = right

    def interpret(self, context):
        return self.left.interpret(context) +
self.right.interpret(context)

# Context
class Context:
    def __init__(self):
        self.variables = {}

    def set_variable(self, variable, value):
        self.variables[variable] = value

    def get_variable(self, variable):
        return self.variables.get(variable)
```

- Iterator
  - To facilitate the traversal of data structure

This is a behavioral design pattern that lets you traverse elements of a collection without exposing its underlying representation (list, stack, tree, etc.).

Example: This is a list iterator. After initializing data to a list we can go through the list.

```
class MyIterator:
    def __init__(self, data):
        self.data = data
        self.index = 0

    def __iter__(self):
        return self

    def __next__(self):
        if self.index >= len(self.data):
            raise StopIteration
        value = self.data[self.index]
        self.index += 1
        print(value)  # Print the value inside the iterator
        return value
```

- Mediator
  - To facilitate communication between objects

This 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. This makes communications centralized.

Example: There are component objects, between these objects communications done by mediator.

```
class Mediator:
    def __init__(self):
        self.components = []

    def add_component(self, component):
        self.components.append(component)

    def notify(self, sender, event):
        for component in self.components:
            if component != sender:
                component.receive(event)

class Component:
    def __init__(self, mediator):
        self.mediator = mediator

    def send(self, event):
```

```
        self.mediator.notify(self, event)

    def receive(self, event):
        print(f"Received event: {event}")
```

- Memento
  - To store/restore the state of the object

This is a behavioral design pattern that lets you save and restore the previous state of an object without revealing the details of its implementation.

Example:

```
class Originator:
    #user interface for changing and restoring states
    def __init__(self):
        self._state = None
        self._caretaker = Caretaker()

    def set_state(self, state):
        print(f"Setting state to: {state}")
        self._state = state
        self._caretaker.add_memento(Memento(self._state))

    def restore_state(self, index):
        memento = self._caretaker.get_memento(index)
        self._state = memento.get_state()
        print(f"State restored to: {self._state}")

class Memento:
    #is a container that stores states
    def __init__(self, state):
        self._state = state

    def get_state(self):
        return self._state

class Caretaker:
    #keeps track of the stored data of states
    def __init__(self):
        self._mementos = []

    def add_memento(self, memento):
        self._mementos.append(memento)
```

```
    def get_memento(self, index):
        return self._mementos[index]
```

- Observer
  - To get notifications when events happen

This 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.

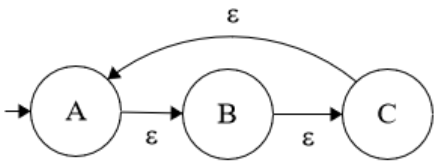
Example: Observers are subscribers to a subject. After updates occur observers get notified (this can be done automatically).

```
class Subject:
    def __init__(self):
        self._observers = []

    def attach(self, observer):
        self._observers.append(observer)

    def detach(self, observer):
        self._observers.remove(observer)

    def notify(self, message):
        for observer in self._observers:
            observer.update(message)

class Observer:
    def update(self, message):
        pass

# Example notifications (users)
class EmailNotification(Observer):
    def update(self, message):
        print("Sending email notification:", message)

class SMSNotification(Observer):
    def update(self, message):
        print("Sending SMS notification:", message)
```

- State
  - To implement the object's behavior by its state

This method shows similarity to 'Finite State Machine's as state changes can be done with conditions and in different states different operations can be done. This 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. Different from Strategy method states may know about each other. Throughout the states different alterations can happen to the object, and this can be done multiple times.

Ex: This code represents shown finite state machine. (State changes and operations can be way more complex.)




```
class State:
    def do_action(self, context):
        pass

class StateA(State):
    def do_action(self, context):
        print("State A action")
        context.state = StateB()

class StateB(State):
    def do_action(self, context):
        print("State B action")
        context.state = StateC()

class StateC(State):
    def do_action(self, context):
        print("State C action")
        context.state = StateA()

class Context:
    def __init__(self):
        self.state = StateA()

    def request(self):
        self.state.do_action(self)
```

- Strategy
  - To facilitate the algorithm's flexibility

This 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. Different from State method strategies almost never know about each other.

Example:

```
from typing import Union
```

```
# Strategies
class Strategy:
    def do_operation(self, num1, num2):
        pass

class AddStrategy(Strategy):
    def do_operation(self, num1, num2):
        return num1 + num2

class SubtractStrategy(Strategy):
    def do_operation(self, num1, num2):
        return num1 - num2

class MultiplyStrategy(Strategy):
    def do_operation(self, num1, num2):
        return num1 * num2

# Interface for user
class Context:
    def __init__(self, strategy: Union[AddStrategy, SubtractStrategy,
MultiplyStrategy]):
        self.strategy = strategy

    def execute_strategy(self, num1, num2):
        return self.strategy.do_operation(num1, num2)
```

- Template
  - To provide high-level blueprints in base class

This 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.

Example: After initializing an AbstractClass, initiate template_method and series of operations get done. Some operations get overridden by subclasses (in this example single) to unify different types of objects' cases under AbstractClass.

```
from abc import ABC, abstractmethod

class AbstractClass(ABC):
    def template_method(self):
        self.common_operation1()
        self.specialized_operation1()
        self.common_operation2()
        self.specialized_operation2()

    def common_operation1(self):
```

```
        print("AbstractClass: Performing common operation 1")

    def common_operation2(self):
        print("AbstractClass: Performing common operation 2")

    @abstractmethod
    def specialized_operation1(self):
        pass

    @abstractmethod
    def specialized_operation2(self):
        pass

class ConcreteClass(AbstractClass):
    def specialized_operation1(self):
        print("ConcreteClass: Performing specialized operation 1")

    def specialized_operation2(self):
        print("ConcreteClass: Performing specialized operation 2")
```

- Visitor
  - To define a new operation on a group of objects or hierarchy

This is a behavioral design pattern that lets you separate algorithms from the objects on which they operate.

Example: There are elements and visitors. When elements (tried to) get visited by a visitor; elements can accept or reject this visitor, visitor may do different operations on this element.

```
# Define the Visitor interface
class Visitor:
    def visit(self, element):
        pass

# Define the elements that can be visited
class ElementA:
    def accept(self, visitor):
        visitor.visit(self)

class ElementB:
    def accept(self, visitor):
        visitor.visit(self)

# Define concrete visitors
class ConcreteVisitor1(Visitor):
```

```
    def visit(self, element):
        print("ConcreteVisitor1 visiting", element.__class__.__name__)

class ConcreteVisitor2(Visitor):
    def visit(self, element):
        print("ConcreteVisitor2 visiting", element.__class__.__name__)
```

For Further Reading:

- Design Patterns
- Design Patterns Elements of Reusable Object-Oriented Software by Gamma et al (Gang of Four)