Contents

Design Patterns

Types of advantages

Ease of use : Creating a subclass based on the base class is easy to manage, it only requires the subclass to provide either a concrete implementation of an abstract method, or a more specific implementation of a method that is allowed by the base class.

open-closed principle : the design philosophy is to be “Open to Extension, Closed to Modification”. Here the base class provides a framework code that can be extended through inheritance to allow instances of new-but-related classes with new fields and methods. This allows designers to be achieve new design requirements without having to change the code of the base class, or the algorithms and data structures which operate on instances of the base class.

reusability of the code : Duplication of code is minimized through the use of base classes to establish a common pattern among subclasses. “Inheritance” means subclasses only need to write down overwritten methods for the base class to use.

flexibility : Due to its reliance on inheritance to establish the behavior of subclasses, usually subclasses are restrained to inheriting from one base class at a time. As a result, any subclass is restrained to follow the general behavior established by its parent base class.

maintainability : Reading the flow of code is difficult due to the disjoint nature of the code. Code within the base class only provides the steps that its subclasses will take, whereas subclasses only contain details for a step. In addition, additional functionality is difficult to implement due to the tight coupling between classes. Adding features to the base class requires the change to be applied to all related subclasses.

Visitor

The visitor design pattern provides a method of separating an algorithm on an object and the objects actual class implementation. Since the pattern separates the visitor (operations) from the object structure, it's very easy to add new visitors as long as the structure remains unchanged.

Allows you to:

- add methods to classes of different types without much altering to those class.
- define external classes that can extend other classes without majorly editing them
- create a separate visitor concrete class for each type of operation and to separate this operation implementation from the objects structure.

Used when:

- there are many distinct and unrelated operations
- Object structure is not likely to be changed but is very probable to have new operations which have to be added

Comparison

Advantages

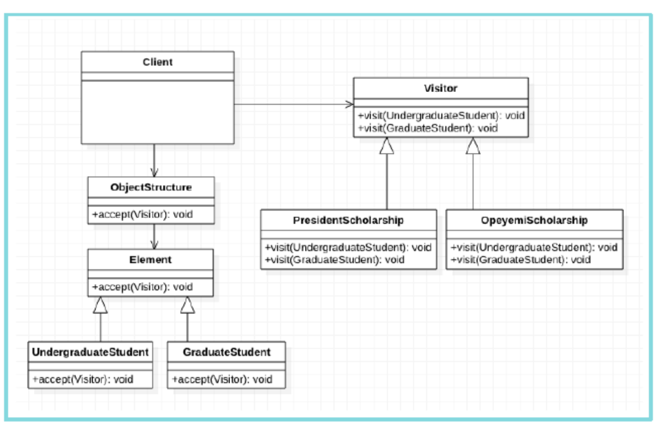
- Follows open/close principle
- Allows new operations to be added without changing implementation
- A visitor can have state

Disadvantages

- Does not fit for pattern 1 that updates arguments frequently.
- Some non-hierarchy behaviors should not be implemented via visitor pattern, since they will be applied to whole system.

Non-functional Properties

Maintainability	Center to visitor, increases maintainability
Testability	Each sub class has its own method to debug
Extensibility	Easy to write own method
Reusability	No need to change structures to add new operations



Template

Describes (and realizes) the common interactions between components. The **template** *pattern defines the skeleton of an algorithm for an operation while deferring some behaviour to the elements that are being operated on.*

Implementation details:

- Create a notion of an interface (either an interface or class) or a component of an algorithm that doesnt vary between different datatypes (or both). Then use inheritance to create a specific implementation for the datatype addressed.
- in higher level languages (C#, Java by type-erasure) where every class is a “subclass” of a super base class, (java.lang.Object in the case of Java), this can be used with many standard library algorithms and data structures

Comparison

Advantages

- ease of use: Creating a subclass based on the base class is easy to manage, it only requires the subclass to provide either a concrete implementation of an abstract method, or a more specific implementation of a method that is allowed by the base class.
- open-closed principle: The base class provides a framework that can be extended through inheritance to allow instances of new-but-related classes with new fields and methods. This allows designers to achieve new design requirements without having to change the code of the base class, or the algorithms and data structures which operate on instances of the base class.
- reusability: Code duplication is minimized through the use of base classes to establish a common pattern among subclasses. Subclasses only need to override methods that are not defined for their use-case.

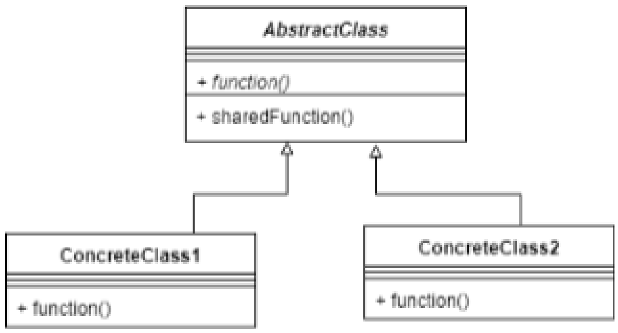
Disadvantages

- flexibility: Due to its reliance on inheritance to establish the behavior of subclasses, usually subclasses are restricted to inheriting from one base class at a time. As a result, any subclass is restricted to follow the general behavior established by its parent base class.
- maintainability: Reading the flow of code is difficult due to the disjoint nature of the code. Code within the base class only provides the steps that its subclasses will take, whereas subclasses only contain details for a step.
- tight coupling: Additional functionality is difficult to implement due to high coupling. Adding features to the base class requires the change to be applied to all related subclasses.

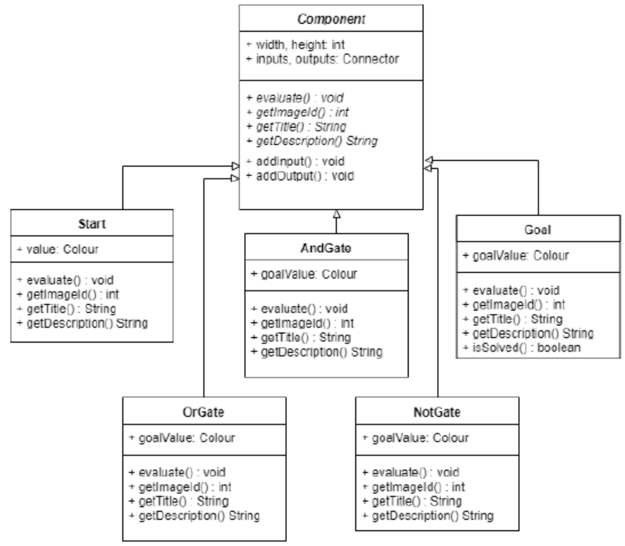
Non-functional Properties

Something

1.3 Template



AbstractClass
+ function()
+ sharedFunction()
ConcreteClass1
+ function()
ConcreteClass2
+ function()



Component
+ width, height: int
+ inputs, outputs: Connector
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String
+ addInput() : void
+ addOutput() : void
Start
+ value: Colour
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String
AndGate
+ goalValue: Colour
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String
Goal
+ goalValue: Colour
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String
+ isSolved() : boolean
OrGate
+ goalValue: Colour
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String
NotGate
+ goalValue: Colour
+ evaluate() : void
+ getImageId() : int
+ getTitle() : String
+ getDescription() String

Strategy

The **Strategy** *pattern resembles a* **State** *pattern but it encapsulates algorithms instead of data.*

You can see that the Context class in the Strategy Class Model is an (aggregator) has a Strategy interface (aggregate).

Comparison

Advantages

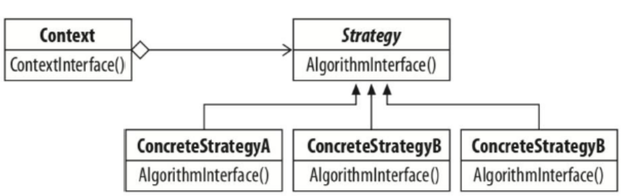
- Flexibility: a solution to a problem can use many options and it is easy to apply the selected algorithm. Users can choose the most suitable algorithm for their systems.
- High encapsultation: it is easy to add, remove, or switch algorithms because each strategy is encapsulated into separate classes. Changing one algorithm does not affect the others. Additionally, each algorithm can be tested independently.
- Loosely coupled: algorithms are not reliant on each other within the context entity. They can be changed or replaced without changing the context entity.
- Readability: the pattern reduces the number of conditional statements such as if-else statements or switch statements. Conditionals can be computationally expensive.
- Reusability: Algorithms and behaviours can be easily reused, due to their high level of encapuslation.

Disadvantages

- Prior knowledge about each algorithm is required. Users must know about various strategies/algorithms to select the best one for them.
- Performance: It increases the number of objects in the application. a. It requires many objects to do its job, which increases memory requirements. b. It may cause an impact on performance of the application.

Non-functional Properties

Maintainability	It is easy to modify or replace algorithms, which can be done in separate classes.
Testability	Since each algorithm is encapsulated into separate classes, it allows developers test each algorithm separately. This is less complex and tends to be more reliable.
Extensibility	When users need new algorithms, it is easy to add them since it can be done by creating new strategy classes. This creation process does not affect other algorithms.
Reusability	Algorithms and behaviours can be easily reused because they are encapsulated.



State

Given an object that needs to change its behaviour based on its internal state at run-time, the **State** *pattern encapsulates the number of states in a given context. A context calls its cooresponding state to perform specific behaviour, which changes based on the current value of the state object.*

This pattern should be used when the application's behaviours can be clearly divided into independent states that have specific and distinct behaviours, and when the application needs to be able to change its state and behaviours at run-time.

Example. A flashlight has two states, on and off. When the flashlight is on, pressing the power button will turn off the flashlight, and vice versa.

Implementation details:

- CONTEXT: an instance of a class that owns (contains) the state. The context is an object that represents a class that can have more than one state.
- STATE: an abstract class or interface. STATE is the base class for all possible states. It defines all possible method signatures that all states must implement.
- CONCRETESTATE: a class that implements the actual state behavior for the context object. It inherits from the base STATE class. The CONCRETESTATE class must implement all methods from the abstract base class STATE.

The State design pattern allows full encapsulation of an unlimited number of states of a context. The context object calls its state object to perform specific behavior. The behavior is differentiated by the concrete state at the run-time.

Comparison

Advantages

- Maintainability: Adding, removing, and modifying states is streamlined and simple via modifying the corresponding concrete state object.
- Readability: Improved cohesion due to aggregation of all behaviours of a given state in its corresponding concrete state class.
- Low coupling: Each state is independent of each other states' behaviour and modifications

Disadvantages

- Maintainability: Since each concrete state is implemented as a class, more classes are required and more code needs to be written
- Maintainability: must implement all the functions in the abstract state, even if a given class is not related to a function used primarily in a different class.
- Maintainability: Difficult to maintain due to all states being required to implement a new function when new functionality is added to the interface.

Non-functional Properties

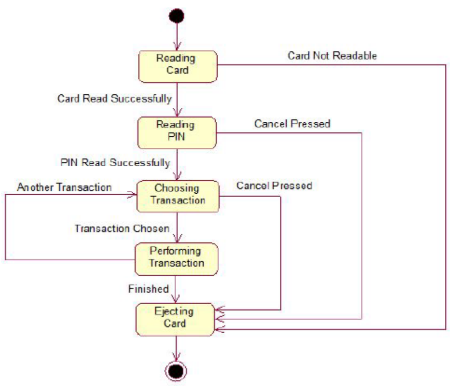
Scalability : The State design pattern allows an unlimited number of states for a given object.

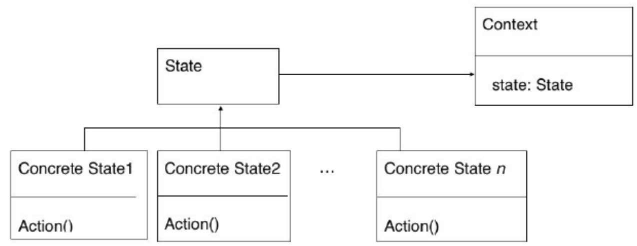
Adaptability : Adding, removing, and modifying states is as simple as modifying a concrete object class.

Dependability : Since each state is independent of the others, states with errors do not interfere with the functionality of other states.

Negative Maintainability: Since each state requires a separate class, there can be a large number of concrete classes, resulting in the code base being harder to maintain. In addition, since every method in the abstract class must be implemented in the concrete classes, much more code needs to be written.

We will be presenting two examples in class of real-life applications that implement the state design pattern. The first example is an ATM. We will walk the class through how one would implement it and describe how its behaviour would change based on different states.





Proxy

A **proxy** *is a wrapper or agent object that is being called by the client or user to access the real object behind the scenes.*

This pattern is widely used in applications that require security protection and access control.

Implementation details

In general, a proxy is a class that is functioning as an interface (or placeholder) to something else.

Virtual Proxy (a type of caching) Proxy returns a default or cached result if the real object either takes some time to create or involves heavy computation. Virtual proxies delay the initialization or computation of the real object until it is needed.

Remote Proxy Used when a resource is remote. Communicating with the real object might involve serialization or marshalling of data. That logic is encapsulated in these proxies.

Protection Proxy Used for access control and partial encapsulation. Users will only have access to functions provided by the interface. The application provides different interfaces to different clients with different access rights.

Comparison

Advantages

- Maintainability: Internal change to the "Real Subject" does not affect the proxy consumers because access is abstracted through the proxy interface. Developers can easily add new methods into the interface for clients to use.
- Low Coupling: reduces the coupling between client and the real subject by providing an abstracted interface between the client and subject.
- Performance: The use of caching in the proxy can increase the performance of some systems.

Disadvantages

- Performance: The extra layer of abstraction could impact performance in some cases.

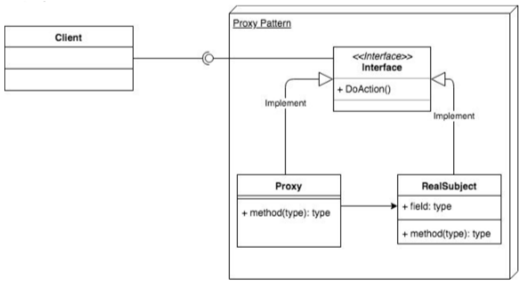
Non-functional Properties

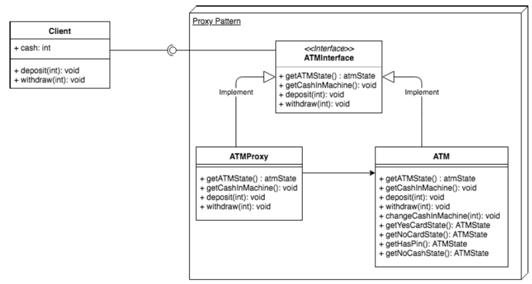
Security	Proxy pattern guarantees that only authorized users can access the resource. Different interfaces can be seen as different access rights.
Performance	The initialization of expensive objects can be delayed by using a proxy object that exposes the same interface as the original object. Caching and delayed initialization allow for performance gains.
Negative Inconsistency	"This pattern introduces another layer of abstraction which sometimes may be an issue if the RealSubject code is accessed by some of the clients directly and some of them might access the Proxy classes. This might cause disparate behaviour."
Negative Ambiguity	The client may not know that the RealSubject it is accessing now is not same as the previous one.

Example

Proxies are often used to interface with a network connection, a large object in memory, a file, or some other resource that involves heavy computation or that is impossible to duplicate.

The banking application below with deposit functions is an example.





Observer

The **Observer** *pattern is characterized by a subject and many observers which are "observing" the subject and reacting to change. The subject keeps a list of objects to notify when it changes, but otherwise has no information on the observer objects (other than the notify interface).*

Comparison

Advantages

- Loosely Coupled: Since a subject only knows about a observer interface and not specifically what each concrete observer does. One can modify the object and subject independently, so long as they maintain the observer interface.
- One to Many Relationship: When a subject changes state (or data), all its dependent observers are notified and updated automatically. When the system needs to send data to many objects on change, it can be an efficient solution.
- Consistency: As the observers are updated automatically when the subject changes its state, they are consistent with the subject.

Disadvantages

- Inefficiency: When each observer is also a subject, and each subject has a large amount of observers, the speed of processing the notification to a target object is slow (this is usually implemented as a for loop). This is because there are a lot of repeated "notifies". Some of the observers in the observer list have already been notified but there is no accurate way to detemine if it has been notified or not.
- Circular dependency: cyclical recursive calls can occur when there is an observer loop, which may lead to operating system panic. A circular dependency occurs when the UML has a cycle and each dependency has a notify function. This is easy to detect, but in practise if the design is complex then it may require more effort to solve. The problem is worse for highly automated system.

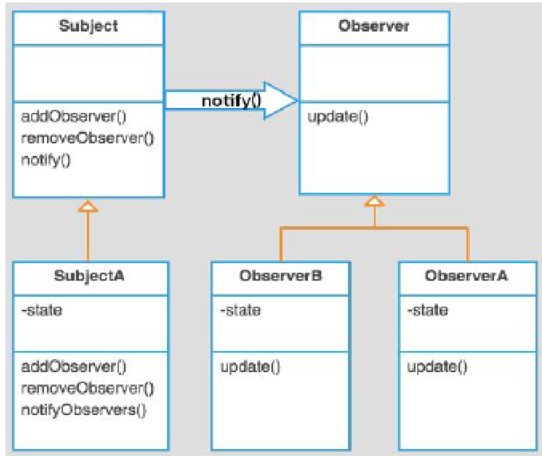
Non-functional Properties

Scalability Using the observer pattern makes scaling an application easy, since adding more observers to a subject is trivial. In the MVC design pattern, a Model can have any number of Views observing it, and each View will take the data relevant to it from the Model to display.

Maintainability It is easy to maintain and organize an observer system. Removing and adding observers is simple, and since observers are completely decoupled from the subject the overall system is flexible and can be changed to meet the needs of developers.

Negative Inefficiency Inefficiency occurs when there is a long chain of dependency or objects are in several other subjects observer lists. The number of calls can grow exponentially if there are repeated objects in the notify list. The Observer pattern should be avoided if there would be a long chain of dependencies between observers.

1.7 Observer


Subject
addObserver()
removeObserver()
notify()
notify()
Observer
update()
SubjectA
-state
addObserver()
removeObserver()
notifyObservers()
ObserverB
-state
update()
ObserverA
-state
update()

Mediator

A **mediator** *is an object that encapsulates a web of relations or interactions between sets of other objects, acting as an intermediary which decouples dependent objects. This allows objects to communicate without referring to each other explicitly. Instead, objects send requests to the mediator, which processes and directs them to the appropriate subject.*

Mediator patterns are best suited for situations where a set of objects communicate in complex ways. Multiple unstructured interdependencies creates difficulty in understanding the process of events and the ability to reuse objects.

Comparison

Advantages

- Low coupling: Since objects communicate with a mediator instead of directly, they are unaware of other component's implementations.
- Maintainability: adding, deleting, and modifying components and relations is easy since components are encapsulated. By separating relations between classes and grouping them in a different class, any change to one component will not affect the rest of the code.
- Code reuse: Since objects communicate in a common shared way with a central mediating object, code can be reused between objects.
- Flexibility: Mediators model the inter-relationships of objects to allow modification and extension of these inter-relationships through subclassing and allows flexibility.
- Readability: Centralized communication between objects can make it clearer when objects are communicating, and with which other objects.

Disadvantages

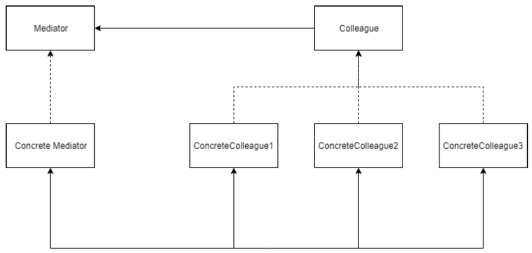
- Readability: The mediator can become "God object" that knows too much or does too much. This can lead to a complicated and hard to understand system.
- Maintainability: The system can become counterproductive, ineffective, and risky if the mediator controls too much, or if objects communicate in a complex and poorly defined way.

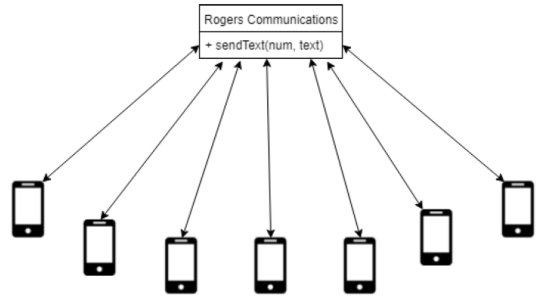
Non-functional Properties

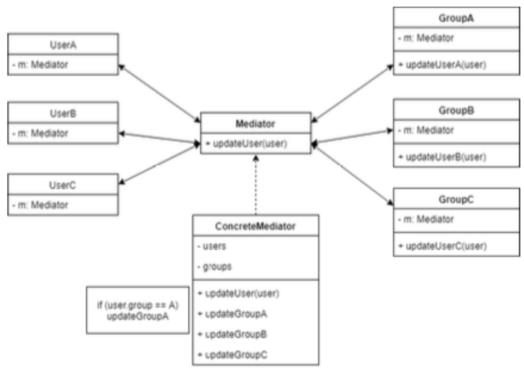
Complexity	It increases developer understanding needed to work with the components. Individual components have clearer interactions, which are defined through a standard interface. The MEDIATOR class that centralizes communication creates an easy way to see all relations.
Scalability	Low coupling due to the lack of dependencies between components allows for new components/relations which will not affect existing components/relations. The addition of components from other applications just requires a new mediator.

Example

When texting your friend, you are not making a direct connection between your phones. Many mediators are involved in this process. Bits that make up your message is sent to a cell tower closest to you. The switching service is then handled by your carrier which helps establish the connection to your friend on your behalf. The message is then passed to the cell tower closest to your friend. Finally, the message appears on your friends phone. In this scenario, your carrier is the main mediator.







Flyweight

An object that minimizes memory usage by sharing as much data as possible with other similar objects.

A way to use objects in large numbers when a simple repeated representation would use an unacceptable amount of memory. While often some parts of the object state can be shared. The **Flyweight** *pattern describes how to share objects to allow their use at fine granularity without prohibitive cost.*

Flyweights should be used when a component requires a large number of objects, the storage costs are high for the number of objects needed, it would be difficult to maintain the number of objects, and the application does not depend on object identity.

Implementation

Each "flyweight" object is divided into two pieces: the state-dependent (extrinsic) part, and the state-independent (intrinsic) part. Intrinsic state is stored (shared) in the Flyweight object. Extrinsic state is stored or computed by client objects, and passed to the Flyweight when its operations are invoked. Flyweights are stored in a Factory's repository. The client restrains herself from creating Flyweights directly, and requests them from the Factory. Each Flyweight cannot stand on its own. Any attributes that would make sharing impossible must be supplied by the client whenever a request is made of the Flyweight.

Comparison

Advantages

- Save memory by reduce the repeat data
- Reduction of number of objects to handle when application requires a large number of objects
- If the objects are naturally immutable, then impact on performance of using a Flyweight is negligible
- Working with Flyweights is easy in a language like Java where all object variables are references and a garbage collector is responsible for removing old objects.

Disadvantages

- Move state outside the object breaks encapsulation
- If the object is not naturally immutable, then might affect performance in some case
- Little trickier in language like C++ where objects can be allocated as local variables on the stack and destroyed as a result of programmer action.

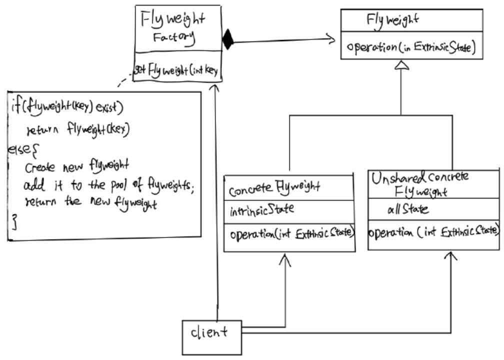
Non-functional Properties

Data integrity might lose if the data is not intending to share (lost encapsulation)

Performance might increase in some case like browsing the website with same image, save download same image time. However, in some case the performance might decrease due to save memory that require search the data.

Reusability since flyweight save common use the same data in just one copy, in that case save certain memory. It is similar to the helper function, that the same data can be used in different class.

1.9 Flyweight



Factory

The **Factory** *method pattern is a class-creation design pattern, meaning that its purpose is to deal with object creation.*

The factory method pattern creates a predefined interface for object creation within a parent class, while at the same time allowing for child classes to determine exactly what type of objects are created. This makes it so that object creation responsibility falls on the child classes, and the class that uses the new object can treat the process of object creation as a black-box. The class only needs to be concerned with providing the correct data and it can assume that the correct object will be instantiated and returned to them.

This pattern proves to be very useful over time as it can significantly reduce maintenance costs.

Implementation

The Factory pattern standarizes object creation through the use of inheritance and subclasses to instantiate objects. It uses a "factory method" to create objects, rather than the developer using the constructor of the objects themselves. This allows for greater flexibility and dynamism when determining what type of object to construct. This factory method is specified within an interface in a parent class, whose behaviour is then implemented by child classes. These child classes are then responsible for the actual instantiation of the object, and can specify the type of the object. This pattern allows for many different child classes that can all implement the factory method and return different types.

Comparison

Advantages

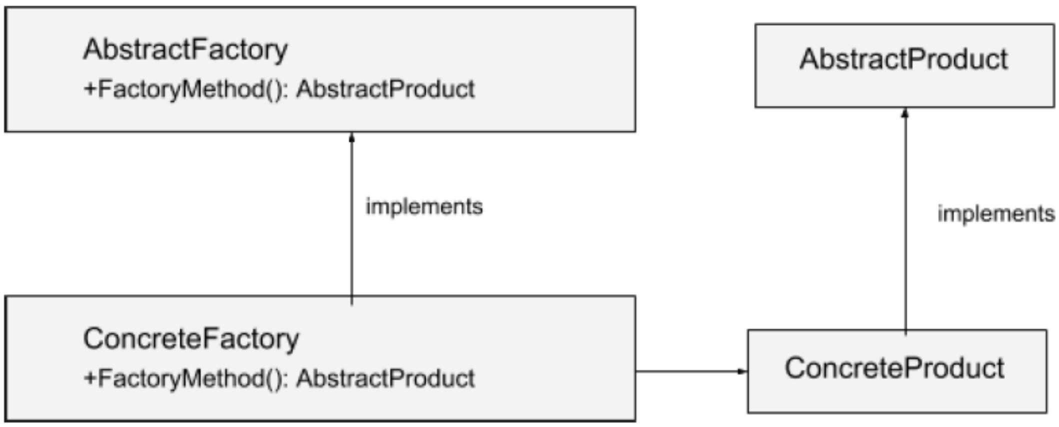
- Readability: It provides a level of abstraction for object creation. Instead of a developer needing to fully understand what subclass they need and how to instantiate it, they can use the factorys exposed method to generate an instance.
- Low coupling: Allows for a separation of concerns between an objects creation and usage. There is a level of abstraction that means the object instantiated can be determined at runtime. The developer can request an object that will meet the abstract products requirements without knowing what subclass will be created.
- Encapsulation: This pattern can help developers hide the implementation details of the subclass by only exposing an interface to the user. This leads to a decrease in coupling within the overall application.
- Maintainability: The factory method pattern also improves the maintainability of the system. Developers only need to create a new subclass which implements the exposed common interface in order to create a new type without bother implementing the entire structure of the new class type.

Disadvantages

- Efficiency: If it is not used within the correct scenarios. The additional layer of overhead that the pattern adds by requiring the creation of subclasses that are tasked with object creation can become inefficient. With simple, low complexity classes that do not change, it is much easier to just instantiate objects within the parent class rather than delegate that works to child classes.
- Maintainability: If the pattern is overused to allow for dynamism within a system that does not need it, it will become overly complex. If every object is created through a factory method (thus creating new base classes, base products, and each concrete implementation) the code will be unnecessarily complex, difficult to follow, and hard to test. Thus this design pattern should only be used when its benefits clearly outweighs the added overhead.

Non-functional Properties

Evolvability	All that is required to meet new requirements is to create another subclass of the object with the new functionality.
Complexity	Components can be created and perceived as their parent class. The developer only has to work with the abstraction and not the specifics, thus decreasing the overall complexity of the system.
Negative Efficiency	The added overhead of creating child classes can be quite expensive.
Negative Complexity	The additional abstraction through the factory can negate any complexity benefits, and even make the code base more complex and difficult to understand.



Facade

The goal of a **Facade** *is to create an object that provides a simplified, unified interface to a more complex, larger body of code such as the various interfaces of a subsystem.*

Comparison

Advantages

- Low Coupling: Clients are decoupled from a subsystem. Avoid tight coupling between a client and its subsystem by introducing an independent facade interface
- Readability: Simplify complex code blocks and provide convenient methods. Wrap several code blocks to a more elegant set of APIs.
- Maintainability: Facade provides a single point of entry to a subsystem, improving usability and simplicity.

Disadvantages

- Efficiency: Adds a layer to the code stack, which may affect performance.
- Readability: Developers still need to know implementation details, and the pattern will increase the size of the code base.
- Evolvability/Adaptability: if the Facade is the only access point for the subsystem, it will limit the features and flexibility that "power users" may need.

Non-functional Properties

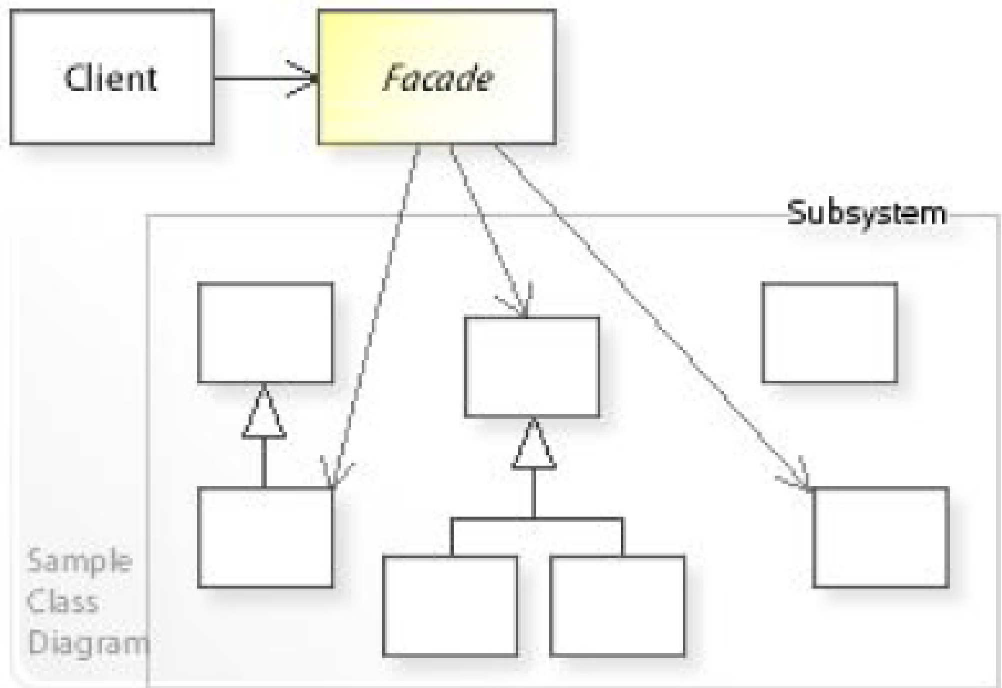
Complexity	The pattern allows the client to work through this singular interface to existing subsystem components.
Evolvability	Working through a Facade minimizes dependencies for the client, making it easier to implement, change, and use.

Example

Facade is an extremely versatile pattern, able to be applied to various situations. This can include:

- Database access
- Network communication
- Any code libraries
- Input/output interfaces

Real life example is the customer service department at any company. The company handles many things such as sales, returns, order inquiries and shipping. It would be very annoying if you had to access any of these departments through different means, however the use of a customer service department acts as a facade and simplifies the process.


Client
Facade
Subsystem
Sample
Class
Diagram

Decorator

Decorator pattern allows functionalities to be added or removed from an existing object, either statically or dynamically, without changing its original structure. Also, in these processes, the behavior of other objects from the same class will not be influenced. It resolves the problem when subclassing would result a large number of subclasses. It is also known as "Wrapper" Pattern because this pattern utilized a "wrapper" (decorator class) that wraps the original object and appends more functionalities while leaving class methods signature unchanged.

Implementation

Composite and Decorator have similar structure diagrams since they both rely on recursive composition to organize a number of objects. Comparing with composite pattern, the decorator pattern can be viewed as a degenerate composite with only one component. However, a decorator adds additional responsibilities.

Component: It is an interface implemented by both, concrete component and decorators. It is also the interface for objects that can have functionalities added to them dynamically.

Concrete Component: Normally, it is known as a base which needs to be decorated. It also defines an object to which additional functionalities can be added or removed.

Decorator: It represents a base class for all decorators. It maintains a reference to a component object and defines an interface that conforms to component interface.

Concrete Decorator (ie. Co ncreteDecA, ConcreteDecB): It extends the functionality of the component by adding state or adding behavior.

Comparison

Advantages

- Decorator Pattern is flexible and easy to extend functionalities.
- Decorator Pattern is a good solution to permutation issues because a concrete pattern can be wrapped with any number of decorators.
- Decorators allow behavior modification at runtime rather than going back into existing code and making changes.
- It is easy to debug each functionality seperately.

Disadvantages

- Since there are many decorators warp around the component, it is hard to have decorators keep track of other decorators.
- It can be complicated to initialize a concrete component wrapped with many decorators. Sometimes, we may miss some of them.
- Abstract decorator must provide common interface.

Non-functional Properties

Complexity The pattern is extremely reusable by adding new object types in the decorator section to fit in what system requires and needs. New object types can be built on objects that already exist. It is easy for them to decorate these objects because decorator pattern is efficient and flexible.

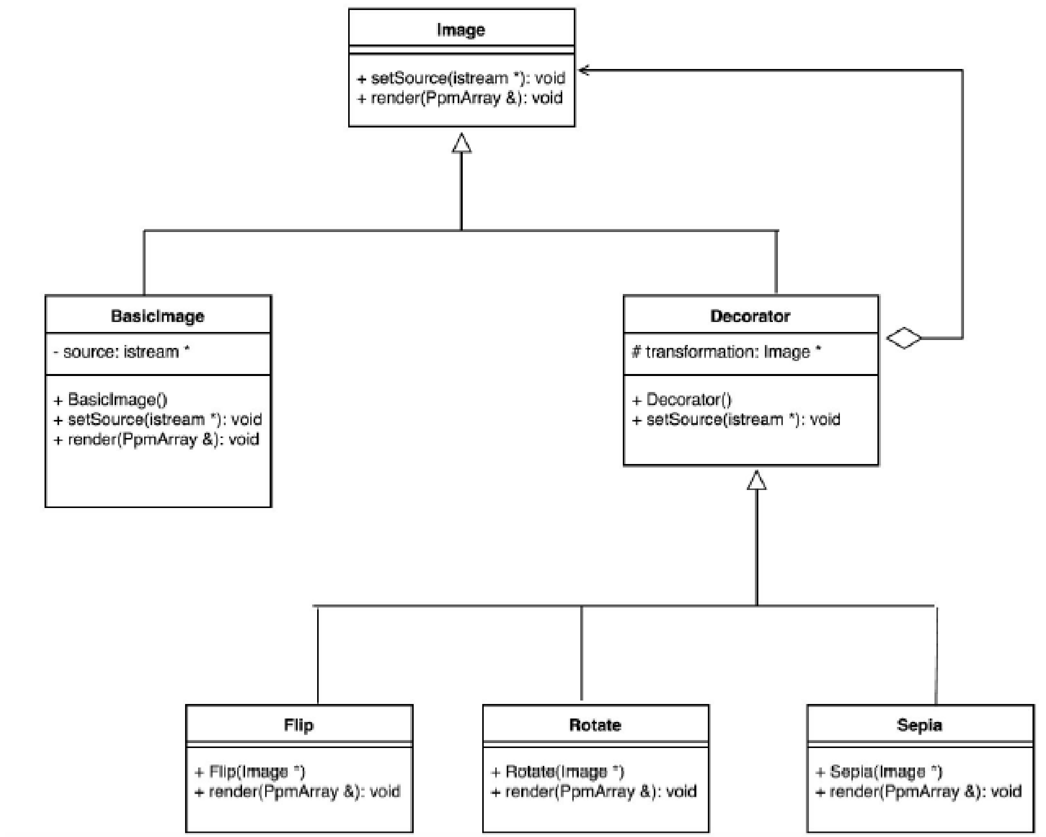


Image
+ setSource(istream *): void
+ render(PpmArray &): void
BasicImage
- source: istream *
+ BasicImage()
+ setSource(istream *): void
+ render(PpmArray &): void
Decorator
transformation: Image *
+ Decorator()
+ setSource(istream *): void
Flip
+ Flip(Image *)
+ render(PpmArray &): void
Rotate
+ Rotate(Image *)
+ render(PpmArray &): void
Sepia
+ Sepia(Image *)
+ render(PpmArray &): void

Composite

Used to manage a hierarchy of components, each of which could be a composite, or a leaf. Components use a single interface, which allows the user to call methods without having to know which type of component it is. Every component can be treated as its own entity thus allowing the whole system to be broken down into parts.

The main theme of the **Composite** *pattern is "Containers that contain elements, each of which could also be a container"*

The composite design pattern should be applied when multiple objects are being used in the same way in which each object has nearly identical code. Additionally if the client does not care about the type of object it interacts with than the composite design pattern is a good choice as it allows the client to operate on objects without the concern for type.

Vocabulary

Client Only aware of Leafs/Composites through the Component Interface

Component An item in the composite pattern, that can either be a leaf or a composite

Leaf Primitive component that cannot contain other components

Composite Component than can contain other components

Topology The composite pattern is most often used to represent hierarchies and tree structures. Composites contained in another composite represent a subsystem and are functional without knowledge of its parent.

Comparison

Advantages

- Readability: The composite pattern simplifies client code that interacts with complex tree structures, since the user does not have to know if they are dealing with a leaf or a composite.
- Evolvability: Makes it easier to add new kinds of components. New components will work with existing client code without client needing to change.

Disadvantages

- Adaptability: all classes in the hierarchy follow a similar interface, which can lead to an overly general design. Therefore it is more difficult to restrict the components of a composite. Since all the classes implement an abstract interface this is not possible without a run-time check for the desired components.
- Evolvability: the composite pattern will increase change resilience for adding specific properties or restrictions to components, since different types of components are often treated uniformly.

Non-functional Properties

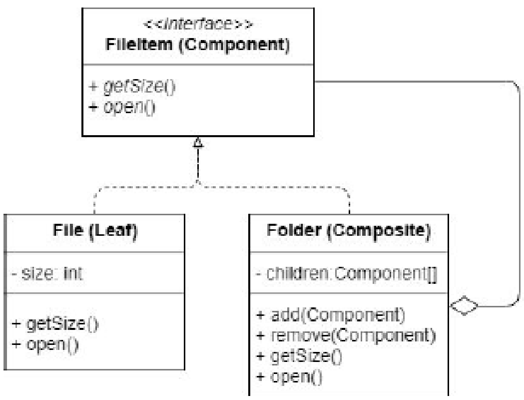
Adaptability The composite design pattern forces containers to work with child nodes through a common interface which allows for recursive operations on the entire hierarchy. This means that as new compositions and leaves are added to the hierarchy they can adapt to the existing code.

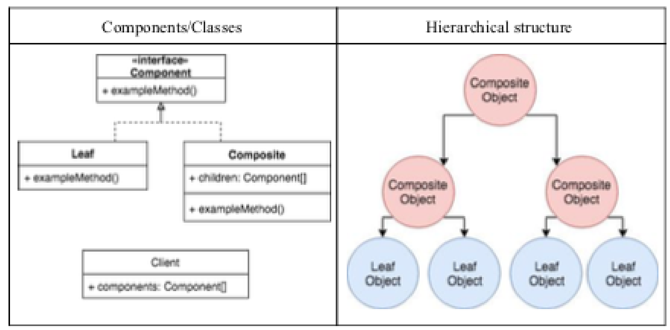
Low Complexity All classes follow a similar interface so the client does not have to worry about class specific code. The client can just treat primitives and composites as homogenous classes.

Low Coupling The composite design pattern reduces coupling by utilizing the same interface for each of the components. Whether it is a leaf or a composite, the class does not need to know any information about the other classes.

Example

Using the composite pattern in this example lets the user interact with the entire hierarchy easily, lets them break the tree into subtrees, and allows users to add new type of components if it is necessary in the future. Note that Folder implements add() and remove() which are not declared in the interface. There are cases where both types of components must have the exact same interface, thus occasionally these functions are declared in the component, but would cause an error if the user tries to add to a leaf.





Command

The **command** *design pattern is a behavioral design pattern that is used for objects to issue requests/commands to receiver objects, while maintaining modular design.*

It does this by encapsulating a command as an object type, thus allowing multiple operations of varying complexity that can be performed on a receiver.

It seeks to solve the problem of supporting potentially thousands of commands, for many different receiver objects, without hard-coding in commands to specific receivers.

Use-case

Hard-coding actions is very space inefficient because you will need to support two different classes to perform the same operation if, for example, you are turning both a radio and a TV on.

The command pattern solves this by decoupling the command caller (the invoker) from the object that knows how to perform the request. Thus, the invoker has no knowledge of who will perform a given task. In the TV example, there would be 1 command called TURNON which can be called on both TV and Radio types depending on what receiver is in the concrete command.

Concrete commands consist of receiver object interface to perform actions on different receiver objects.

Comparison

Advantages

- Complexity: The client could be oblivious to the implementation. It does not care about the related problems of the task such as user-server synchronization and security, and it also has no idea about the actual business process.
- Evolvability: The structure can be easily extended, due to each command is an independent class.
- Complexity: the history stack feature helps the invoker to trace back previous commands, and execute undo operations.
- Low coupling: the invoker has no knowledge of who will perform a task, allowing for loose coupling, and making it easier to add new commands without modifying existing code.

Disadvantages

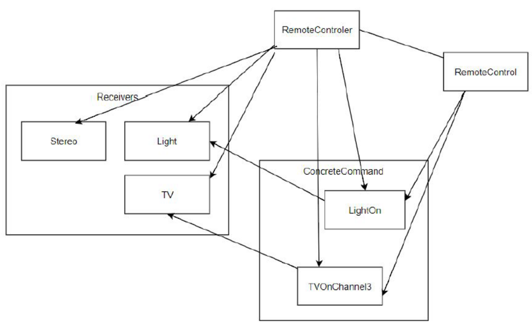
- Efficiency: will be very bulky if the client knows the business process very well, or the process is very simple. This will be a major restriction of a real-time system.
- Complexity: because each command is a separate class, the extension of the system will make the code management difficult.
- Complexity: Each command fulfills an interface of a class, thus every subclass has to implement all of the interfaces that relate to. This also generates a lot of redundant code.

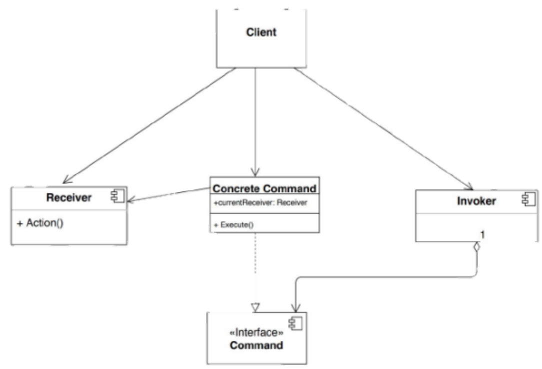
Non-functional Properties

Extensibility Command Design Pattern is perfect for achieving loose Coupling and high Cohesion. Invoker has a Command Interface not the concrete commands, which means invoker is loosely coupled with the concrete commands. New Concrete commands can be easily created under interface and invoker, with no need to know about the new concrete commands. When new receivers are added, invokers don't need to know all the details. Invoker just needs command interface for calling the concrete commands.

Maintainability The Command Pattern has high cohesion this means that classes now have well-defined, narrow responsibilities. Each concrete command class focuses on specific action on the receiver. It is much easier to maintain as these classes are less frequently changed. Each concrete command consists of receiver interface, which can be used to perform specific action on the receiver object.

Scalability Different receivers and commands can be added, which means more functionality can be added without affecting original workflow. When new receiver objects are created, new concrete commands are created which do not affect old concrete commands. As a result, original functionality is not affected. Applications using command design pattern have an advantage of high scalability, where new objects are created to achieve new functionality.





Architexture Styles

Virtual Machine (VM)

Static description: The **virtual machine** *is a middleware between the user and physical machine.*

Dynamic description: The **virtual machine** *style allows separation between user applications with Operating systems. This allows scalability and decouples layers so developers can ignore hardware issues.*

Functional Properties

Multiple Operating Systems Using a virtual machine allows a user to install and use multiple operating system on one physical machine. This reduces costs, as users no longer need to purchase additional physical machines to run separate operating systems and software. This also increases productivity and efficiency since all tasks can be performed on a single machine instead of on multiple machines.

Resource Sharing There is a layer of software between the virtual machine and the host called the **hypervisor** that is responsible for dynamically allocating resources from the host's memory to the virtual machine to allow multiple virtual machines to share resources between themselves. This allows a user to transfer files between virtual machines and the host (for example, to compile for different systems) without the hassle of needing to transfer files between machines.

Non-functional Properties

Scalability Without the need to purchase vast amounts of physical hardware to support different OS's, setting up virtual machines is much cheaper and less time consuming. New virtual machines can be added or expanded upon without having to add additional physical resources.

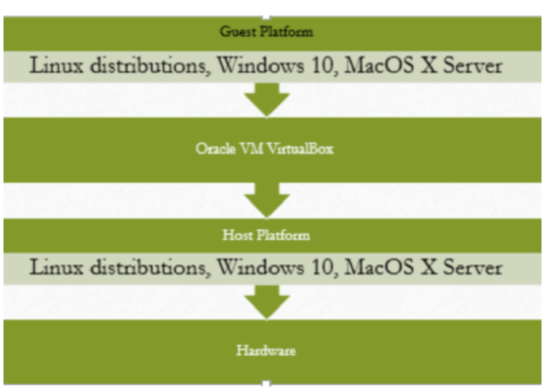
Maintainability Due to the nature of virtual machines being pieces of software, backups of virtual machines can be made easily as the states of these machines can be easily recorded into files. Since the states of virtual machines are just files on the host, they can also be easily cloned and used on another physical machine.

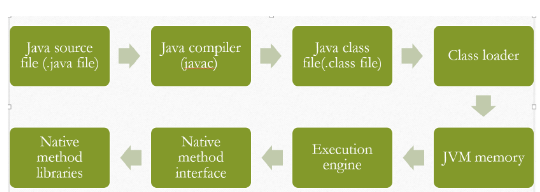
Security isolation Virtual machines are designed in such a way to make software think it is running in a native operating system on a physical machine and that includes viruses and malware. Malware will only run on the virtual machines which will have no impact on the host. Since backups are easily made, a clean version of the virtual machine can also be easily restored.

Negative Efficiency Virtual machines are often slower than physical machine due to indirect access to the host hardware. This means there is higher response time.

Negative Efficiency Virtual machines use more resource due to program overheads. For example, some virtual machines allocate disk space but it's idle. This lends to waste in disk/memory space since the host machine thinks it is in use.

Negative Dependability When running multiple virtual machines on the host OS there could be conflicts which lead to crashes and faults.





Publish and Subscribe

Allows publishers (senders) to broadcast messages to several subscribers (receivers) without them being tightly coupled. Essentially, the publishers are unaware of which application is going to receive the message whereas the subscribers do not really care about who actually sent it.

Implementation

Publisher Application that sends messages.

Broker Delivers every message sent to all suitable subscribers. Publishers send messages the broker, and the subscribers allow the broker to filter the messages. The broker then routes messages to the subscribers that have subscribed to the particular topic.

Subscriber Applications that receive messages. When publishers push messages not all subscribers receive them. A filtering process only delivers messages to interested subscribers. There are two primary methods of filtering messages: topic-based and content-based filtering systems.

Topic-based filtering Messages are broadcasted into logical channels or topics. This system allows subscribes to only receive messages that they have subscribed to. All subscribers that are subscribed to a particular topic will receive all of the same messages.

Content-based filtering Messages are only delivered to a subscriber if the content matches the constraints that are defined and set by the subscriber.

The publish-subscribe architecture style is resilient to many changes. Adding or removing topics is convenient and scalable because it can be done without changing the architecture.

Comparison

Advantages

- Low coupling: Publishers and subscribers are different entities, allowing them to function without being aware of each other.
- Reliability: If any of the publishers and/or subscribers stop working, this will not impact other publishers or subscribers and the application may still be fully functional.
- Scalability: There are several flavours of communication styles that the Pub-Sub model supports, from 1-to-1, to many-to-many. All of these communication styles are possible due to how loosely coupled the components are.
- Scalability: Publishers and subscribers to be added and removed dynamically, as each topic can have any number of publishers and subscribers. Therefore, scaling in terms of adding multiple publishers and subscribers can be easily done.

Disadvantages

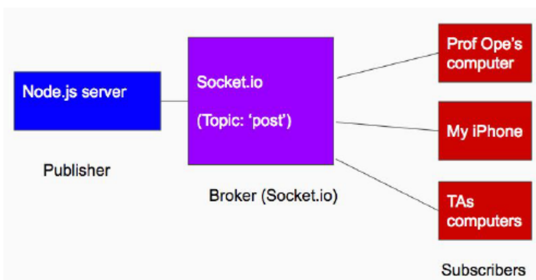
- Stability: Publishers do not directly communicate and do not have complete knowledge of their subscribers. As a result, publishers cannot guarantee that messages have been properly delivered to their subscribers. The message delivering process is dependent on the broker properly delivering the messages. The model can be modified to increase stability by having subscribers sending a confirmation receipt back to publishers, however this adds another level of complexity.
- High Semantic Coupling: After the data structure for a message is created, modifying this existing message type and/or format can get very difficult. All publishers and subscribers that use the message type must be altered to accept the new message type. From a developers standpoint, this may be impossible to do if the publisher or subscriber is in an external API.

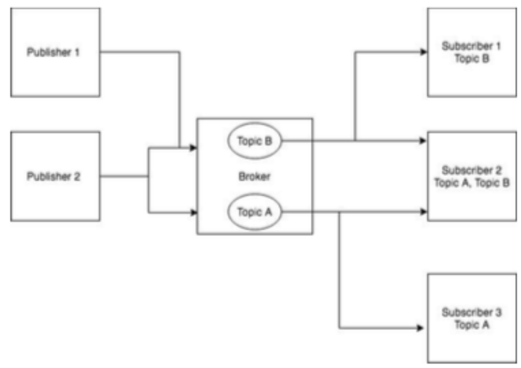
Non-functional Properties

Scalability Scalability is supported by Pub-Sub. As stated in the advantages section of this document, due to the low coupling nature of this architecture adding more publishers and subscribers can be done very efficiently which can help scaling applications a lot.

Dependability There are aspects of dependability that are inhibited by Pub-Sub. This relates to the stability disadvantage of Pub-Sub, as the publisher has no guarantees of messages being delivered. Thus, the guarantee of dependability is sacrificed.

Adaptability Similar to the advantages section of this document, adding new features such as subscribers, publishers and topics can be done easily. However, as discussed in the disadvantages section, modifying existing messages types can get harder.





Pipe and Filter

A very simple, powerful, and robust architectural style comprised of filters, which are used to transform data, and pipes, which pass the data between them.

Pipe and filter *is most useful for asynchronous systems with many data transformations and large processes that can be broken down into sub-tasks. The style allows concurrent and modular application of filters to subsets of the data. Filters must sometimes be serialized (applied one after another) and thus dont always benefit from concurrency (but still benefit from modularity).*

This architectural style also applies to systems where the output of one program becomes the input of another program like the UNIX pipe command (which is where the name comes from).

Implementation

Pipe Carries and transfers data between components (pumps, filters, and sinks). Pipes are directional streams of data, and are generally implemented as a type of data buffer which stores data until the next filter or sink is available to take the data and process it. A pipe can be thought of as a connector between two components.

Filter A component of the system which performs some processing to the data delivered to it by a pipe. The processed data is output to another pipe. A filter can have any amount of input and output pipes.

Pump A data source to the overall system. Pumps can be files as well as input devices such as keyboards, mice, etc.

Sink The ultimate data target (output receiver) of the system. Sinks can be files, databases, output devices (screen, speakers), etc.

Comparison

Advantages

Modularity Components can be pipelined together in many different combinations to create novel applications. Each component is completely separate for maintenance and development purposes.

Scalability Developers can compile and run components in parallel since they have defined inputs and outputs with no side effects.

Maintainability Components do not rely on the implementation of each other, so are easy to test. The encapsulation is useful to create hierarchy and simplifies the use of this style.

Maintainabilty The style creates reusable code due to the separation of concerns of each component

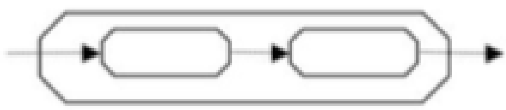
Disadvantages

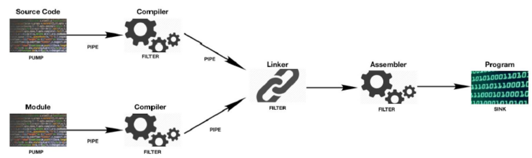
Flexibility Pipe-and-filter is not ideal for passing complex data structures between the components, because they would need to be serialized to a common data type.

It is not useful when components need to interact because pipes do not allow shared access. If the filters are distributed, the usual caveats of distributed computing apply.

Non-functional Properties

Efficiency	Filters work independently to each other, which leads to a very efficient workflow as no components depend on others to work.
Scalability	The system can be scaled up or down by simply adding or removing filters and different pipes.
Maintainability	As mentioned previously.
Negative Evolvability	The cost and development time of the design might be higher than similar designs, as each component is designed individually.
Negative Resilience	Since one broken filter can defect the entire system, if it is the only instance, and the work cannot be rescheduled.





Peer to Peer (P2P)

Computers (called peers) communicate directly with one another, instead of through a centralized server

Data is transferred without a central server (a central server may be used to connect peers, either built into the protocol or as an external service that users use to find each other)

Each peer acts as both a client and a server, meaning each peer can make requests for data and respond to requests for data

Only requirement is an internet connection and a P2P application, and peers using the same protocol

Inherently connected to file sharing, P2P network requests usually represent a file request.

Comparison

Advantages

- Scalability: P2P architecture is particularly useful for distributing large files. This architecture is able to solve the problem of bandwidth and network scaling which exists in other architectures. Namely, that there are too many requests and data through too few internet "pipes". If connections to main google data centres fail, large parts of internet go down.
- Scalability: It is expensive to route data through high-bandwidth cable instead of low-bandwidth cable, more connections is less expensive.
- Scalability: P2P limits data speed to only the cable going into your house, instead of to the slowest cable in the route to a server.

Disadvantages

- Performance/availability: Peer-to-peer systems may not be able to consistently achieve the same performance and availability. Throughput is reliant on the existence of seeders. Popular files are easily and highly distributed, but unpopular files eventually disappear and become unavailable as people stop sharing them. Additionally, performance highly dependent on selection of right peers at right time.
- Administration: There is usually no centralized administrative control over the system. However, managing security, data consistency, data/service availability, backup, and recovery are the responsibility of the end users or their applications.
- Security & trust: Vulnerabilities in systems can be easily distributed/taken advantage of, for example: corrupted data and malware spreads very quickly. Additionally, each IP is publicly available to all peers in the network.

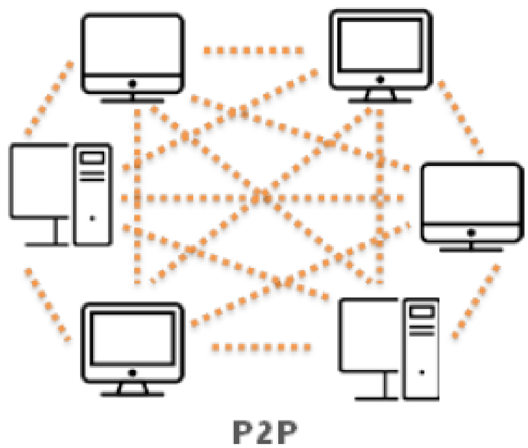
Non-functional Properties

Efficiency With server-client, the server must send copies of files sequentially and each client must download a file from the server, often using one connection. In contrast, with peer-to-peer the files are shared between peers, removing load from the server. Decrease in bandwidth cost for the distributors, the bandwidth is distributed among peers.

Scalability In server-client, distribution time increases linearly with number of users; in P2P, in increases logarithmically with number of users.

Dependability P2P networks are fault tolerant: there is no dependency on a single, central server (except perhaps for the optional tracker server). Capacity of the network increases as peers arrive, and the failure of a peer does not mean failure of the network. Ad-

	ditionally, no government or corporation can stop P2P file sharing without blocking all internet access. The resilience of network increases as number of peers increases.
Maintainability	No need to maintain the network in most situations.
Negative Evolvability	Software using this architecture is inherently distributed, therefore any changes to the design would require each individual nodes P2P application to be updated and for the users to update their applications independently. However, P2P networks function independent of end-user software



Mobile Code

an application that is capable of movement while embedded in internet services such as web pages and emails. The components are made of two parts: Compiler/Interpreter and Execution Dock. The compiler/interpreter is responsible for interpreting the code received. The execution dock is responsible for receiving and executing the code. The components are connected via network, mainly HTTP. Using the established network, data such as program code or program state are transferred.

There are three variants to the architecture: Code-on-demand, Remote execution, and Mobile agents. Code-on-demand variant moves code from a server to clients, utilizing clients resources to execute the code. The remote execution works the opposite, by sending a code from a client to a server. The client in this case can utilize the process power of the server, if resources are limited locally. Lastly, mobile agents allow communication between clients. A mobile code can move from one client to another to add more resources to run the code.

Comparison

Advantages

- Highly dynamically adaptable: the application can seamlessly be started on any mobile platform (client) without actually changing the code. This is a very critical non-functional property; without the ability to be dynamic, the mobile code architecture loses its identity. By keeping the underlying structure of the code the same across all mobile platforms, no modifications are needed to be made to the code.
- remote usability: this is also another non-functional property. This aspect of the architecture allows the code to be quickly evaluated or executed on any mobile device in the system. It is supported by the network connectivity and underlying framework. This means that any of the clients have the ability to compile code, or push it to another device for compilation.
- efficient resource utilization. With mobile code architecture, one device can autonomously migrate to or employ a different node in the system in order to obtain more resources. Overall, these features lead to better performance. Typically, data can run faster when it is closer to its parent dataset. In these cases, the program would experience a higher throughput because it takes less time for each packet of data to transfer.

Disadvantages

- dependability: While network connectivity serves as a powerful resource to the mobile code architecture, it serves as a major point of failure. This architecture relies entirely on a solid network connection. If this connection were to degrade, the system would be rendered useless.
- efficency: Another drawback is the increased amounts of data being transmitted. A repository of code that has not yet been compiled is a significant order of magnitude greater in size than the compiled version. Initially, there would be a lot more data transmitted using this architecture as opposed to just transmitting the results yielded by the application. Additionally, transmitting all of this code takes more time.
- dependability A huge flaw in this architecture is that it allows major security breaches. Transmitting the code base for an application over a network of devices leaves a huge amount of room for hackers and malicious attacks. This is also known as the underlying architecture for a variety of destructive programs such as worms, trojans, rogues, and malware.

Non-functional Properties

Low Coupling While different variations of the Mobile Code architecture may result in varying degrees of coupling between components, the use of this style typically results in reductions in coupling, especially when developers rely on open standards which are well established. Using the Code on Demand variant, clients are interchangeable from the perspective of the servers which they interact with, since all of the clients (mobile devices) have web browsers which conform to the same standards regardless of maker. Similarly, the Remote Execution pattern allows for low coupling between mobile devices and servers, as long as the code which they desire to execute remotely conforms to the interpreter which runs on the server. Both of these variants result in lower coupling than their alternatives. Finally however, the Mobile Agent relies on a bit more coupling, as mobile devices must rely on each other as well as servers for resource sharing, meaning that theres increased complexity in ensuring various types of mobile devices are interoperable. This results in moderate coupling between the modules which must run on these different devices.

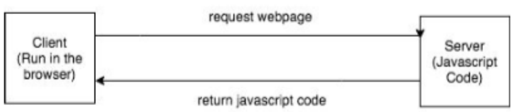


Figure 2. Code-on-demand example diagram

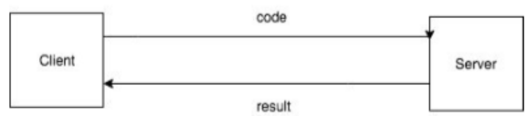
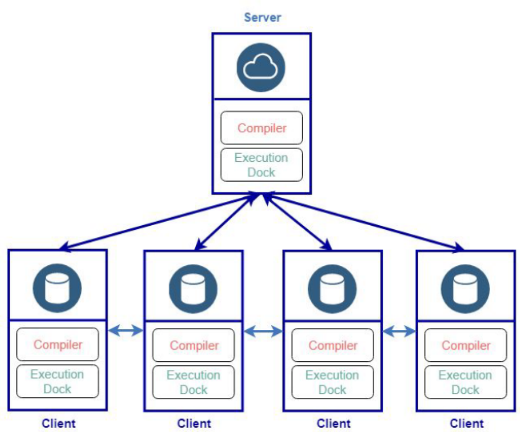


Figure 3. Remote execution example diagram



Layered

A layered architecture style divides components into layers with specific functions. For each unique project, there is no specified number of layers that it must possess and developers decide on the number of layers depending on the needs of the project. This architecture is best suited for microservices, and systems without much business logic to complicate relationships between layers. This is because each layer is only required to fulfill its own responsibilities without taking on the responsibilities of the other layers for the sake of organization. Over the years, it has become the most popular style due to its simplicity, ease of development, and organization.

Comparison

Advantages

- Testability: Components can be mocked or stubbed since they belong to specific layers of the architecture. Due to this, it is relatively easy to test functionality of isolated functionalities. For example, a presentation component can be mocked to focus on testing a business component, or the business layer can be mocked to test certain aspects of the presentation layer.
- Maintainability: Layers are created to separate the concerns of the components. As an example, business logic should only be contained in the business layer. Because of this, if there are changes to one layer, other layers components should not be affected, making layers easy to update and maintain for future changes.
- Ease of development for teams: Since this pattern is very well known and simple to understand, it also provides teams with ease of development. Different people are usually given tasks specific to their domain of knowledge, so it makes sense for each person to focus on their tasks without having to understand all parts of the application. As an example, a person who works on the presentation layer does not need to know how data is stored in the database layer. Likewise, a person that works on the database layer does not need to understand how the presentation layer is implemented. Thus the architecture supports the non-functional requirement of complexity.
- Cohesion: If each layer is well defined and only contains functions that are related to the needs of that layer, the layer has high cohesion. For example, the database layer should only have components which deal with writing, querying, and generally managing the data.
- Coupling: Each layer is considered to be either open or closed. Requests can bypass open layers, while if the layer is closed the request must go through that layer. There should be clear documentation or communication of which are open and closed, and the reason for their implementation. Depending on their architecture, layers can provide low coupling. However, a layered architecture can have high coupling, which is a disadvantage, if software developers or architects do not follow best practices.

Disadvantages

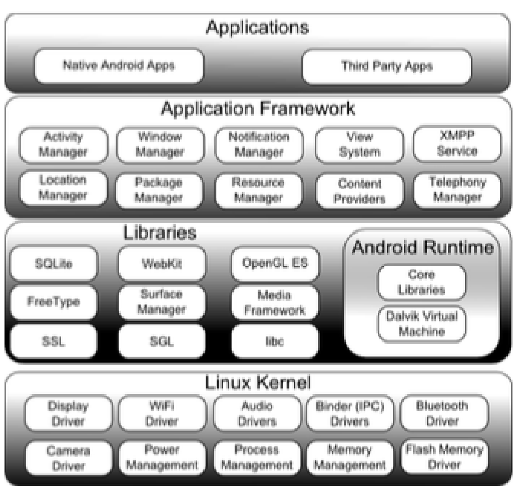
- Low Scalability: Due to the nature of layered architecture being very simple, it is difficult to use its principles on larger and more complex projects. This is due to the architecture being monolithic in nature, and further organization and complexity is difficult to implement without abstracting from the layered principle. For example, it is possible to further abstract each layer adding complexity but it is difficult to keep the simple layered architecture principles. Therefore, since the architecture offers little support and guidelines for expanding to meet the requirements of larger and more complex projects the non functional property of scalability is low.

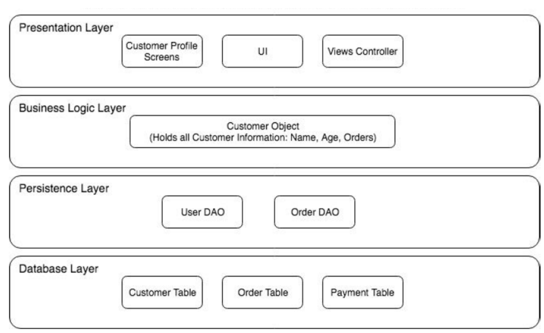
- Inefficiencies: As perceived from the diagrams thus far, a potential request may have to go through multiple layers to fulfill a request. Although this can be somewhat alleviated with open and closed layers, the architecture as a whole suffers from general inefficiency as requests need to often go through multiple layers instead of one source. Difficult to Deploy: In cases where layers or components (a common pitfall using the architecture historically) within the layer are highly coupled, it creates a scenario where layers or components highly depend on each other. Then, it becomes that changing one component needs several other components to be affected and thus rebuilt, which takes time. Thus, it is often not efficient for highly coupled layers to be used in things like a continuous deployment pipeline.

- Low Agility: Also due to the potential coupling, the pattern itself may have low agility which is a non functional property which measures how the architecture responds to quick continuous changes. Although some features can be isolated in this pattern, if components or layers are highly coupled, changing a component may cause the developer to need to make changes in other components and layers if they depend on each other. Since coupling between components within layers is a common pitfall using this architecture, it generally does not meet the non functional property of agility.

Non-functional Properties

Description See above.





Interpreter

An interpreter is a computer program that directly executes , i.e. performs, instructions written in a programming or scripting language , without requiring them previously to have been compiled into a machine language program. Interpreters translate the (source) code instructions one by one and execute them. For example, Python.

The interpreter style is an architectural style that is suitable for applications in which the most appropriate language or machine for executing the solution is not directly available.

Interpreter style is also called virtual machine style. The virtual machine often includes the pseudo code that is to be interpreted and the interpreter engine.

The interpreter engine includes the syntax interpreter and the current state of the interpreter. To pass data from one instruction to the other we need to keep the interpreter state. The interpreter parses and executes input commands and then updates the state maintained by the interpreter. We usually use a data structure that records the current state of the interpreter.

There are procedure calls used for communication between interpreter engine and the pseudo code. And also, direct memory access is involved when reading and storing data of the source code, state of the source code and the state of interpreter.

Implementation

There are four components in the interpreter architecture: 1. interpreter. 2. current state of the interpreter. 3. program being interpreted. 4. current state of the program being interpreted.

There are two connectors for interpreter architecture: 1. Procedure calls. 2. Direct memory accesses.

Comparison

Advantages

- Interpreters can be used to run scripts and macros. A macro records keyboard and mouse inputs so that they can be executed later. This allows users to record interactions with the user interface which may be either repetitive or complex, and then replay the recorded actions in a simple and quick way.

- An interpreter allows you to add functionality to a system, or extend existing functionality of a system. This is done by composing pre-existing functions together in a specific sequence, and in order to create something new. These pre-existing functions are defined by the system architecture and offered to the user. The developer, thus, avoids the need to implement all possible combinations of functionality.

- Having a system with a built in interpreter is not only beneficial to developers, it encourages end users to implement their own customizations. Toward this end, a system can offer an easier way to use language that has domain specific abstractions suited to the needs and thinking of the end users.

- 1. Interpreters encourage end users to implement their own customizations. This is an advance over requiring end users to use the general programming languages that professional software developers use.

- 2. Easy for debugging. It will examine each line and the results of the execution are visible. Errors are caught as they happen since the interpreter stops when it cant interpret a line. This is very helpful for people to debug.

- 3. Less memory. Compare to executable file. Because only a few lines of source code needs to be in memory at any one time.

- 4. This can make your system more portable, it can work on platforms that the interpreter supports.

Disadvantages

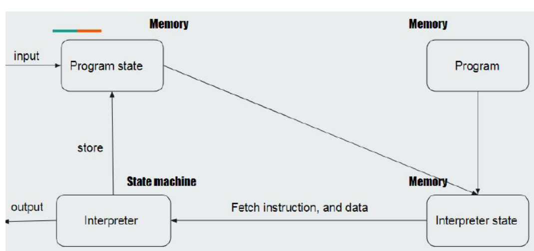
- Performance: Basic implementation spend little time analyzing the source code and use a line by line translate and execute strategy. This is a classic trade off, it may be faster and more flexible for developers to use the interpretive language, but slower for the computer to execute it.

Non-functional Properties

Programmability An interpreter allows users to add functionality to the system or extend existing functionality of a system. For example, a web browser extension which is different from a plug in, is a component that adds new functionality to the browsers. These extensions can be written in different languages depending on the browsers. It is run by an interpreter which is embedded in the browser. For example in firefox, it can be written in C++ or Javascript. Therefore, it offers an easier way for developers to customize their own functionalities.

Portability and flexibility As virtual machines and virtual environments increasing, portability is becoming more and more important. In compiler, the binary code produced by compiler is tailored specifically to a target computer architecture. But in reality, web applications must run in different kinds of machines, so it not effective for the browser to download the binary representation of the remote software. However, interpreter can process the source code directly so that it can allow those machine code intended for one hardware architecture to be run on another using a virtual machine. This can greatly facilitate the portability and flexibility of applications or languages across various platforms.

Security An interpreter or virtual machine does not execute all the source code blindly. Instead it can refuse to execute code that violates any security constraints. A typical example is JS-Interpreter which can sandbox potentially hostile code. This kind of interpreter is secure by creating its own virtual machine. External APIs is not acceptable unless provided by the developers. Therefore, it can protect the system from potential hostile code.



Event Based

Event-based architecture is an architecture style that uses the production and consumption of events to control the behaviour of components. Instead of components communicate directly by referencing or method call, they communicate by sending and receiving events asynchronously.

There are two types of components call event producer and event consumer. Event producer is a component that produces and sends event. It should maintain its internal state and produce an event when some predefined state change happened. Event consumer is a component that receives and consumers event. It should consumer the event that it receives and starts its process with respect to the event. One component can be both event producer and consumer interchangeably in the context of entire architecture by both producing and consuming events. There is only one type of connector in this architecture called event bus. Event bus is the medium on which the events are being transmitted.

Event-based architectures can simplify software design, development, and testing because they minimize the connections between the components. Instead of each component directly communicate to each other with high coupling and complicated structure, they all communicate through the event bus which makes communication elegant. Each component can be developed and tested independently because they do not require to know other components. This can be very beneficial to large projects since the complexity of the project grows linearly instead of exponential.

Most applicable to specific kinds of problems

- *User interface: website browser*
- *Distributed application*

Comparison

Advantages

- Engender specific kinds of change resilience: For removing an event bus and creating producers before creating an event bus, we need to change producers to handle the invalid event bus because producers might not be able to fire an event to an empty place/address For changing an event type for a typed event bus, we also need to maintain consistency for producers and consumers as well.

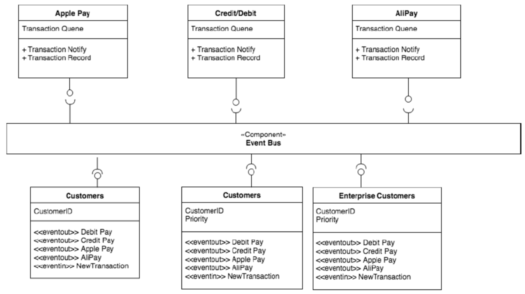
Disadvantages

- The event bus may become a bottleneck. When there are too many producers are sending the message concurrently. Therefore, the number of messages is larger than the number of events which the event bus handled. Not sending message efficiency. The event bus has the queue for event sending or receive. It can not send or receive the message immediately.

Non-functional Properties

Scalability The Space decoupling The event producers and event consumers do not need to know each other. The event producers do not hold references to event consumers or know how many of them are interacting and vice versa. The time decoupling The event producers and event consumers do not need to be actively involved in the interaction at the same time. The synchronization decoupling The event producers are not blocked while producing events and they can receive events. The event consumers can get the notification when an event happens while performing some other concurrent activity. Easy to evolve The architecture is loose coupling, you can easily create a new event to the event bus. Great distribution The event can be almost anything and exists almost anywhere. 2. Scalability: As shown above, we can separate customer by adding priority. Then, delete the previous customer component, add high priority and low priority components. So, the event bus will handle requests according to priority.

Testability each component can be tested by itself since their input and output is testable.



Distributed

Distributed objects is a combination and adaptation of many simpler architectures. It is derived from object-oriented and client-server architecture which allows for objects to be distributed and accessed. When developing applications using this architecture, it is very easy to come across some constraints such as cross-machine and cross-language communication. To address this, additional styles are applied such as pipe-filtering which allow for serialization of parameters which creates uniform communication. This process of filtering, serializing parameters is known as data marshaling.

Comparison

Advantages

- Engender change resilience: The increased redundancy in a distributed system can increase its resiliency. Hardware is prone to failure, so by distributing the functionality and data across a cluster of machines, this allows the system to recover from unforeseen crashes. When certain machines are down, the system can still retain its full functionality since the remaining nodes in the cluster are able to pick up the slack by doing its work. For this to work, the data is also stored redundantly amongst the cluster to ensure that a copy of the data is always available even when a portion of the cluster is offline. By the nature of its design, distributed objects also makes the system more scalable. When there is a big increase in demand, the cluster manager can spin up more machines in the cluster during runtime to accommodate for the extra requests. The performance and resiliency of a cluster can be changed without altering its functionality, this is done by changing the size of the cluster.

Disadvantages

- Using distributed objects allows systems to be designed and developed using segments that are written in different languages with different platforms. However, this induces the applications to be built in the distributed objects style. The first negative behaviour is exhibited in the interactions of components, it tends to be mostly synchronous and it does not take the advantage of distributed systems concurrency. In terms of object interactions, many distributed object style applications may have trouble dealing with data traversal in streams, and also having difficulties with asynchronous invocations. This induces the distributed objects style on the application building process without regarding if its the best style for the application.

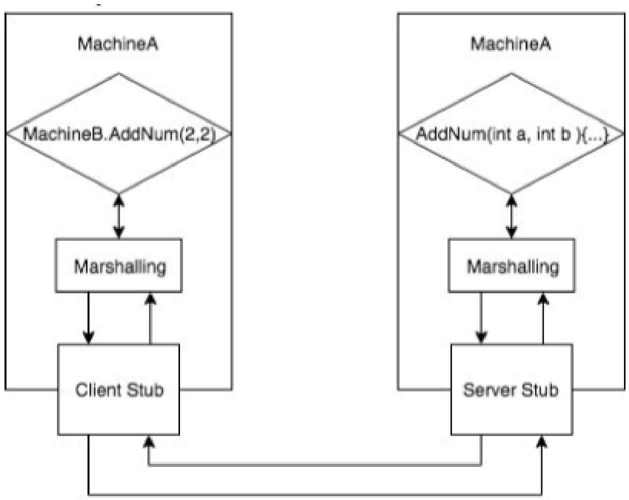
- In terms of the components in a distributed objects style, they are required to explicitly specify the provided interfaces, however, it does not specifying required interfaces, which may cause deeply ingrained dependencies between objects. Another negative behaviour exhibiting from distributed objects style is that the objects are created, linked, and destroyed constantly. Due to all the creation and destruction of the objects, its difficult to fully comprehend the structure and configurations of the application at any given time.

Non-functional Properties

None Gonna have to dig in the rest of this text for them.

Implementation

Implementation of Distributed Objects may involve several important aspects. Firstly, a class named Matrix Class is initialized in a generic, broad object language. That matrix class actually defines the inner components and functions like methods. Most of the times, such is IDL: Interface Description Language. At the very initial stage of compilation, the matrix class is changed to every listed languages, whether they be C++, Java, etc. Every program subsequently involves the feasible file in their system. These blocks of codes comprise of the definition of classes as well as methods for disintegrating the actual class to several components. This transmits them via a connection to other program, regenerating the object on the opposite side.



Constraints	Explanation
Serializability	Data being passed to RPC is achievable without stressing the network

Term	Definition
RPC	Remote procedure call
Data Marshaling	Serialization of parameters and return value during RPC call. Uses pipe-filtering
Objects	Instantiated objects which represent functionality for its host
Stub	Represents the interface to the remote object
Skeleton	Represents the structure of public facing object
Client-Server	Type of interaction between caller and callee
CORBA	Framework aids it distributed objects style development

Synchronous	By default remote RPC calls are synchronous and IO blocking. Methods exist to resolve this. Asynchronous development increases complexity
Performance	Computational power of processing and network can create bottleneck in entire system. Task management systems are needed to address these bottlenecks. Objects representing host machine abstract away the performance capabilities.
Middleware induces bad design pattern	When using services of middleware, often the middleware induces distributed object style when it is not needed.
Streams and high data volume	This style is not resilient to high volume of data and streams.

Client Server

The client-server architecture is a pure network architecture in which each computer or process on the network is either a client or a server. There are 3 major components. First we have the servers which are powerful computers or processes dedicated to managing disk drives (file servers), printers (print servers), or network traffic (network servers). Second, clients are workstations on which users can run applications. Finally we have resources which are files, devices, and even processing power. The components are connected via connectors which are essentially network layer protocols such as TCP/IP.

Comparison

Advantages

- The architecture style allows the system to distribute workload amongst multiple machines or processes. It is very flexible as to allow the architect to decide how to divide tasks amongst the clients and servers. This helps promote the separation of concerns. The architecture style is most beneficial when increasing the modularity of the components and decreasing coupling. This can be done through encapsulation of information with a well-defined standardized interface. The system will also allow centralized control and redesign since all machines and processes should be running software defined by the system architect.

Disadvantages

- Due to its centralized design, need load-balancer and failover systems in order to scale properly. There is a possibility for congestion of traffic, which motivates the need for the load-balancers. A client-server network is also costly to set up, often requiring you to purchase licenses like a copy of Windows NT, which is a family of operating systems for servers, and also client licenses. The hardware required for servers is also needed to be more powerful than a standard workstation, and additionally require employees to manage them. This means paying more for equipment and networking professionals, who dont come cheap, to even run the server.
- The client-server system is especially vulnerable to failures as there is always going to be a limited number of servers relative to clients. If a critical number of them go down, no users will be able to use the system until the servers are fixed or replaced. This makes them vulnerable to denial of service attack, distributed denial of service attack where the perpetrator seeks to make a machine or network resource unavailable to its intended users by temporarily or indefinitely disrupting services of a host connected to the Internet. Denial of service is typically accomplished by flooding the targeted machine or resource with superfluous requests in an attempt to overload systems

Non-functional Properties

Dependability The architecture supports availability as servers are easy to keep running and typically do not have to shutdown or restart for many days. It also supports dependability as control and distribution of resources and data are controlled by a dedicated server.

Heterogeneity clients and servers often function as disparate parts.

Scalability the centralized servers can be updated with minimal impact to the client.

Negative Efficiency since the server handles all the stress and demand of the system. When there is an unanticipated amount of stress and the server becomes congested, performance can slow down drastically or even fail to perform which affects all users.

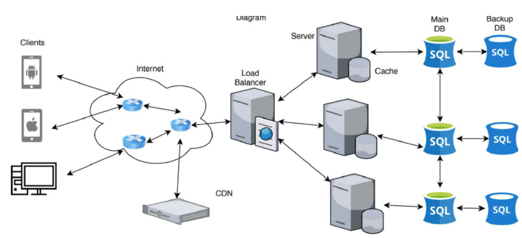
Negative Transparency? It also inhibits transparency because communication is restricted to requests and clients are unable to see fetch processes running on the server.

Implementation and Example

As seen from the diagrams, the flow of the data is unidirectional and forms a cycle. It is usually initiated by the client requesting some kind of data and the server processing the request and sending some kind of data back to the client. A typical topological data flow goes as follows:

1. Client request data from server
2. Load balancer routes the request to the appropriate server
3. Server process the request client
4. Server queries appropriate database for some data
5. Database return the queried data back the server
6. The server processes the data and send the data back to the client
7. (This process repeats)

All technology companies today use this architecture, Uber, Facebook, Airbnb, etc.



Blackboard

a behavioural design pattern for systems that need to integrate multiple individually specialized computation modules to solve complex problems where information is ambiguous, and the path to the solution is not known in advance. Its architectural topology can be separated into 3 main sub-categories: the blackboard, the knowledge sources, and the controller, as shown in Figure 1. In general, the blackboard is a shared memory space holding information representing the state of a problem on which knowledge sources (KS) will operate when recruited by the controller, applying their specialized knowledge to contribute to the ultimate formation of a solution. This cooperative process will be discussed in more detail in the next sections.

The blackboard architecture is ideal for solving problems where information is ambiguous or the path to the solution is not known in advance. The blackboard is a shared memory space that is responsible for acting as a hub for all streamed data, solutions, and partial solutions. The KSs, also called experts or agents, are responsible for performing very specific tasks to contribute to the final solution. A KS is generally used to determine if the problem has been solved or solved enough. Not all KSs need to contribute to a solution or to be run in order to sufficiently find the solution to a problem. Controllers are used to orchestrate the KSs. Many algorithms can be used with the controller to help optimize the execution of KSs.

The blackboard is a shared memory space. This means that all the information streamed into the system or processed by the KSs will persist in this shared space, fully accessible by all components in the system. At any given point in time, the blackboard is not required to have the full solution to the problem the system is built for. Instead, it will hold partial solutions to smaller subproblems solved and, eventually, due to the non-deterministic nature of the control process, will contain a solution that is deemed viable to a certain degree of precision. The KSs are the experts responsible for processing and contributing to the solution as a whole.

Implementation

Knowledge sources, also called agents, can be thought of as specialised experts in being able to perform very specific tasks. From the perspective of the blackboard, the KSs form a panel of individuals, unaware of each other, who will contribute their niche resources to advance the problem toward an acceptable solution state. Incidentally, this decoupling of resources makes blackboard architecture very modular, making reuse of KSs very easy for new blackboard implementations. Collectively, the incremental solutions processed and reposted to the blackboard by the KSs will converge on a solution. One of the KSs may be responsible for marking a solution presented on the blackboard as viable. The degree of the viability of a solution depends entirely on the problem and the defined criteria for an acceptable solution.

In some implementations of this architecture, a controller is not even necessary. The KSs evaluate the information presented on the blackboard and, if able, they process them on their own, possibly editing metadata associated with the information they want to process to keep track of the problem state. However, the purpose of this pattern is to provide an architectural framework that is capable of solving complex, non-deterministic control problems. This means that the KSs may not necessarily run linearly; they can run in parallel. Optimization is at the root of control problems where resource allocation in parallel computation is necessary to most efficiently compute a solution to a problem. This is where a controller comes into the picture to help address the optimization problem.

The controller is responsible for assigning tasks to the KSs to process information on the blackboard. The goal is to converge on a solution that is considered acceptable for the problem. The way in which the controller, blackboard, and KSs communicate (i.e. event-based, polling, publisher-subscriber, etc.) is less important than the roles they play, and thus not rigidly defined in the architecture.

Non-functional Properties

Reusable A single KS can be used by multiple blackboards. Since they are independent from each other, they can be reused in other blackboard architecture problems.

Scalable Because of the flexibility of the KSs it is easy to add and remove them. If we wish to have a better solution, adding agents could help. The controller just needs to be modified to take into consideration the changes. Overall, if the system requires more processing power, then additional agents can be added to create a better throughput.

Robust If a KS fails to complete its task or is unavailable, then a solution might still be found thanks to the other KSs. Note that it might not be as optimal or complete.