Behavioral Patterns

Jim Yu

IBM
China Development Lab
Greater China Group

Why Behavioral Patterns

- Implement program behaviors in an object-oriented and flexible way
- Assign responsibility among classes or objects
- Encapsulate program behaviors that might change
  - e.g. algorithms, state-dependent behaviors, object communications, object traversal
- Reduce coupling in the program
- decouple request sender and receiver

Iterator

Next, please!

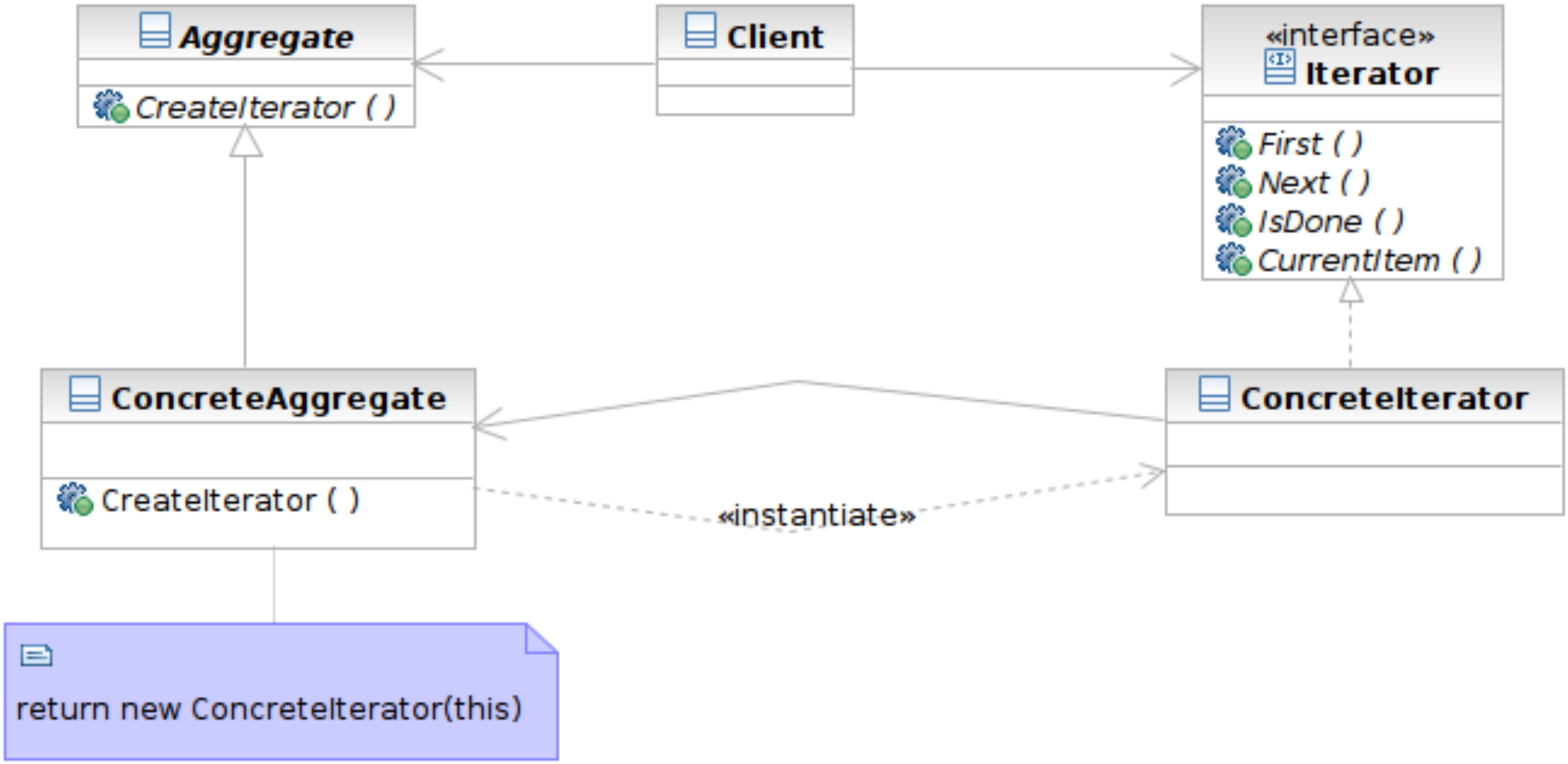
Challenge

- Show your belongings
  - Iterate over the items in you have and display them
- Save the progress
  - Iterate over the player's object graph and save them
- First attempt:
  - Traverse the linked list via each node's next pointer
  - Depth-first traverse the player's object graph

Iterator

- Problem: we often want to iterate over a collection of objects. How can we do this in a flexible way?
- Think: what's the effort if you replace your LinkedList with an ArrayList? Or even a BinarySearchTree? Can you provide multiple traversal methods?
- Target: given an aggregate (collection) class, we want to traverse its elements without knowing how it's implemented.

Structure


Aggregate
CreateIterator ( )
Client
«interface»
Iterator
First ( )
Next ( )
IsDone ( )
CurrentItem ( )
ConcreteAggregate
CreateIterator ( )
ConcreteIterator
«instantiate»
return new ConcreteIterator(this)

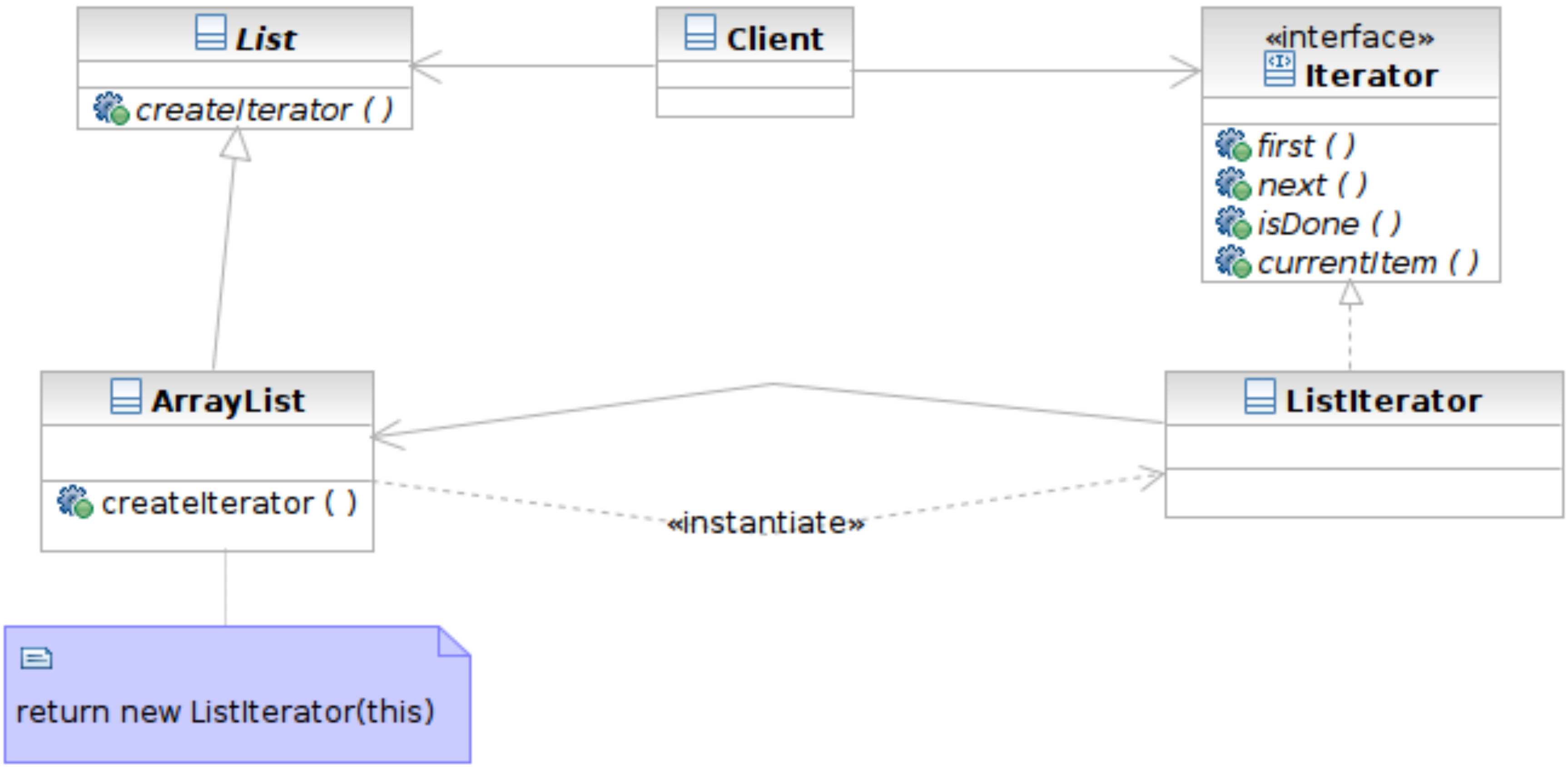
Participants

- □ Class **Iterator** defines an interface for accessing and traversing elements
- □ Class **ConcreteIterator** implements the Iterator interface; keeps track of the current position of traversal
- □ Class **Aggregate** defines an interface for creating an Iterator object
- □ Class **ConcreteAggregate** implements the Iterator creation interface to return an instance of the proper ConcreteIterator

Applicability

- Use the Iterator pattern
  - to access the elements of an aggregate object
  - to support multiple traversals of aggregate objects
    - forwards, backwards, depth–first, etc.
  - to provide a uniform interface for traversing different Aggregate structures
    - linked lists, array, tree, graph, etc.

Sample Structure



Samples

- List and Iterator:
  - class List and Iterator
- Concrete List and Iterator
  - class ArrayList and ListIterator
- Using Iterator
  - Method PrintUsers.testPrintUsers()
  - Reverse Iterator: method ReverseIterate.testReverseIterator()

Consequences

- It supports variations in the traversal of an aggregate: replace the iterator and the traversal algorithm is changed
- Iterators simplify the Aggregate interface: Iterator methods are not implemented in each concrete Aggregate (you may also reuse concrete Iterators)
- Support for more than one traversal of the Aggregate: just add Iterator factory methods

Related Patterns

- **Composite**: use iterator to traverse the composite object structure
- **Factory Method**: creates the concrete iterator

Chain of Responsibility

I can't handle it, could you please?

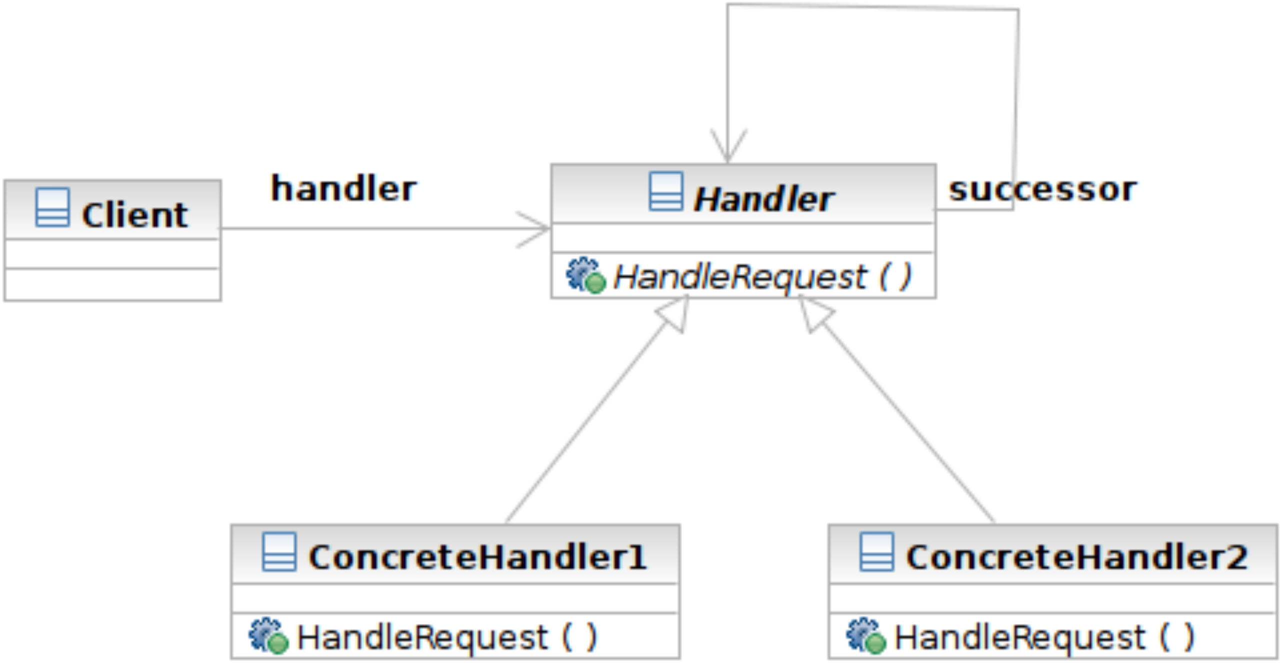
Challenge

- You are implementing the user input handler of the GUI widgets
  - The widgets have parent-children relationships
  - If the object can be selected, then the object takes the focus and performs the action
  - If the object cannot be selected, then try to select the object's parent
- First attempt: code it using if ... then ...

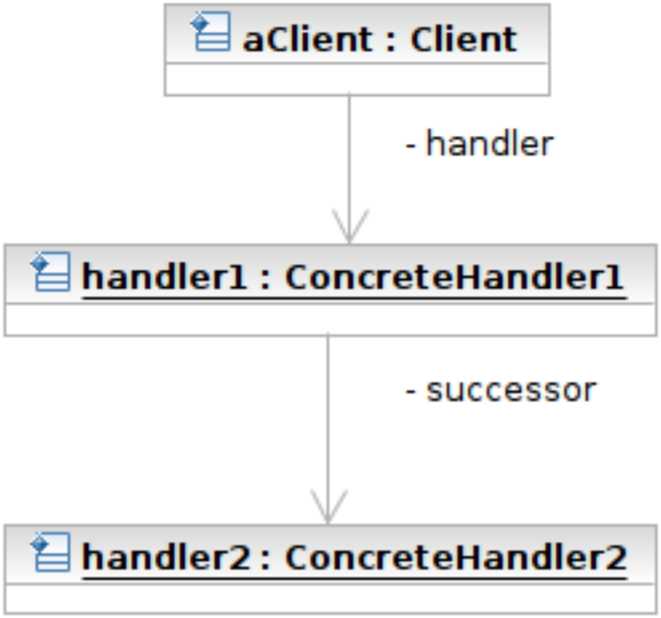
Chain of Responsibility

- Problem: how can you handle a request in a flexible way if multiple objects may take responsibility?
- Think: what is the effort if the widgets are composed differently? What if some widgets are added?
- Target: decouple the request sender and handler by chaining the possible handlers and passing the request along the chain until handled.

Structure


Client
handler
Handler
successor
HandleRequest ( )
ConcreteHandler1
HandleRequest ( )
ConcreteHandler2
HandleRequest ( )

Structure


aClient : Client
- handler
handler1 : ConcreteHandler1
- successor
handler2 : ConcreteHandler2

Participants

□ Class Handler defines an interface for handling requests

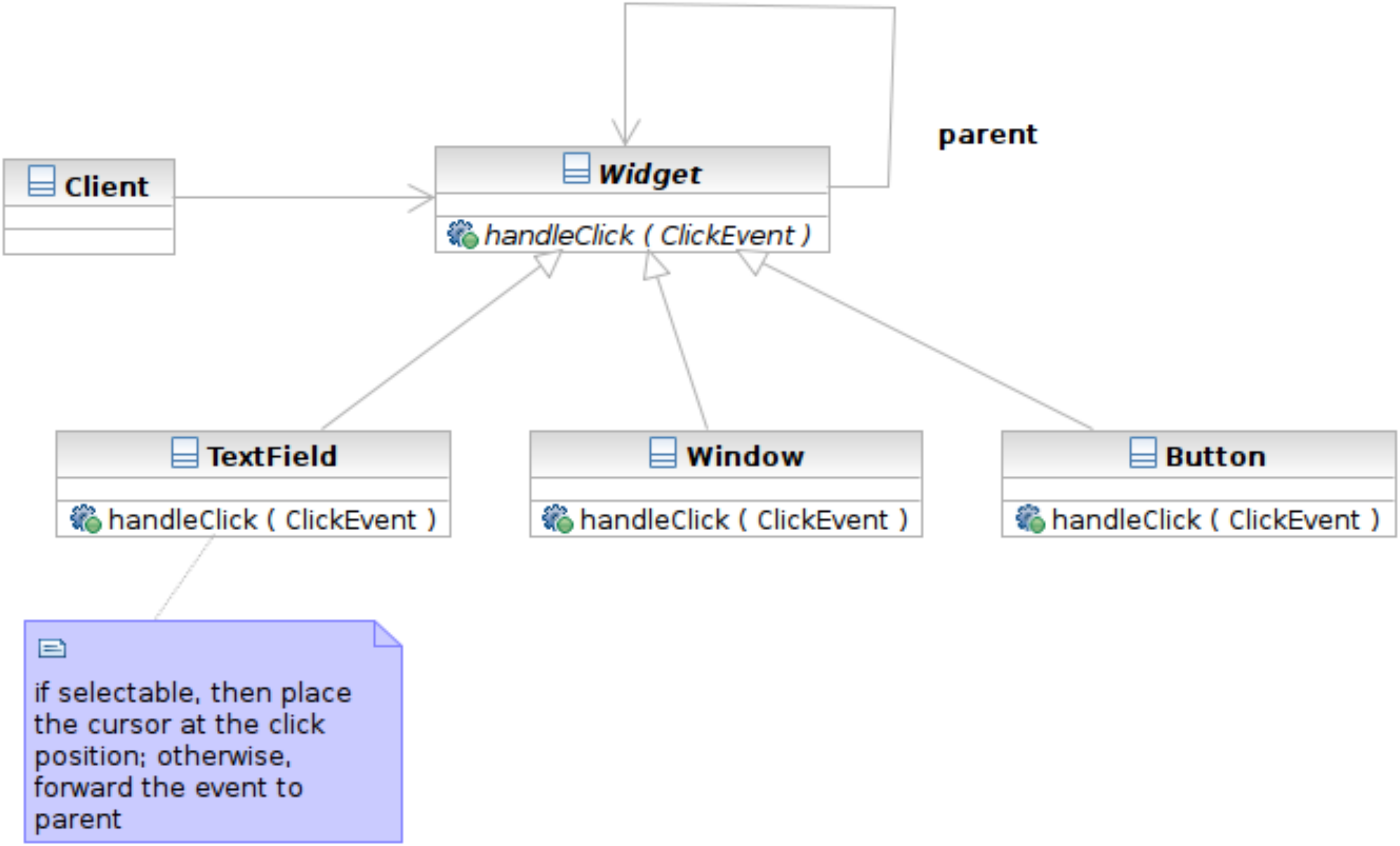
□ Class ConcreteHandler handles requests or forwards the request that it cannot handle to its successor

□ Class Client initiates the requests to a ConcreteHandler object

Applicability

- Use Chain of Responsibility when
  - more than one object may handle a request, and the handler is not known a priori.
  - you want to issue a request to one of several objects without specifying the receiver explicitly
  - the set of objects that can handle a request should be specified dynamically.
    - by modifying the chain

Sample Structure


parent
Client
Widget
handleClick (ClickEvent)
TextField
handleClick (ClickEvent)
Window
handleClick (ClickEvent)
Button
handleClick (ClickEvent)

if selectable, then place the cursor at the click position; otherwise, forward the event to parent

Samples

- Handler: class Widget
  - defines the request handling interface
  - holds the reference to its successor (parent in this case)
- ConcreteHandlers: class TextField, Window, Button
  - handle or forward the request
- Client

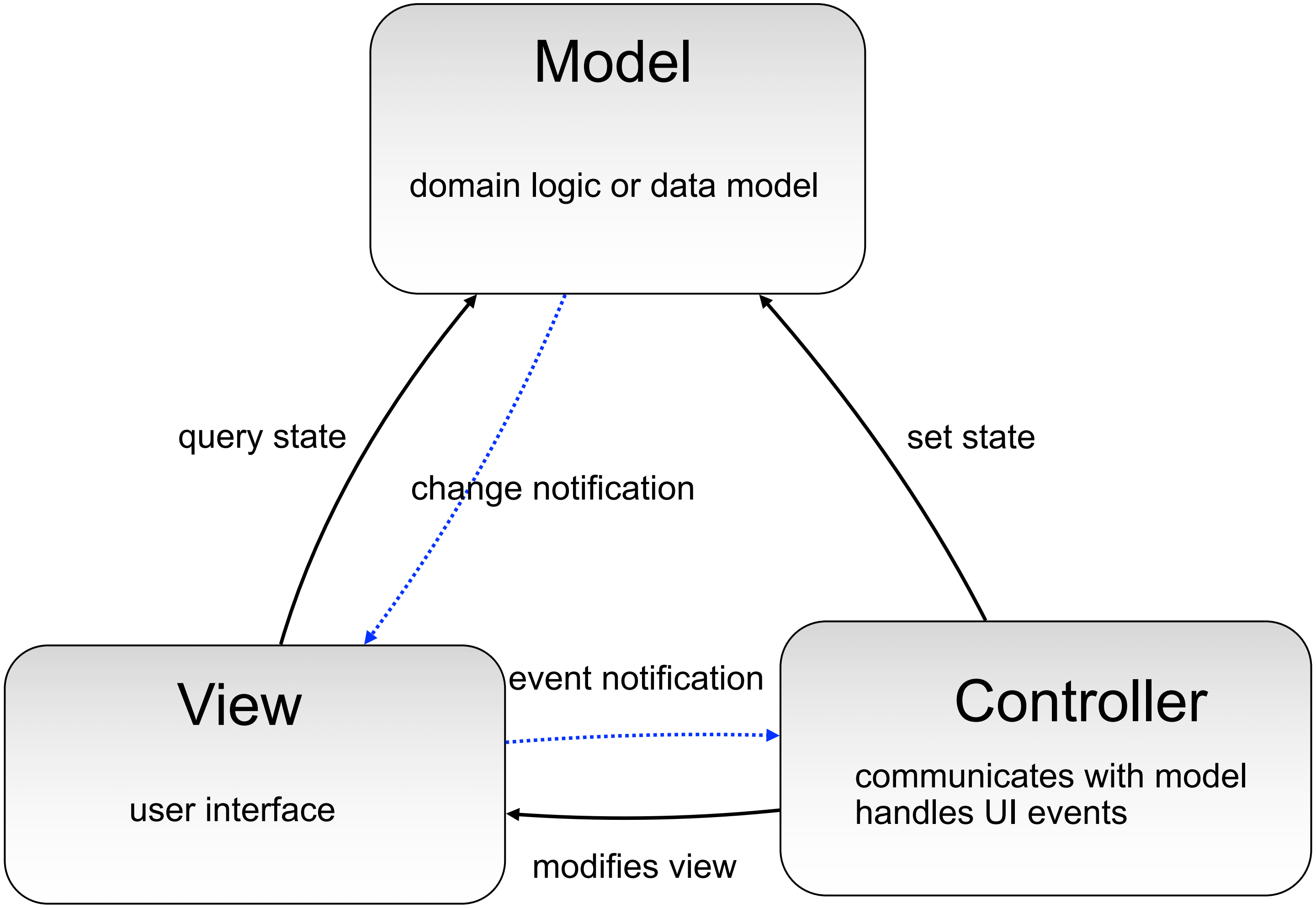
Consequences

- **It reduces coupling.** The pattern frees the client from knowing which handler will handle the request.
- **It adds flexibility in assigning responsibilities to objects.** Just modify the chain at run-time.
- **The receipt is not guaranteed.** The request can fall of the end of the chain without ever being handled.

Related Patterns

- **Composite:** parent node acts as the successor

Model–View–Controller (MVC)



Observer

This is my number. Call me when you're available.

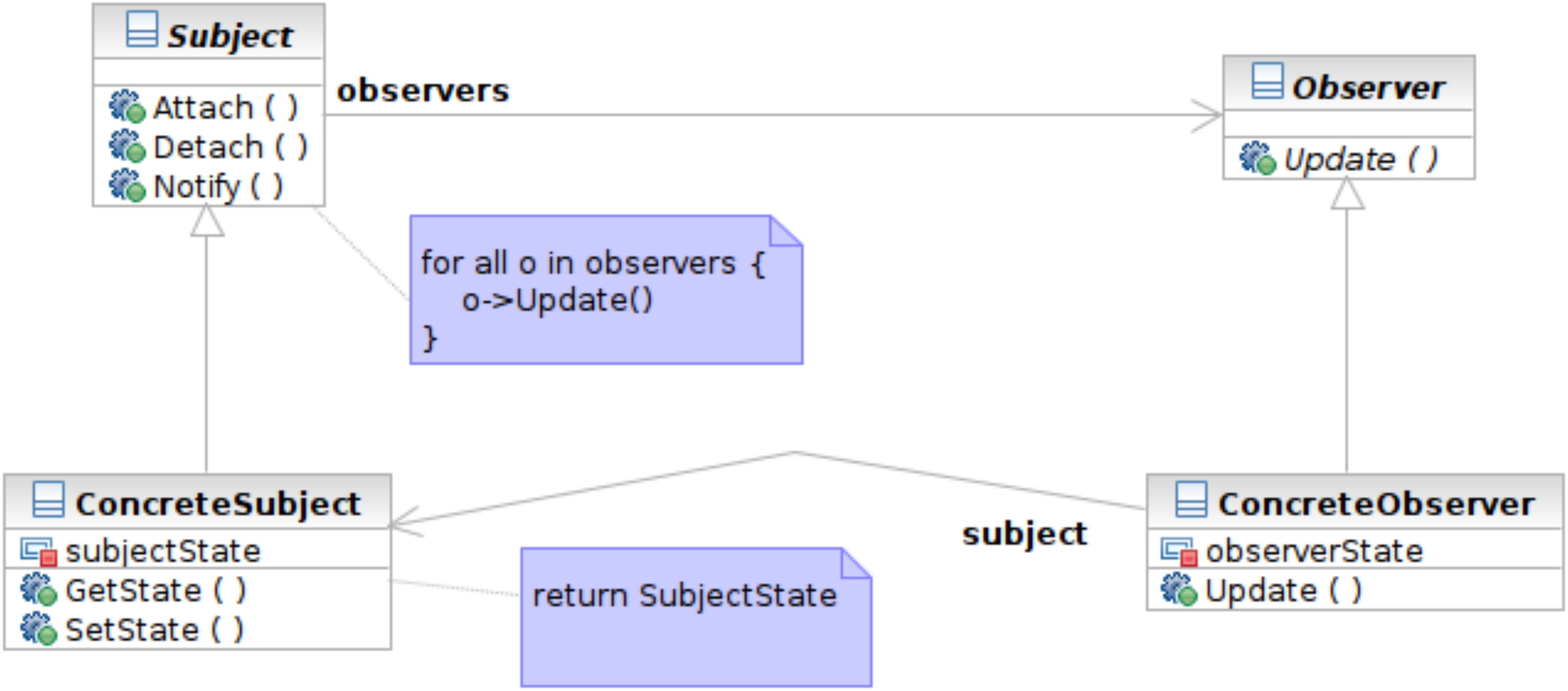
Challenge

- The user interface should listen to events and react to some events
  - Some player sends a message
  - Your belongings are stolen
- First attempt: poll each events in a big event loop
  - Polling wastes CPU cycles when there is no events
  - Spaghetti code of the event loop

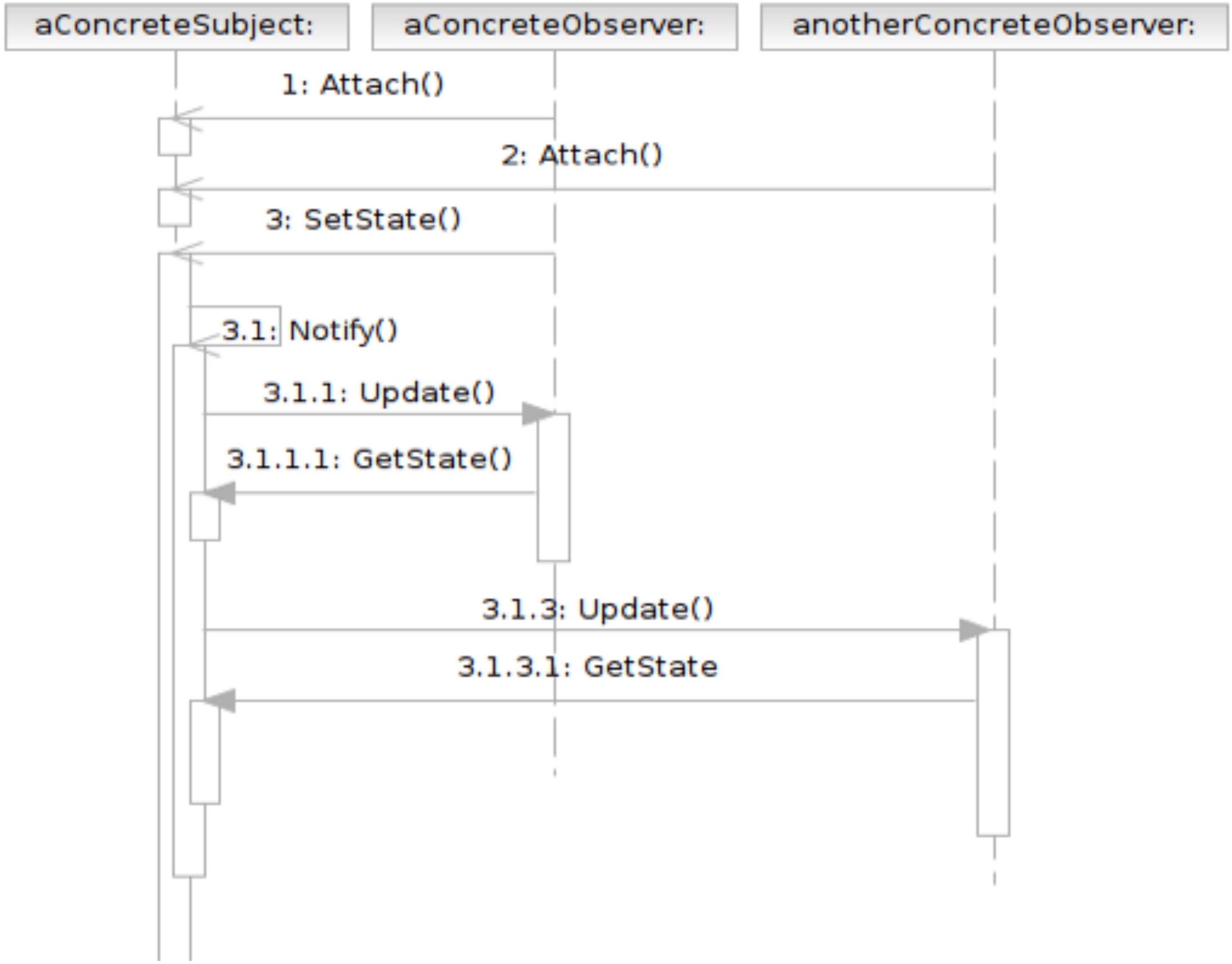
Observer

- Problem: we want to listen to events that we are interested in. How can we do this in a flexible way?
- Think: what is the effort if you want to add event types or listeners? Is your implementation extensible and efficient?
- Target: define a relationship between objects so that one (observer) can be notified if another (subject) updates.

Structure


Subject
Attach ( )
Detach ( )
Notify ( )
observers
Observer
Update ( )
for all o in observers {
    o->Update()
}
ConcreteSubject
subjectState
GetState ( )
SetState ( )
return SubjectState
subject
ConcreteObserver
observerState
Update ( )

Interaction



Participants

- Class **Subject** knows its observers and provides an interface for attaching and detaching Observer objects
  - A.K.A **Publisher**, who generates events and sends notifications
- Class **Observer** defines an updating interface
  - A.K.A. **Subscriber**, who is interested in the events

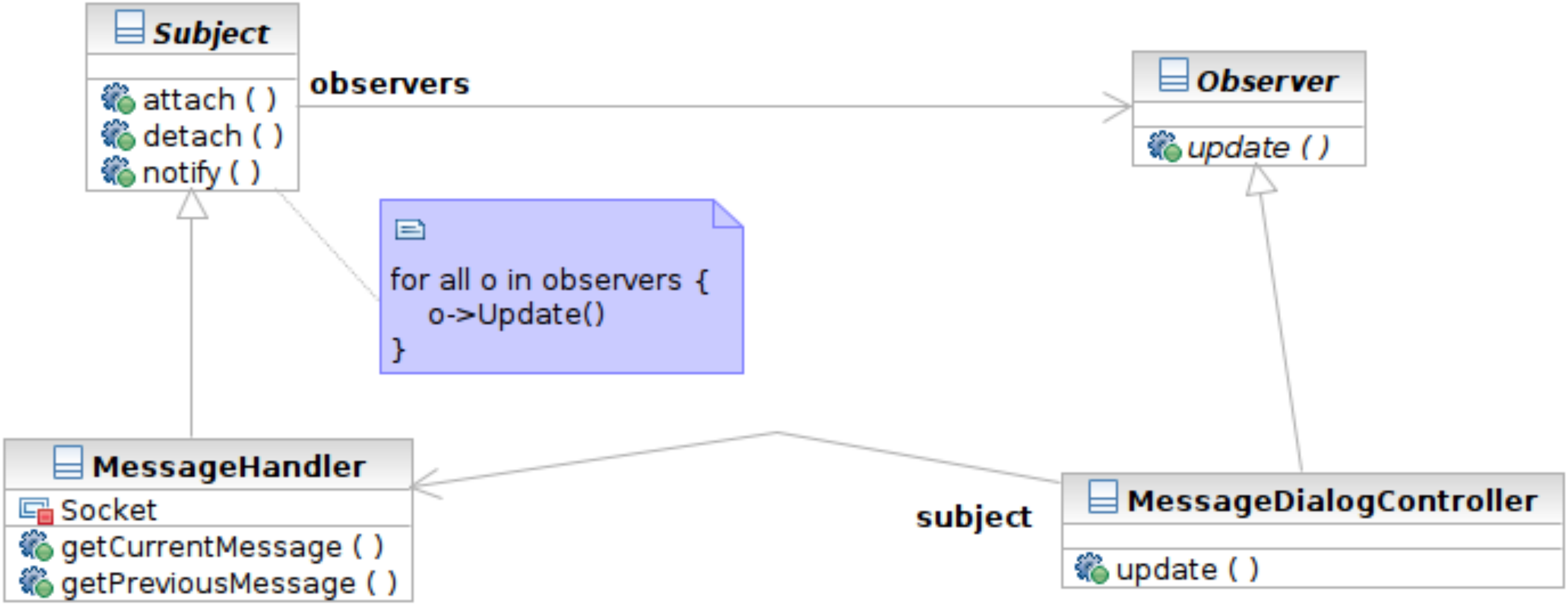
Participants (Cont'd)

- Class **ConcreteSubject** stores state and sends notifications to observers
- Class **ConcreteObserver** maintains a reference to a ConcreteSubject object; stores states; implements the Observer updating interface

Applicability

- Use the Observer pattern when
  - an abstraction has two aspects, one (observer) dependent on the other (subject).
  - a change to one object (subject) requires changing others (observers), and you don’t know how many objects need to be changed
  - an object (subject) should be able to notify other objects (observers) without making assumptions about who these objects are (the observers' classes).

Sample Structure



Subject

- attach ( )
- detach ( )
- notify ( )

observers

Observer

- update ( )

```
for all o in observers {
    o->Update()
}
```

MessageHandler

- Socket
- getCurrentMessage ( )
- getPreviousMessage ( )

subject

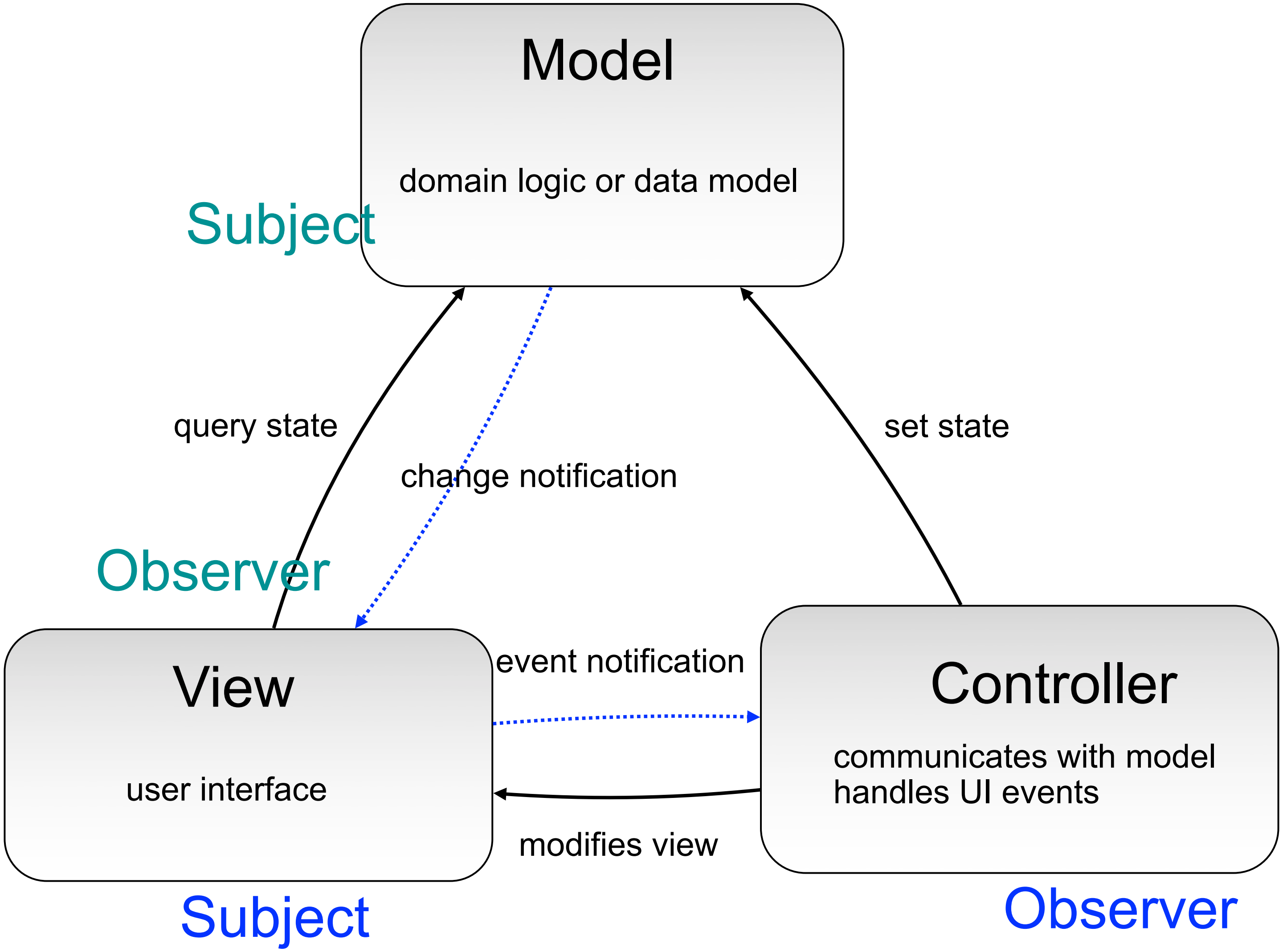
MessageDialogController

- update ( )

Samples

- Class Observer
- Class Subject
- Concrete Subject: Class MessageHandler, sends/receives messages to/from network
- Concrete Observers: MessageDialogController, observes the event

MVC and Observer Pattern



Consequences

- Abstract coupling between Subject and Observer. All a subject knows is that it has a list of observers.
- Support for broadcast communication. The notification is broadcast automatically to all interested observers.
- Unexpected notifications. An innocuous operation on the subject may cause all registered observers to be updated.

Related Patterns

- **Mediator**: mediator may receive the communication from the colleagues using the observer pattern

Mediator

Would you please transfer the call to Mr. Anderson, please?

Challenge

- In your user interface, different widgets should act in response to others
  - click item button, the item list shows up
  - select one friend in the list and detail information is displayed accordingly on another panel

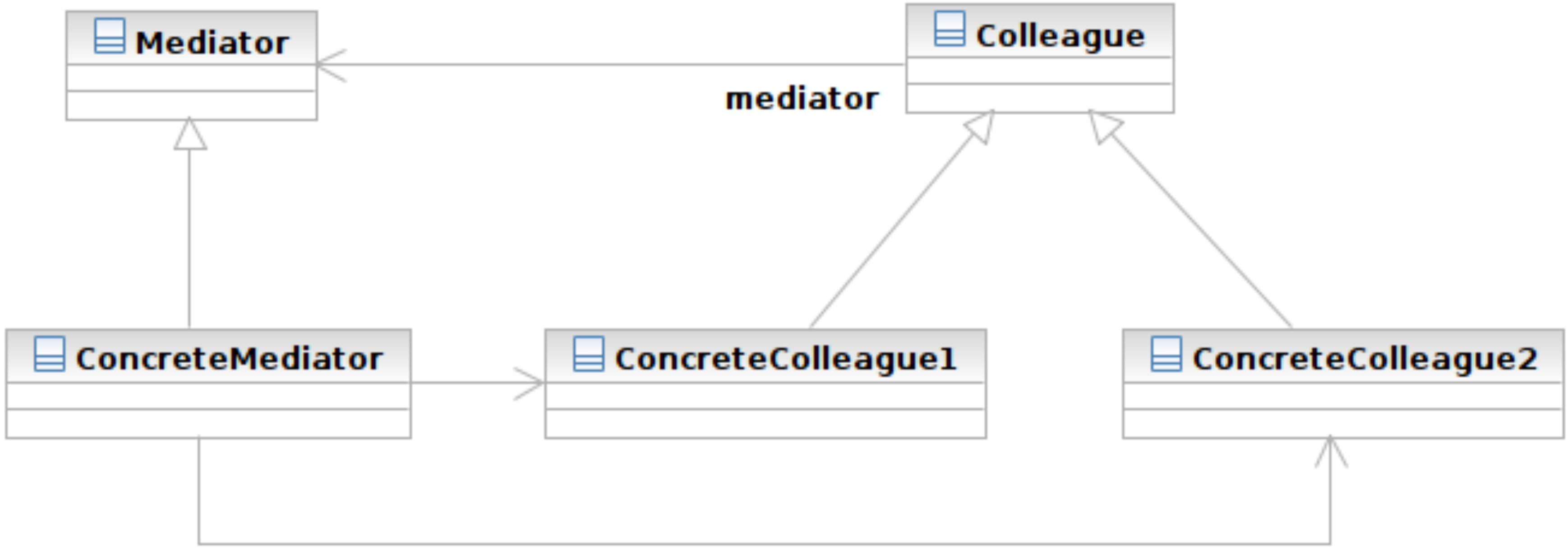
Challenge (Cont'd)

- First attempt:
  - Each widget has references to other widgets and checks other widgets for updates
  - Worst case: each widget knows about all other widgets: O(N^2) complexity of the relationships

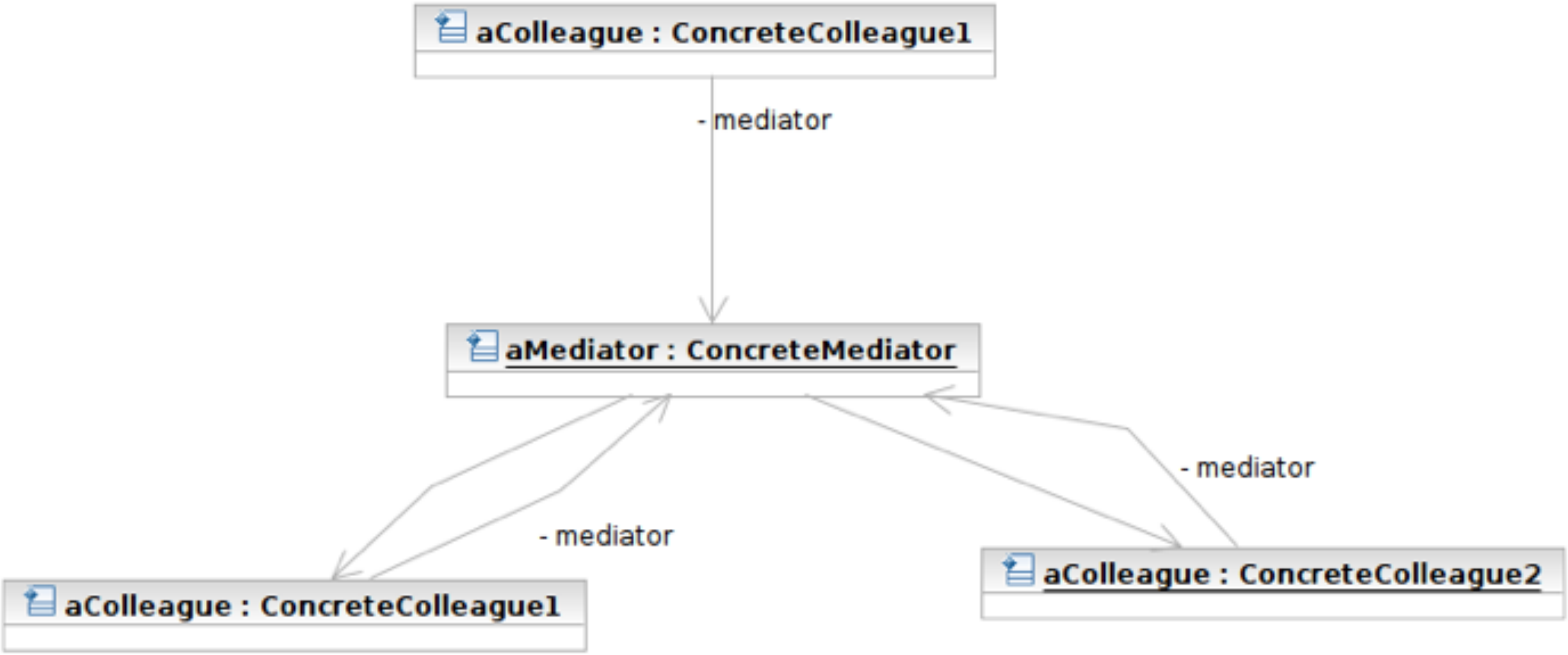
Mediator

- Problem: how can we handle interactions between a set of objects in a flexible way?
- Think: what is the effort if you decide to add one more widgets to the user interface?
- Target: encapsulate the interaction between objects. Objects don't refer to one another and interaction can be varied independently.

Structure


Mediator
Colleague
mediator
ConcreteMediator
ConcreteColleague1
ConcreteColleague2

Structure


aColleague : ConcreteColleague1
- mediator
aMediator : ConcreteMediator
- mediator
- mediator
aColleague : ConcreteColleague1
aColleague : ConcreteColleague2

Participants

- Class **Mediator** defines an interface for communicating with Colleague objects
  - Often acts as the **Controller** in the MVC design pattern
  - Often acts as the **Observer** in the Observer pattern
- Class **ConcreteMediator** knows and maintains its colleagues and implements their interactions

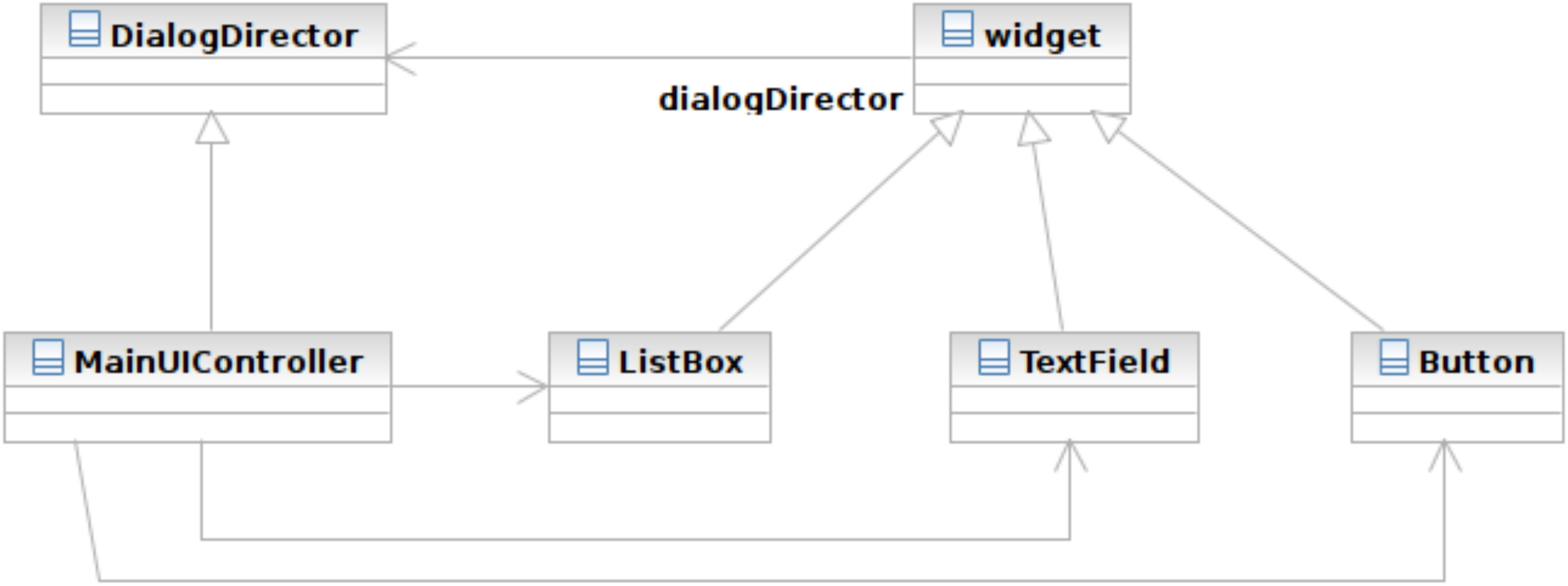
Participants

- Class **Colleague** knows its Mediator and communicates with other colleagues via mediator
  - Often the View components in the MVC pattern
  - The **Subjects** in the Observer pattern

Applicability

- Use the Mediator pattern when
  - a set of colleagues communicate in a well-defined but complex ways.
  - reusing a colleague is difficult because it refers to and communicates with many other objects
  - you want to customize some objects' behaviors and interactions without a lot of subclassing: encapsulate in a mediator

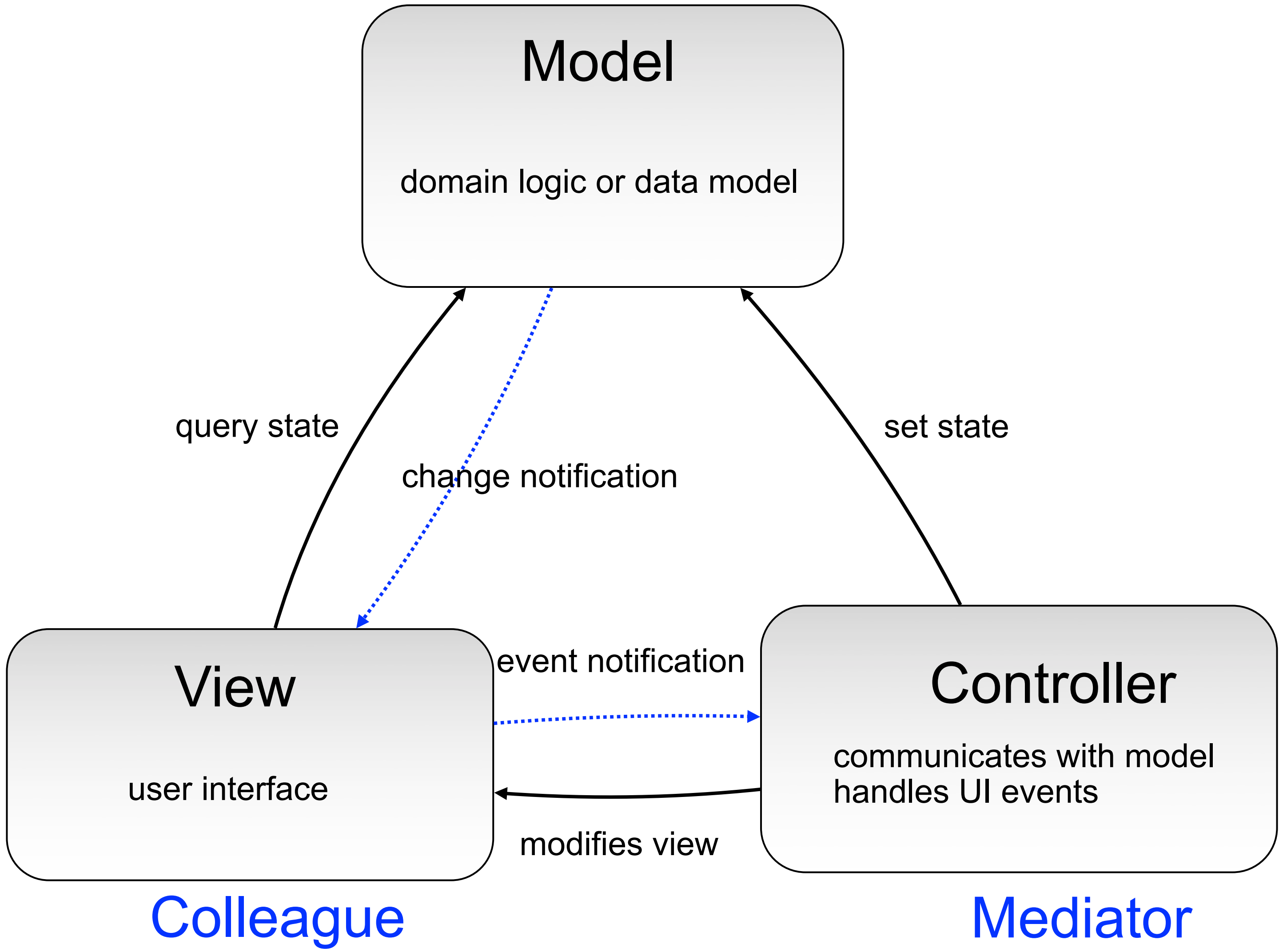
Sample Structure



Samples

- Mediator: class DialogDirector
- Colleague: class Widget
- Concrete Colleagues: ListBox, TextField, Button, and many other GUI components
- Concrete Mediator: MainUIController
  - Implementing DialogDirector::CreateWidgets()
  - Implementing DialogDirector::update()
    - Observer pattern

MVC and Mediator Pattern



Consequences

- It limits subclassing. A mediator localizes behavior that otherwise would be distributed among several objects.
- It decouples colleagues. Colleagues don't have to know one another
- It simplifies object protocols. Many-to-many interactions between colleges is replaced with one-to-many interactions between the mediator and its colleagues.

Consequences

- It abstracts how objects cooperate. Mediators separate colleagues' interactions from their own behaviors
- It centralizes control. Complexity of interaction is centralized in the mediator.

Related Patterns

- **Facade**: facade provides the interface of the subsystem to the outer world. It's one–way communication. Mediator facilitates two–way communications between colleagues.
- **Observer**: colleagues communicate with the mediator using the Observer pattern

Command

This is an order, effective on next Monday.

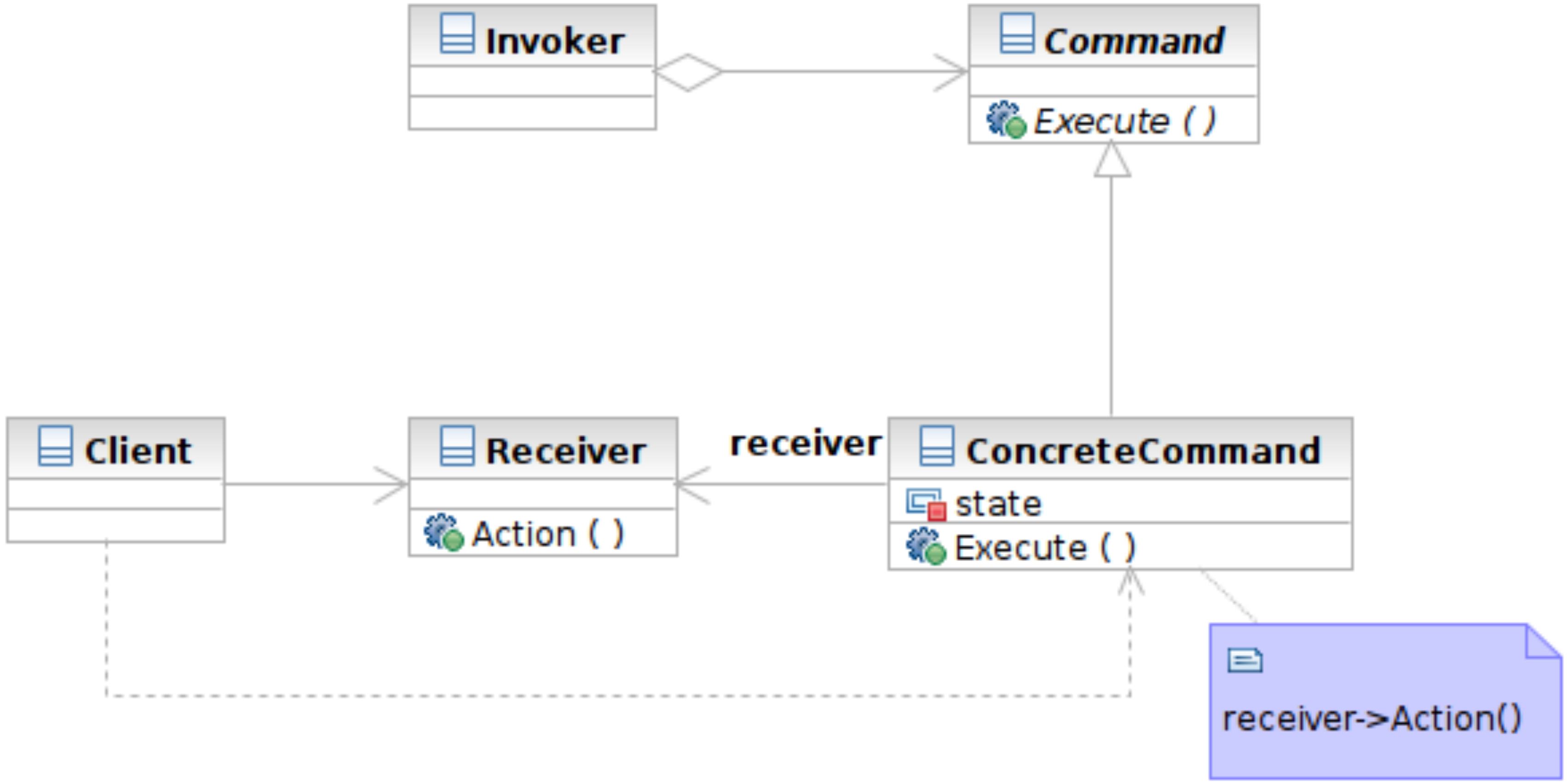
Challenge

- We want to customize the behaviors of the reusable widgets
  - Add a new user when “buy item” button is pushed
  - We have “sell item”, “drop item” and many more widgets performing different actions
  - Widget classes don't know anything about the action, but has to execute it
    - perform the action when the button is pushed
- First attempt: subclassing the widgets

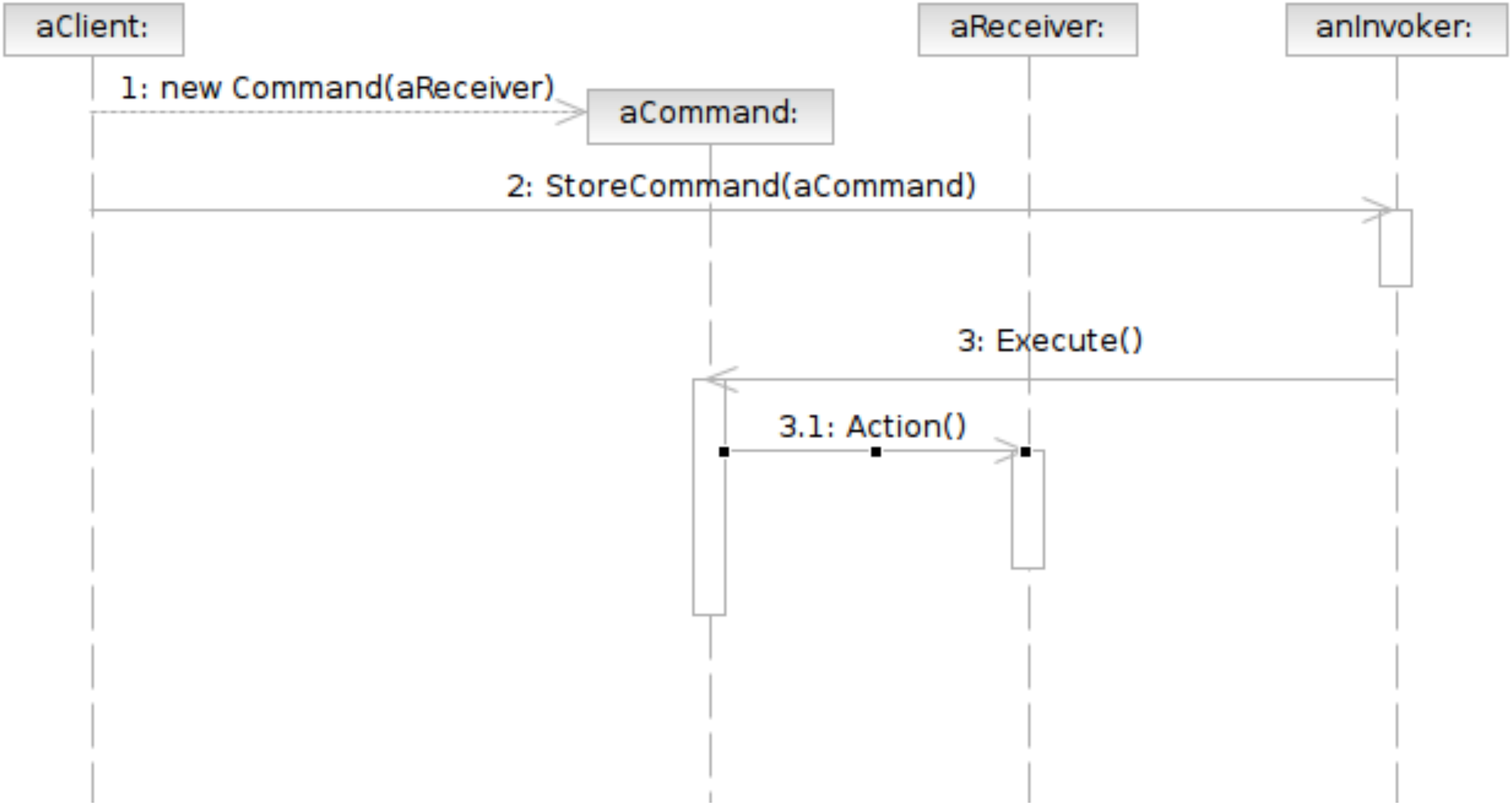
Command

- □ Problem: how can we define actions that can be invoked by other objects at later times
- □ Think: is subclassing flexible? What if you have many actions to perform or you are not allowed to subclass the invokers?
- □ Target: encapsulate actions as objects such that the actions can be passed to invokers, be queued and invoked later, and be undone

Structure


Invoker
Command
Execute ( )
Client
Receiver
Action ( )
receiver
ConcreteCommand
state
Execute ( )
receiver->Action()

Interaction



Participants

- Class **Command** declares an interface for executing an operation.
- Class **ConcreteCommand** defines a binding between a Receiver object and an action; implements Execute by invoking the corresponding operations on Receiver
  - note that there hasn't to be only one receiver used in a command
  - a receiver isn't always necessary for a command to execute, either

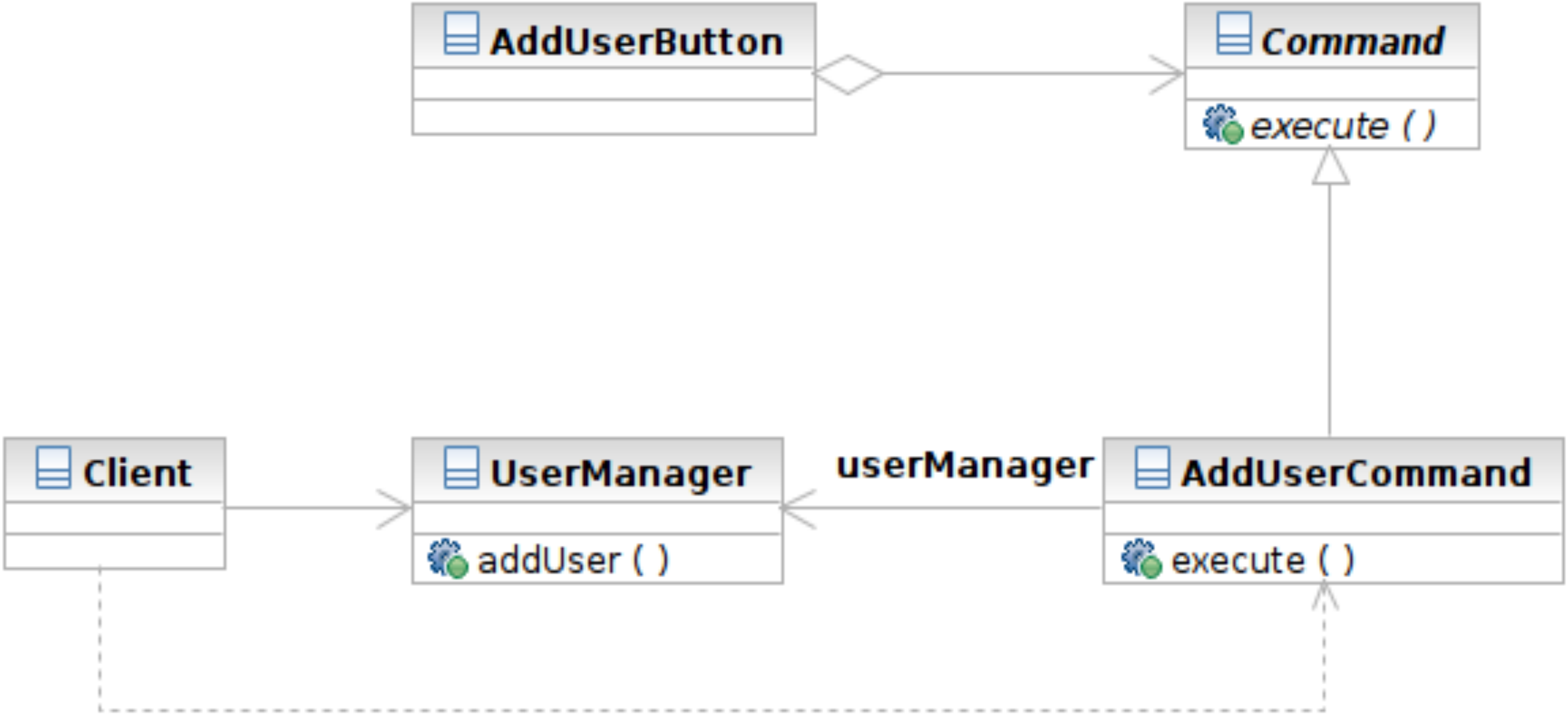
Participants (Cont'd)

- Class **Client** creates a ConcreteCommand object and sets its receiver
- Class **Invoker** asks the command to carry out the request
- Class **Receiver** knows how to perform the operations

Applicability

- Use the Command pattern when
  - to parameterize objects (e.g. widgets) with an action (command) to perform.
  - instead of subclassing
  - specify, queue and execute requests at different times.
  - support undo.
  - support macro commands (commands composed of other commands)

Sample Structure



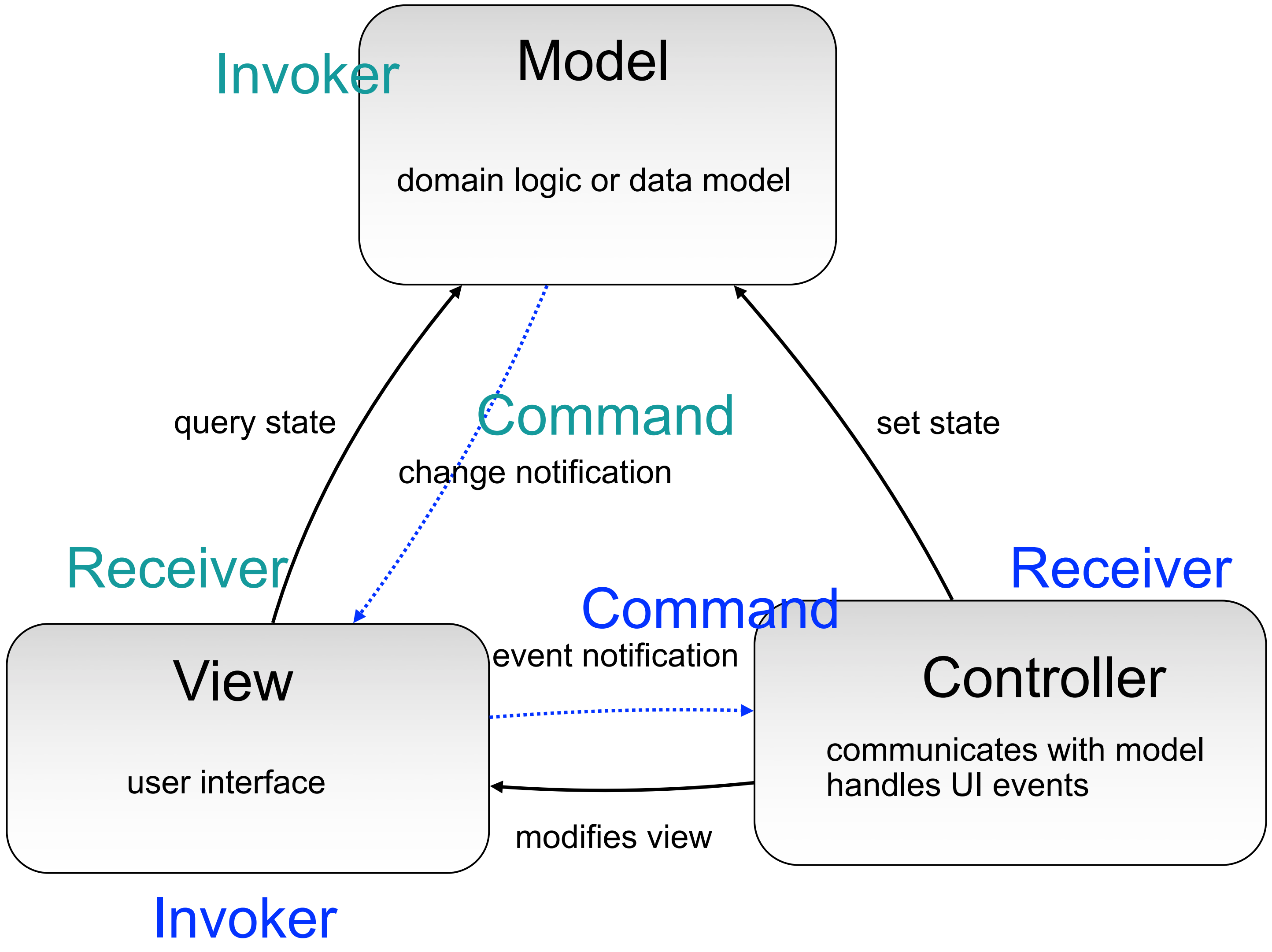
Samples

- Command: class Command
  - defines the interface
- ConcreteCommand: class AddUserCommand
  - implements execute()
- Receiver: class UserManager
  - who receives the command
- Client: class Client
  - creates the command
  - associates the command with the receiver

Samples (Cont'd)

- Invoker: class AddUserButton
  - who triggers the execution of the command
  - e.g. user pushed the button
- Composite Command: class MacroCommand
  - the composite pattern
  - is composed of other commands

MVC and Mediator Pattern



Consequences

- It decouples the invoker from the receiver.
- Commands are first-class objects. They can be assembled into a composite (macro) command.
- They can be extended easily.

Related Patterns

- **Composite**: used to implement MacroCommands
- **Memento**: used to remember the state the command requires for undoing the operation
- **Prototype**: cloning a command before putting on the command history list

Template Method

Fill the blanks.

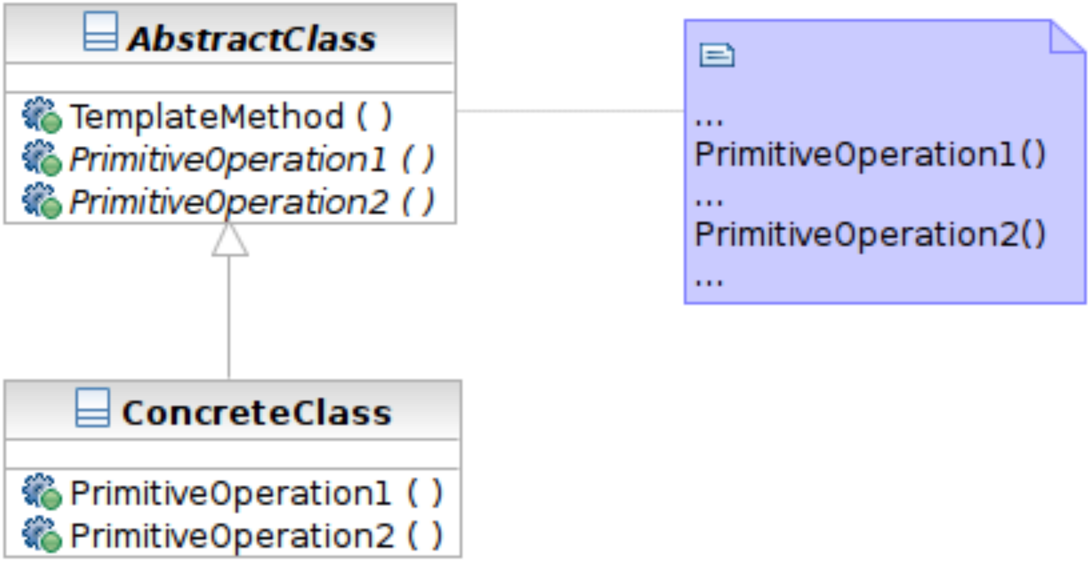
Challenge

- Validating user account on registration
  - check registered account ID
  - validate address, phone number in multiple countries
  - validate credit card
- First attempt: one concrete validator for each country. Each validator performs all validations.
  - some logic are the same for all countries and can be shared

Template Method

- □ Problem: how can we do both code reuse and customization of one algorithm?
- □ Think: how much code is redundant in the big validation method? What is the effort to change the validation logic?
- □ Target: define the skeleton of an algorithm in an operation and defer some steps to subclasses.

Structure


AbstractClass
TemplateMethod ( )
PrimitiveOperation1 ( )
PrimitiveOperation2 ( )
ConcreteClass
PrimitiveOperation1 ( )
PrimitiveOperation2 ( )
...
PrimitiveOperation1()
...
PrimitiveOperation2()
...

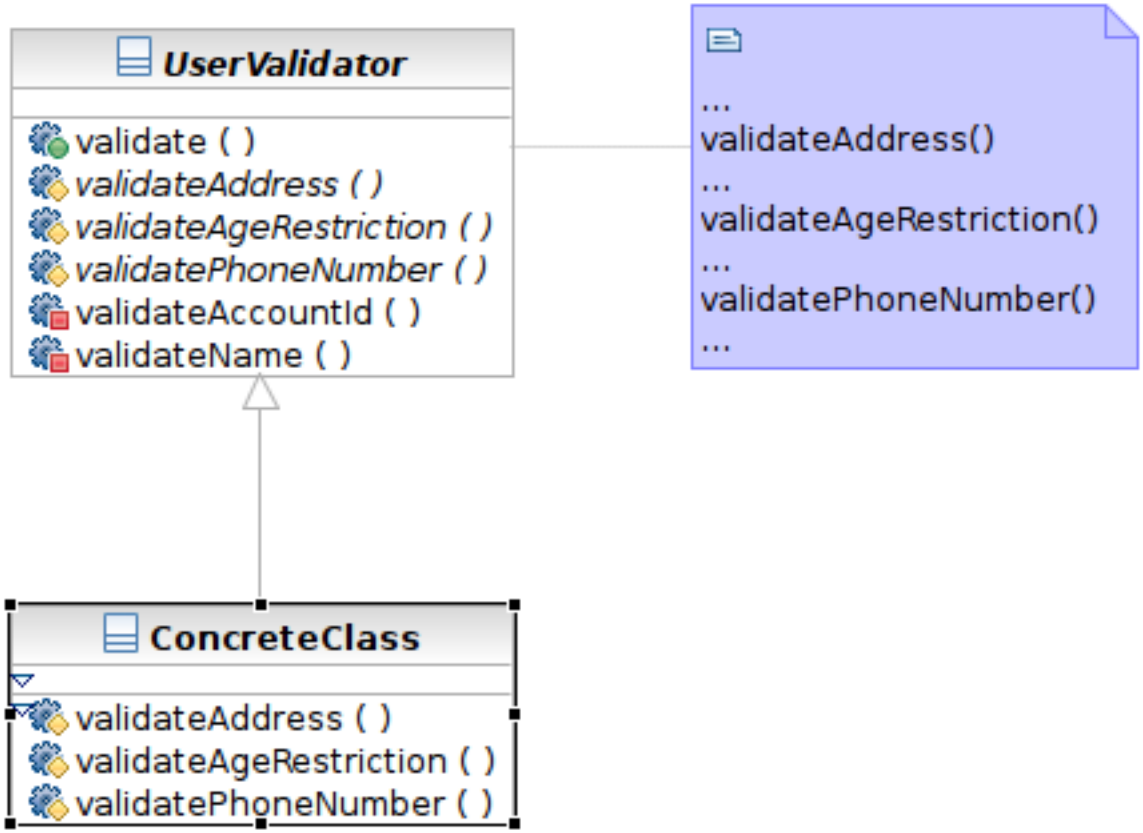
Participants

- Class **AbstractClass** defines abstract primitive operations (steps) of an algorithm; implements a template method defining the skeleton of an algorithm.
- Class **ConcreteClass** implements the primitive operations.

Applicability

- The Template Method pattern should be used
  - to implement the invariant parts of an algorithm once and leave it up to subclasses to implement the behavior that can vary.
  - when common behavior among subclasses should be factored and localized in a common class to avoid code duplication.
  - to control subclasses extensions. Extensions are permitted in implementations of primitive operations.

Sample Structure



Samples

- AbstractClass: class UserValidator
- ConcreteClass:
  - class TaiwauUserValidator and USUserValidator

Consequences

- The Hollywood principle. Don’t call us, we’ll call you.
  - why calling from parent class?
- Template methods call the following kinds of operations:
  - concrete operations
  - concrete AbstractClass operations
  - primitive operations
  - factory methods
  - hook operations

Related Patterns

- **Factory Method**: often acts as the primitive operation that is called by a template method
- **Strategy**: template method varies part of the algorithm via inheritance. Strategy delegates the entire algorithm to another object.