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Chapter 4
Simple Patterns for Extensibility

- Recursive Extensibility
  - Object Recursion
  - Composite
  - Decorator
  - Chain of Responsibility
- Flat Extension
  - Proxy
  - *-Bridge
  - Observer

Literature (To Be Read)

- On Composite, Visitor: T. Panas. Design Patterns, A Quick Introduction. Paper in Design Pattern seminar, IDA, 2001. See home page of course.
- Gamma: Composite, Decorator, ChainOfResponsibility, Bridge, Visitor, Observer, Proxy
- J. Smith, D. Stotts. Elemental Design Patterns. A Link Between Architecture and Object Semantics. March 2002. TR02-011, Dpt. Of Computer Science, Univ. of North Carolina at Chapel Hill
  http://www.cs.unc.edu/techreports/02-011.pdf

Optional Literature

- Marko Rosenmüller. Towards Flexible Feature Composition: Static and Dynamic Binding in Software Product Lines. PhD thesis, Fakultät für Informatik, Otto-von-Guericke-Universität Magdeburg, June 2011.
  http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.220.8672
- Marko Rosenmüller, Norbert Siegmund, Sven Apel, and Gunter Saake. Flexible Feature Binding in Software Product Lines. Automated Software Engineering, 18(2):163-197, June 2011.
  http://wwwiti.cs.uni-magdeburg.de/iti_db/publikationen/ps/auto/RSAS11.pdf

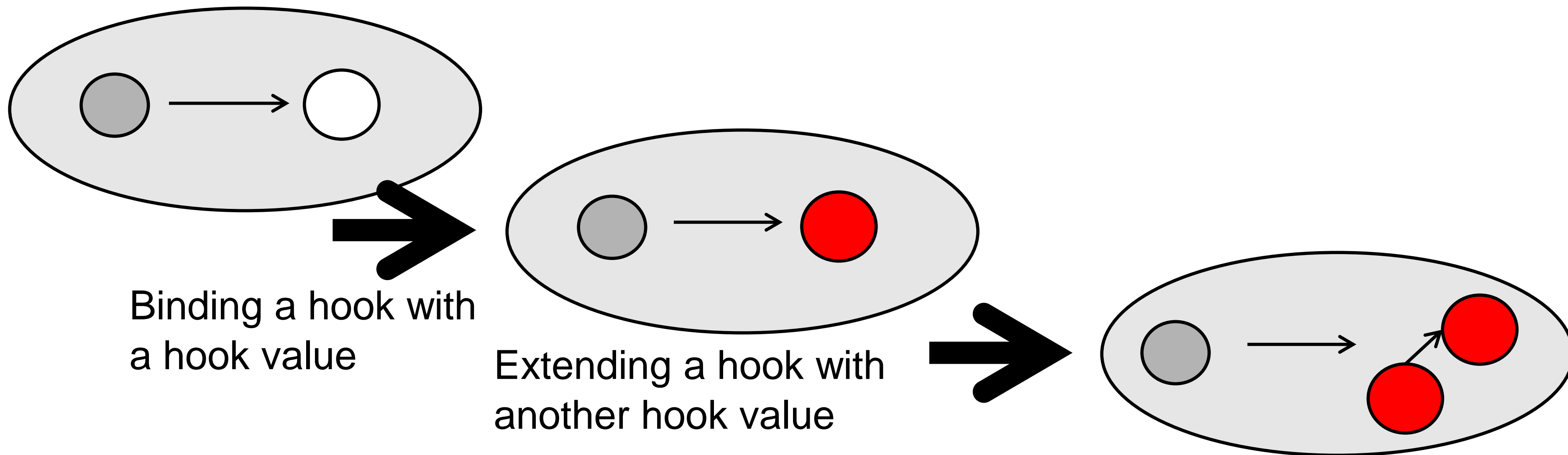
Goal

- Understanding extensibility patterns
  - **ObjectRecursion** vs **TemplateMethod**, **Objectifier** (and Strategy)
  - **Decorator** vs **Proxy** vs **Composite** vs **ChainOfResponsibility**
- **Parallel class hierarchies** as implementation of facets
  - Bridge
  - Visitor
  - Observer (EventBridge)

Static and Dynamic Extensibility

Variability vs Extensibility

- Variability so far meant
  - Static extensibility, e.g., new subclasses
  - Often, dynamic *exchangability* (polymorphism)
  - But not dynamic extensibility
- Now, we will turn to patterns that allow for dynamic extensibility
  - Most of these patterns contain a 1:n-aggregation that is extended at runtime

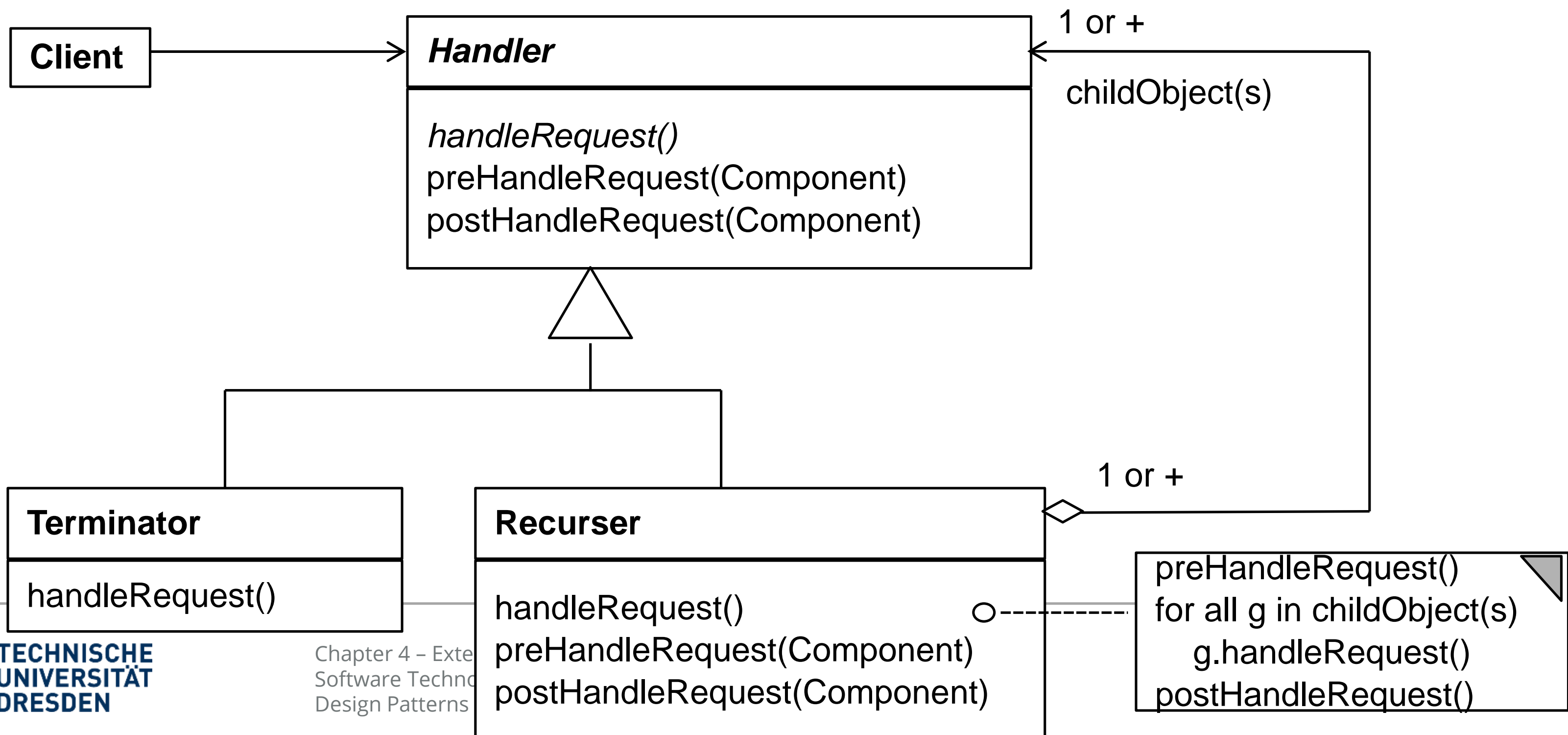


3.1 Recursive Extension

3.1.1 Object Recursion Pattern

Object Recursion

- Similar to TemplateMethod, Objectifier and Strategy
- But now, we allow for *recursion* in the dependencies between the classes (going via inheritance and aggregation)
- The aggregation can be 1:1 (lists, 1-Recursion) or 1:* (trees, n-recursion), *:* (DAGs or graphs, n-recursion)

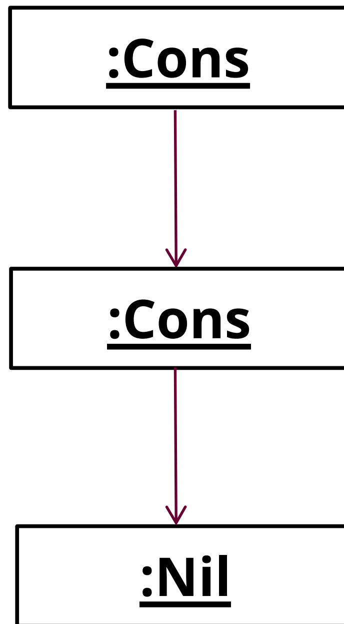


Incentive

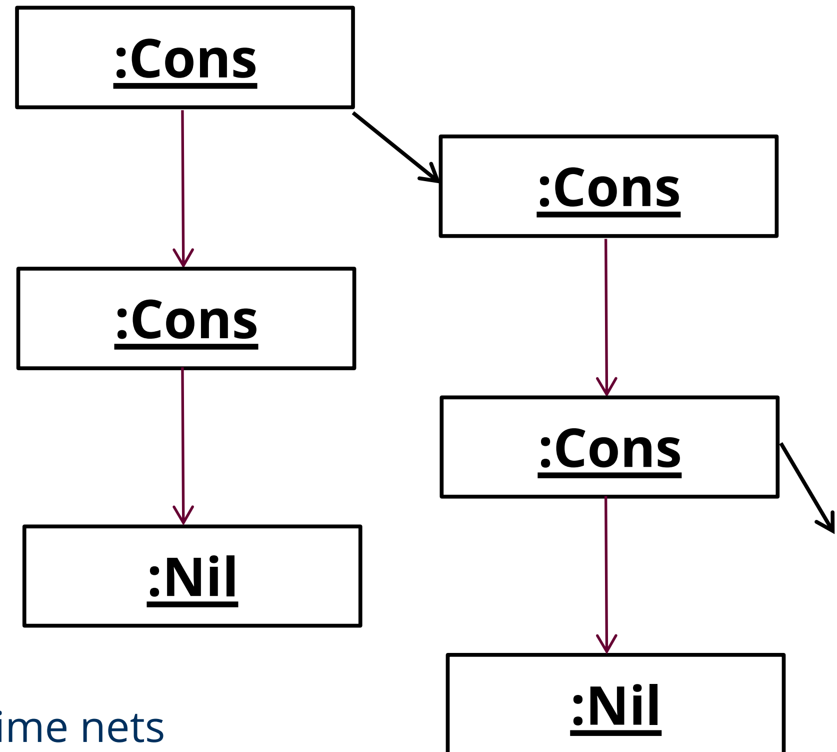
- ObjectRecursion is a simple (sub)pattern
  - in which an abstract superclass specifies common conditions for two kinds of subclasses, the Terminator and the Recurser (a simple *contract*)
- Since both fulfill the common condition, they can be treated uniformly under one interface of the abstract superclass

Object Recursion – Runtime Structure

1-ObjectRecursion creates lists



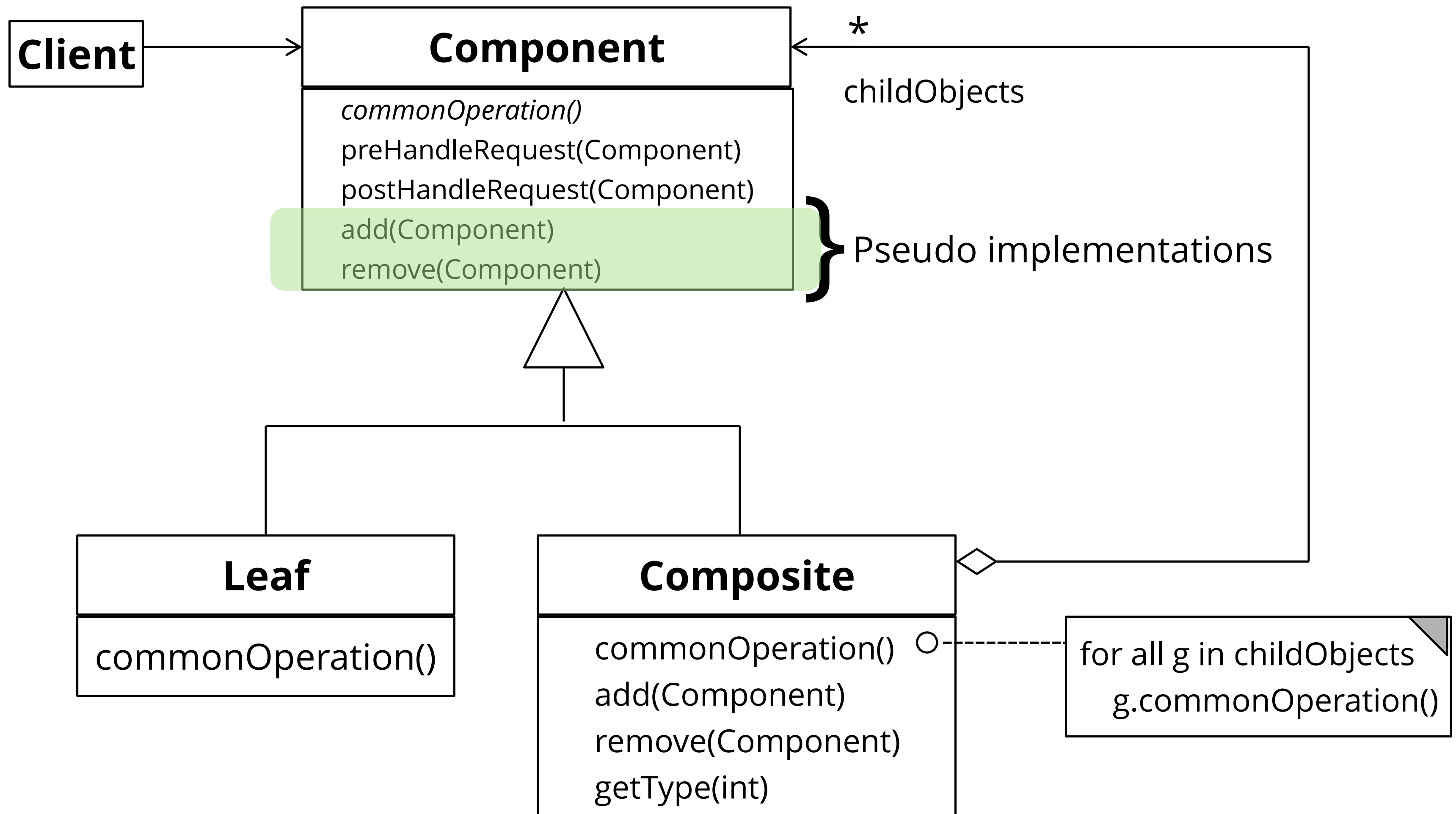
n-ObjectRecursion creates trees, DAGs, and graphs



The recursion allows for building up runtime nets

3.1.2 Composite

Structure Composite



Piece Lists in Production Data

```
abstract class CarPart {
    int myCost;
    abstract int calculateCost();
}

class ComposedCarPart extends CarPart {
  int myCost = 5;
  // here is the n-recursion
  CarPart [] children;
  int calculateCost() {
    for (i = 0; i <= children.length; i++)
    {
      curCost +=
          children[i].calculateCost();
    }
    return curCost + myCost;
  }
  void addPart(CarPart c) {
    children[children.length++] = c;
  }
}
```

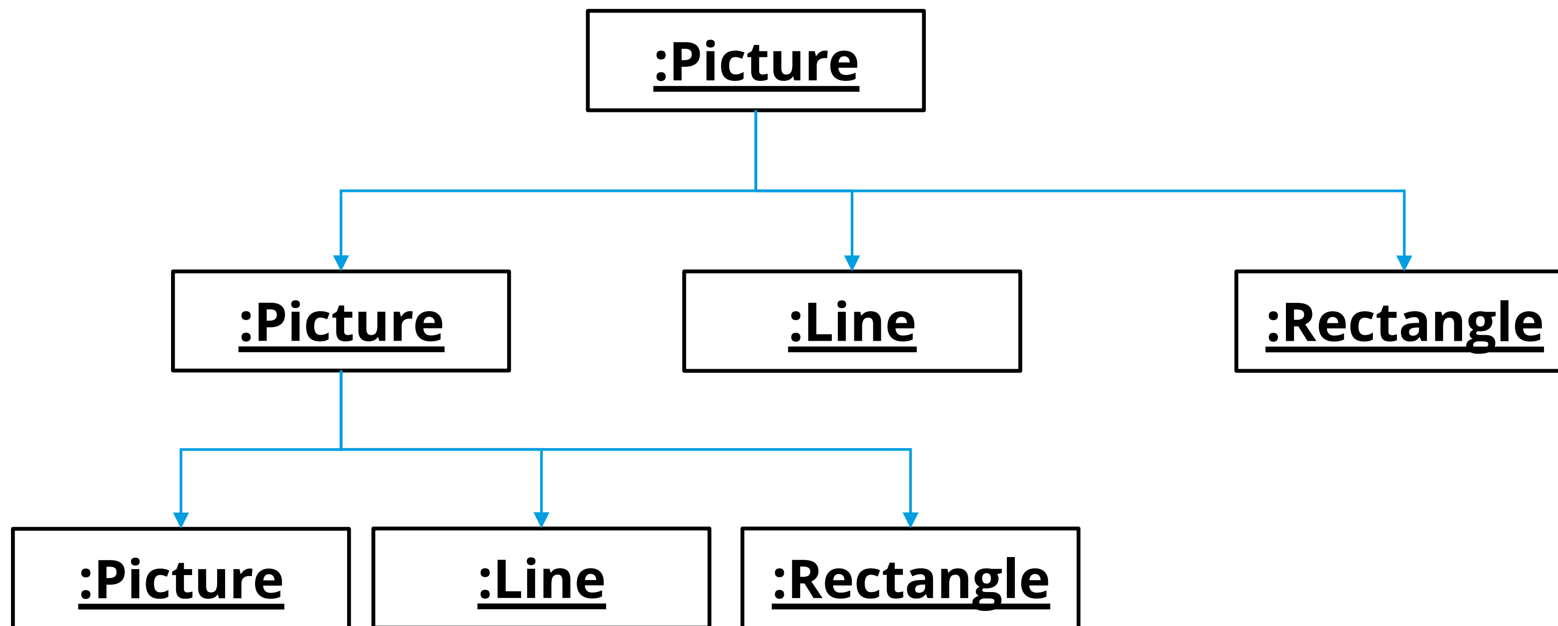
```
class Screw extends CarPart {
      int myCost = 10;
      int calculateCost() {
           return  myCost;
      }
}

// application
int cost = carPart.calculateCost();
```

Purpose

- The Composite is older as ObjectRecursion, from GOF
  - ObjectRecursion is a little more abstract
- As in ObjectRecursion, an abstract superclass specifies a contract for two kinds of subclasses
  - Since both fulfill the common condition, they can be treated uniformly under one interface of the abstract superclass
- Good method for building up trees and iterating over them
  - The iterator does not need to know whether it works on a leaf or an inner node. It can treat all nodes uniformly for
    - Iterator algorithms (map)
    - Folding algorithms (folding a tree with a scalar function)
- The Composite's secret is whether a leaf or inner node is worked on
- The Composite's secret is which subclass is worked on

Composite Run-Time Structure

Part/Whole hierarchies, e.g., nested graphical objects



common operations: draw(), move(), delete(), scale()

Dynamic, Recursive Extensibility of Composite

- Due to the n-recursion, new children can always be added into a composite node
- Whenever you have to program an extensible part of a framework, consider Composite

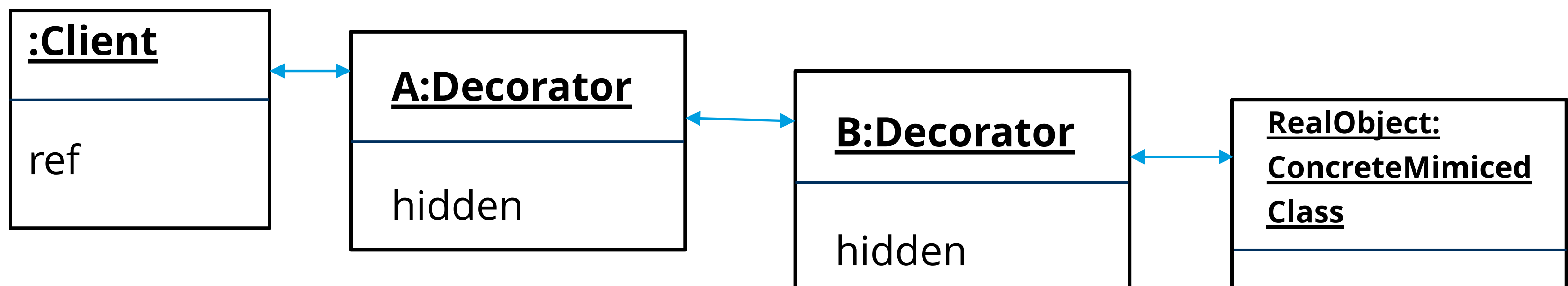
Relations of Composite to Other Programming Domains

- Composite pattern is the heart of functional programming
  - Because recursion is the heart of functional programming
  - It has discovered many interesting algorithmic schemes for the Composite:
    - Functional skeletons (map, fold, partition, d&c, zip...)

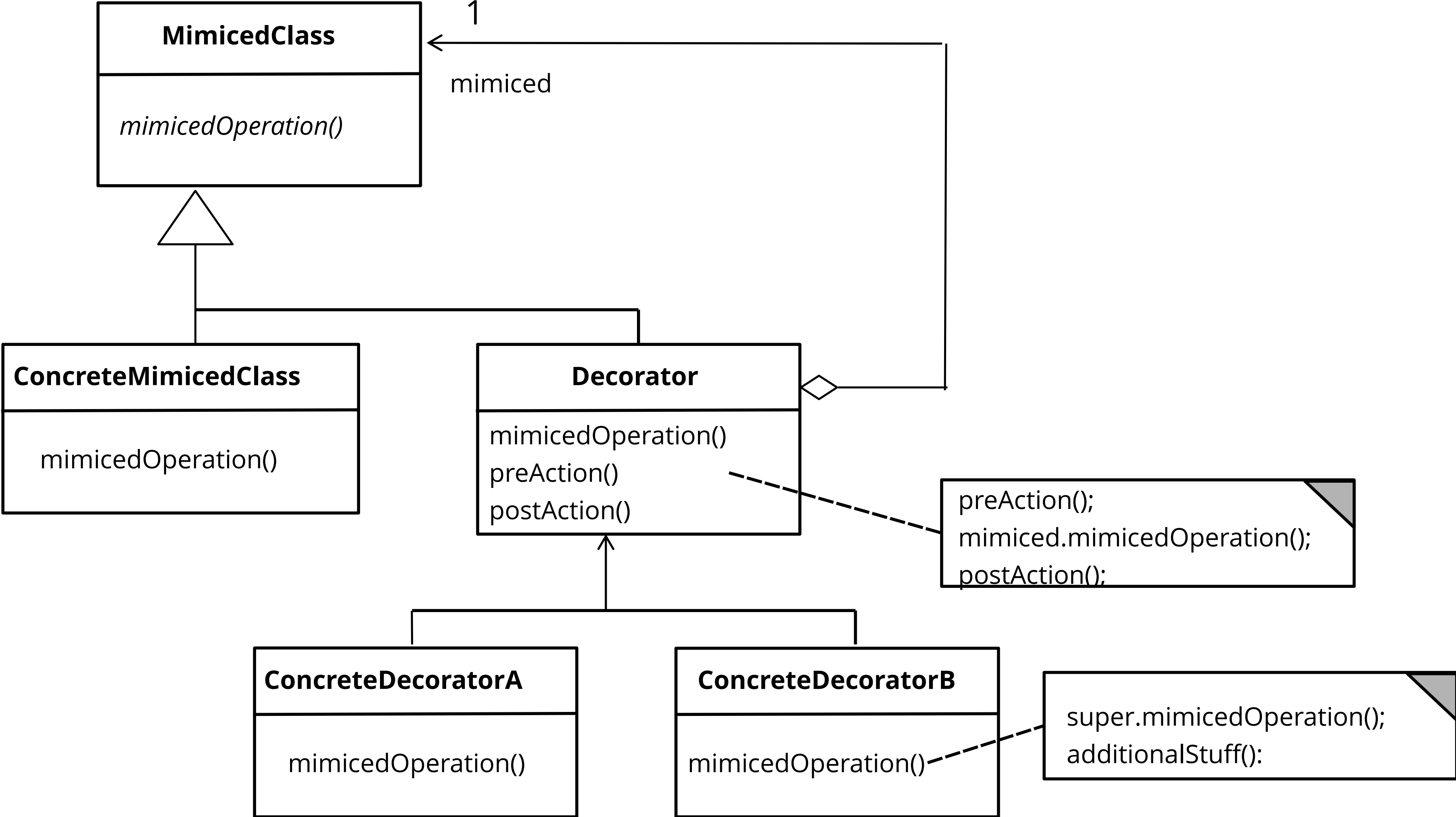
3.1.3 Decorator

Decorator Pattern

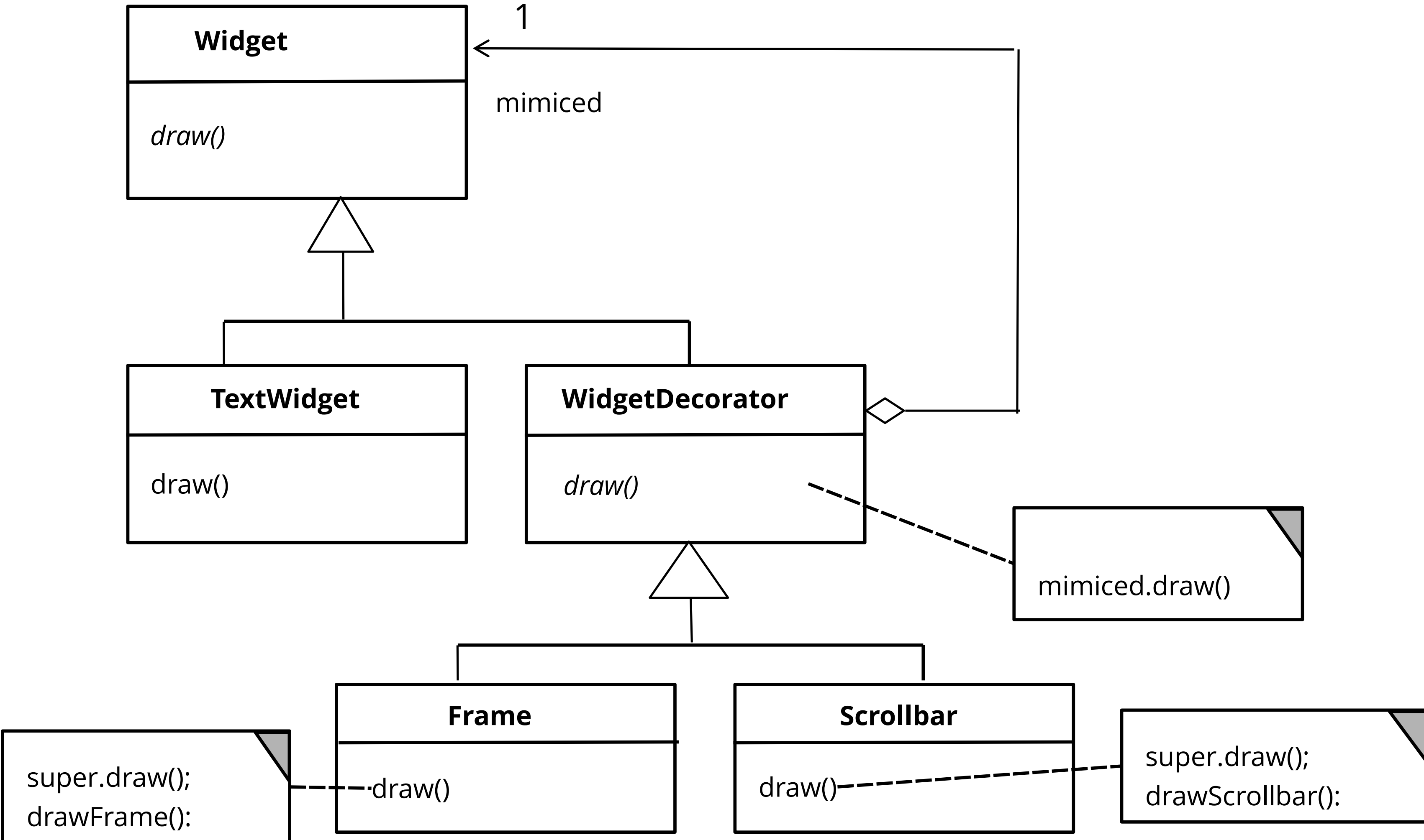
- A Decorator is a *skin (wrappers)* of another object
  - Core objects are at the end of a decorator chain
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
  - Combines inheritance with aggregation
- Similar to ObjectRecursion and Composite, inheritance from an abstract Handler class
  - That defines a contract for the mimiced and the mimicing class



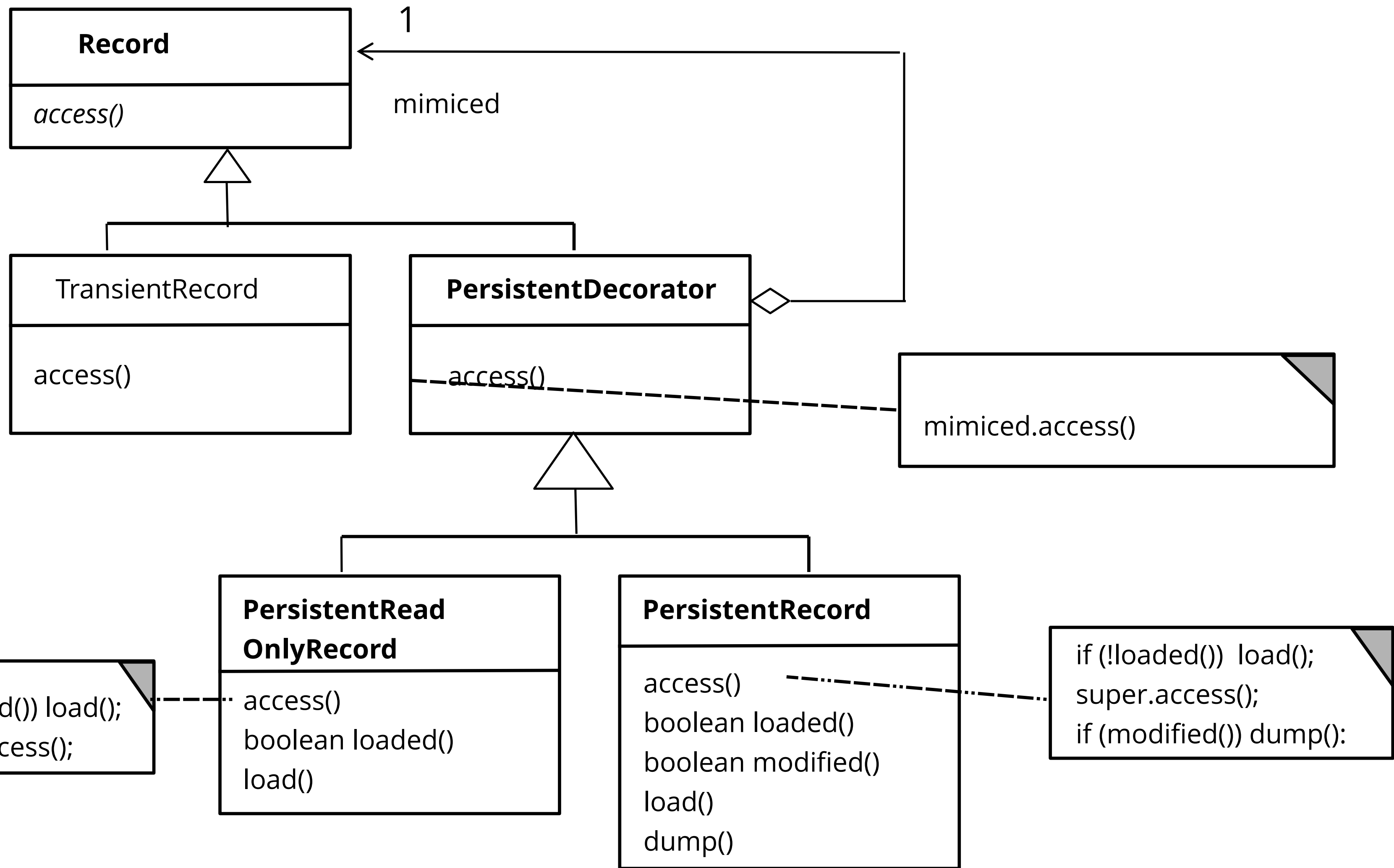
Decorator – Structure Diagram



Decorator for Widgets

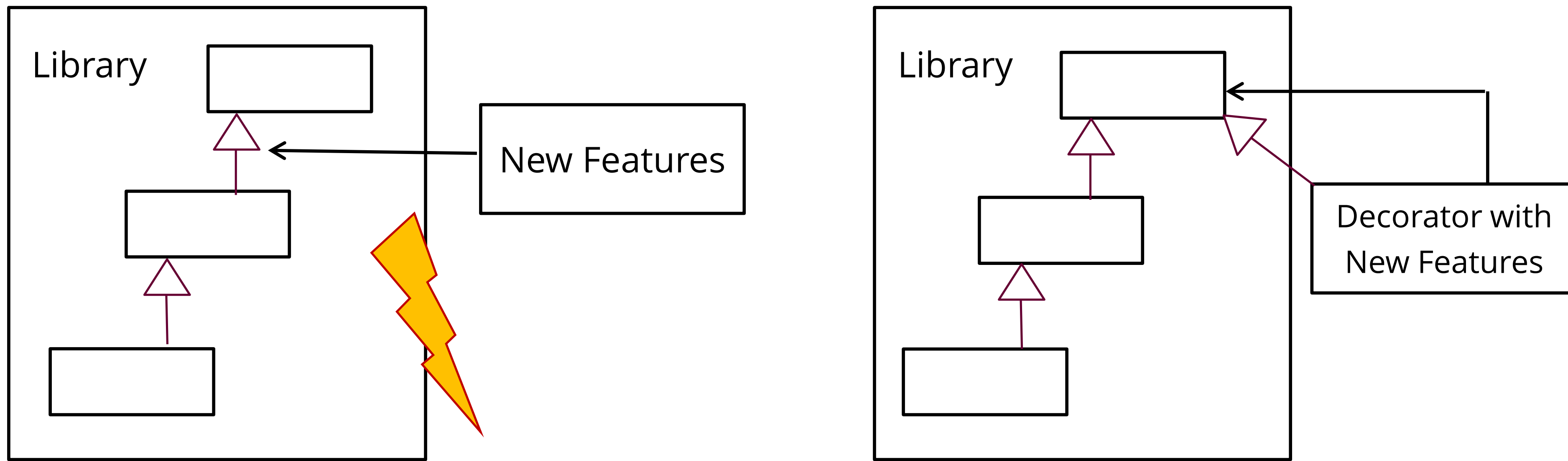


Decorator for Persistent Objects



Purpose Decorator

- For extensible objects (i.e., decorating objects)
  - Extension of new features at runtime
  - Removal possible
- Instead of putting the extension into the inheritance hierarchy
  - If that would become too complex
  - If that is not possible since it is hidden in a library

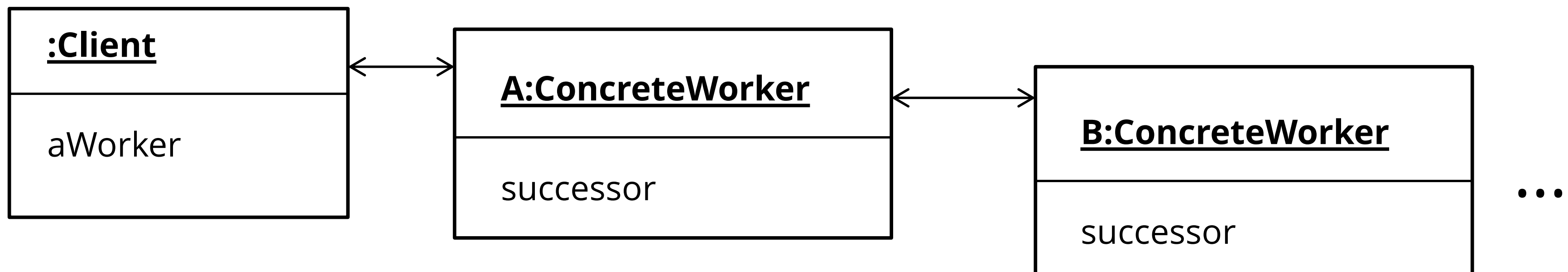


3.1.4 Chain of Responsibility

Chain of Responsibility

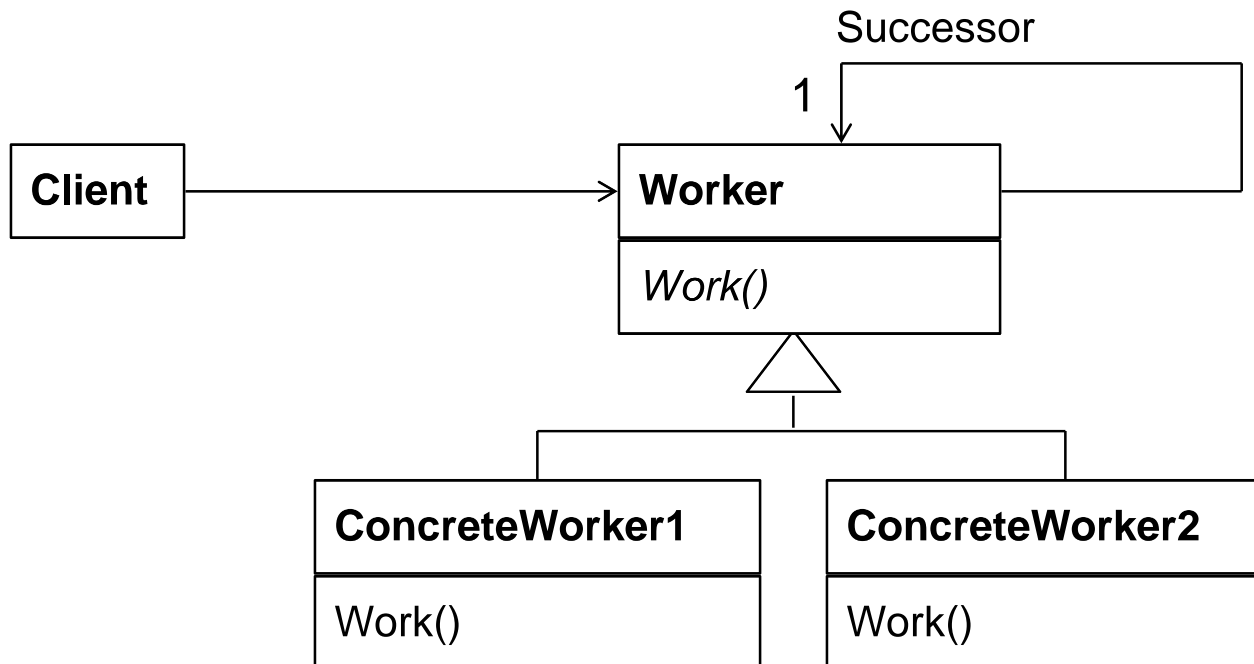
- Delegate an action to a list of delegatees that attempt to solve the problem one after the other
  - They delegate further on, down the chain
  - No core object

ObjectStructure:



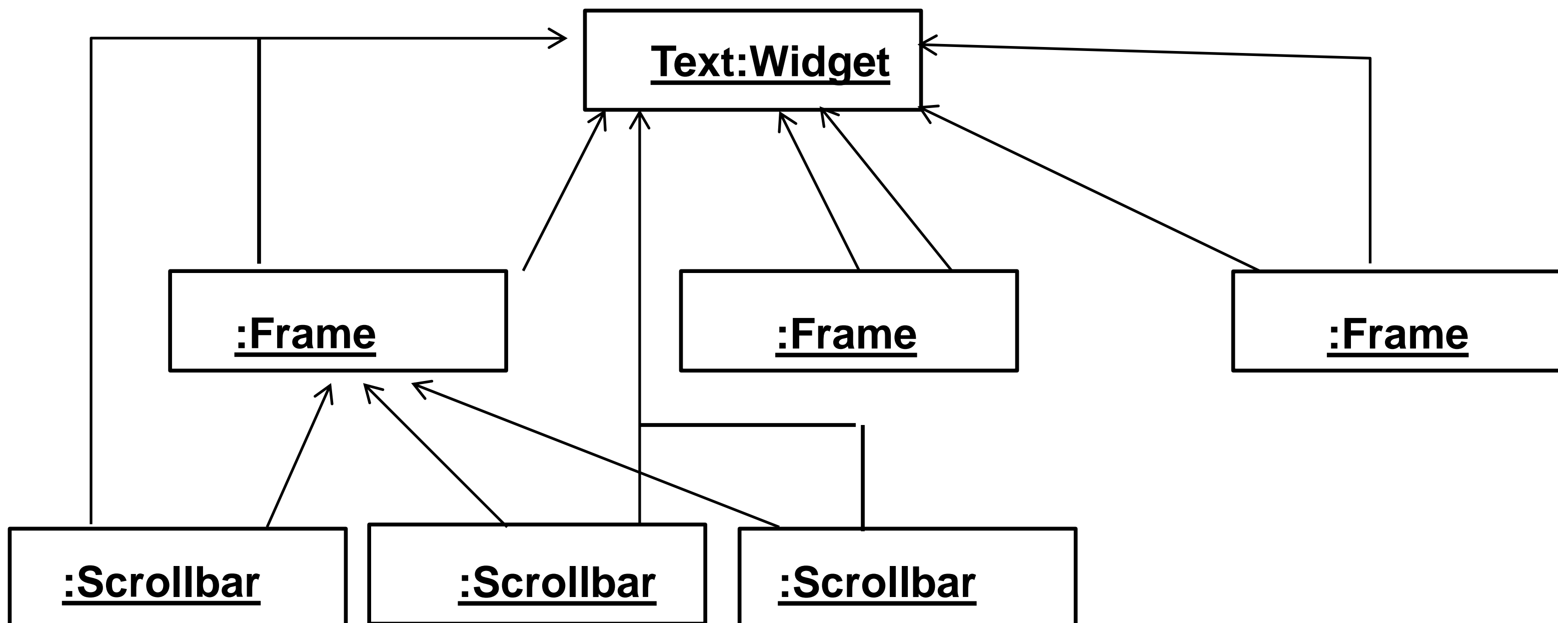
Structure for ChainOfResponsibility

- A Chain is recursing on the abstract super class, i.e.,
  - All classes in the inheritance tree know they hide some other class (unlike the ObjectRecursion)



Chains in Runtime Trees

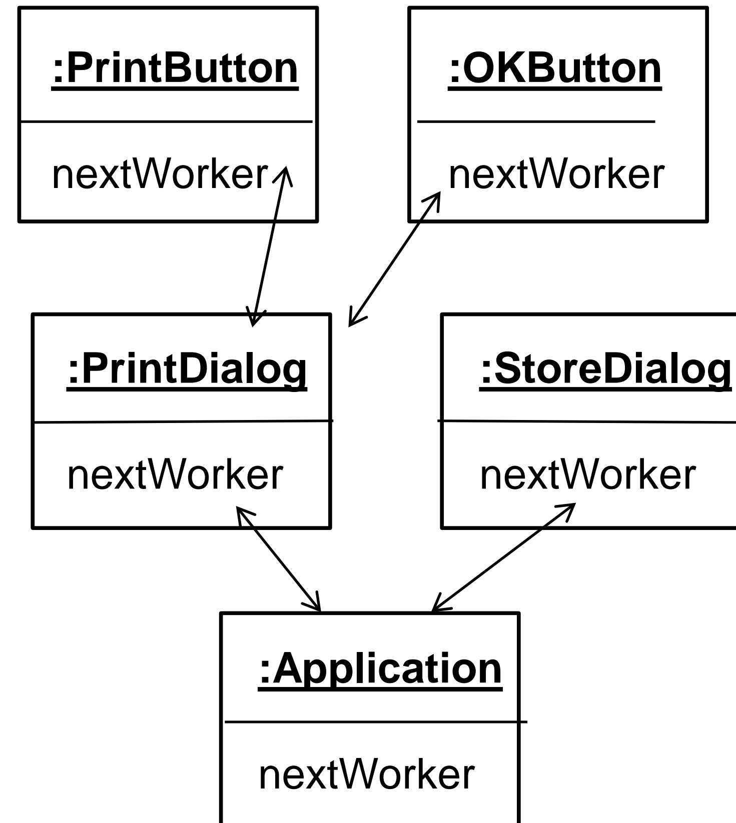
- Chains can also be parts of a tree
- Then, a chain is the path upward to the root of the tree



Example ChainOfResponsibility: Help System for a GUI

nextWorker
HelpWorker
WorkOnHelpQuery()
Application
Widget
Dialog
Button
WorkOnHelpQuery()
showHelp()
StoreDialog
PrintDialog
OKButton
PrintButton

ObjectStructure is a Tree of Help Functions:



Help System with Chain

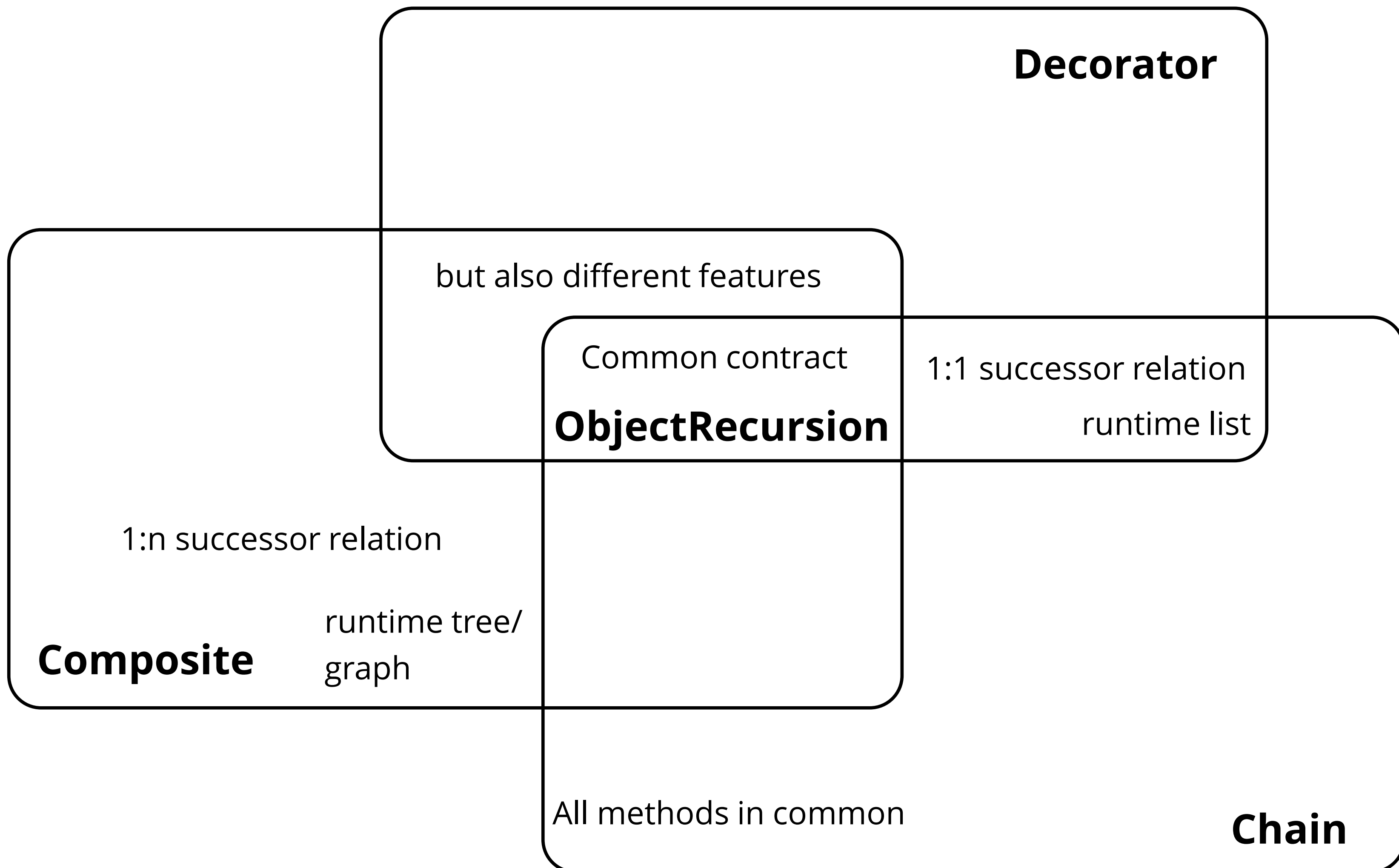
```
abstract class HelpWorker {
    // here is the 1-recursion
    HelpWorker nextWorker;
    void workOnHelpQuery() {
     if (nextWorker != null)
       nextWorker.workOnHelpQuery();
}
class Widget extends HelpWorker {
 // this class can contain fixing code
}
class Dialog extends Widget {
   void  workOnHelpQuery() {
       help();
    super.workOnHelpQuery();
   }
}
class Application extends HelpWorker
{  ....}
```

```
class Button extends Widget {
     bool haveHelpQuery;
     void workOnHelpQuery() {
       if (haveHelpQuery) {
           help();
       } else {
          super.workOnHelpQuery();
       }
     }
}

// application
button.workOnHelpQuery();
// may end in the inheritance
hierarchy up in Widget, HelpWorker
// dynamically in application object
```

ChainOfResponsibility - Applications

- Realizes *Dynamic Call*:
  - If the receiver of a message is neither known at compile-time nor at allocation time (polymorphism), but only at runtime (i.e., depends on the current net of objects)
  - Dynamic call is the key construct for service-oriented architectures (SOA)
- Dynamic extensibility: if new receivers with new behavior should be added at runtime
  - Unforeseen dynamic extensions
  - However, no mimiced object as in Decorator
- Anonymous communication
  - If identity of receiver is unknown or not important
  - If several receivers should work on a message

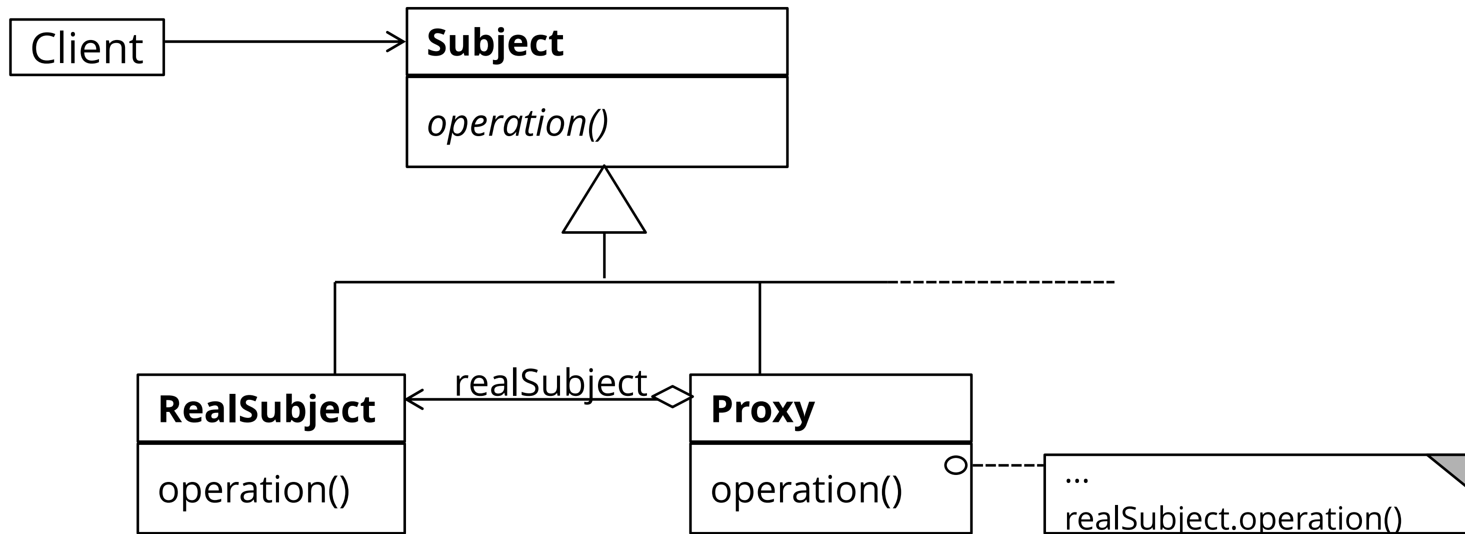
Composite vs Decorator vs Chain



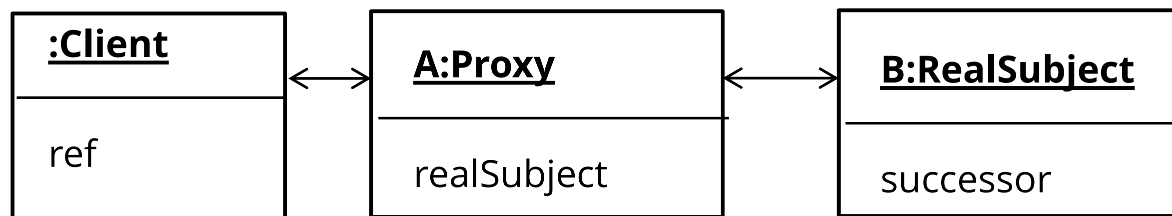
3.2. Flat Extensibility
3.2.1 Proxy

Proxy

Hide the access to a real subject by a representative



Object Structure:



Proxy

- The proxy object is a *representative* of an object
  - The Proxy is similar to Decorator, but it is not derived from ObjectRecursion
  - It extends **flat:** It has a direct pointer to the sister class, *not* to the superclass
  - It may collect all references to the represented object (shadows it). Then, it is a facade object to the represented object
- Consequence: chained proxies are not possible, a proxy is one-and-only
  - Clear difference to ChainOfResponsibility
- Decorator lies between Proxy and Chain.

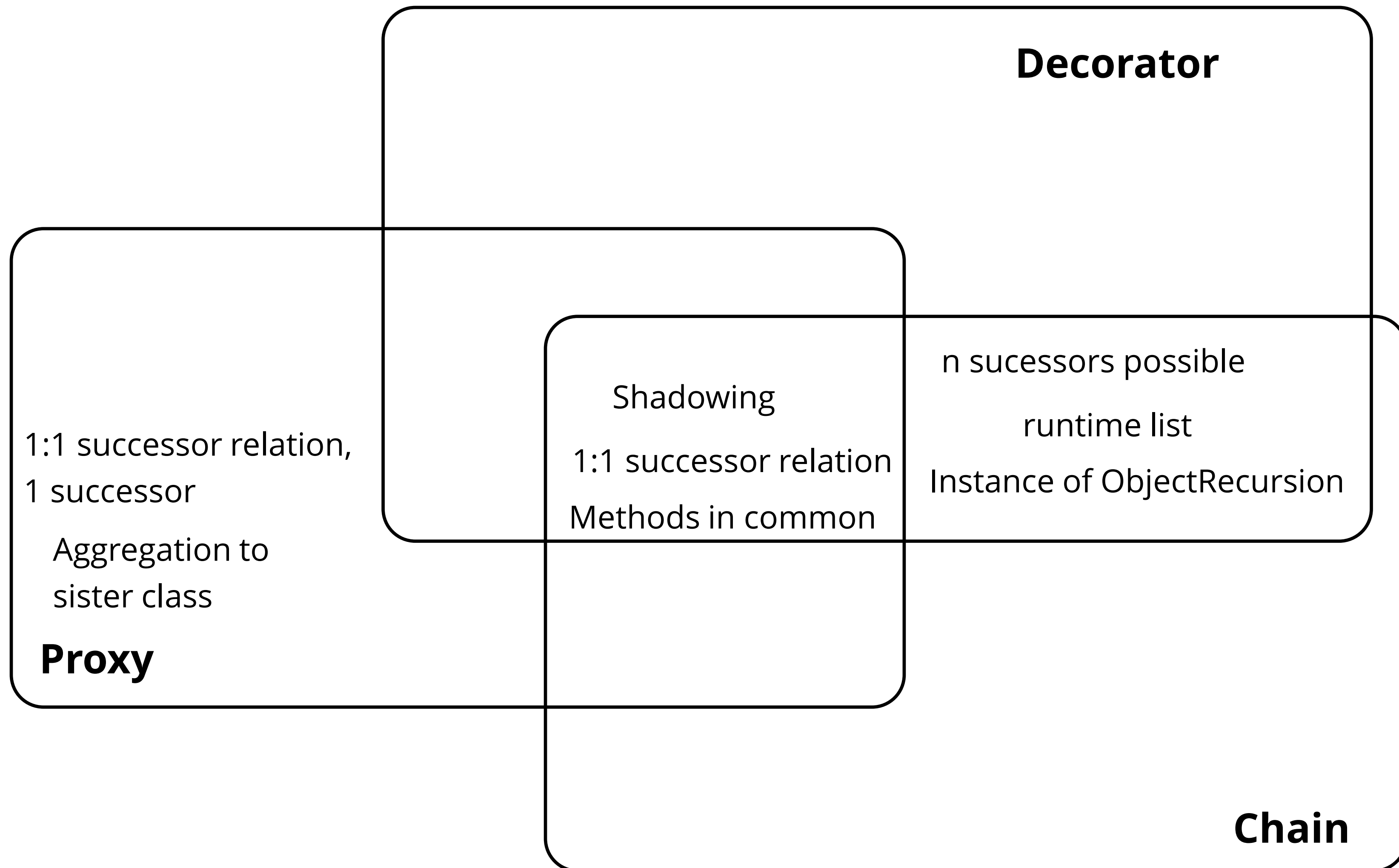
Proxy Variants

- *Filter proxy (smart reference):* executes additional actions, when the object is accessed
  - Protocol proxy: counts references (reference-counting garbage collection
  - or implements a synchronization protocol (e.g., reader/writer protocols)
- *Indirection proxy (facade proxy):* assembles all references to an object to make it replaceable
- *Virtual proxy:* creates expensive objects on demand
- *Remote proxy: representative* of a remote object
- *Caching proxy:* caches values which had been loaded from the subject
  - Remote
  - Loading lazy on demand
- *Protection proxy*
  - Firewall

Proxy – Other Implementations

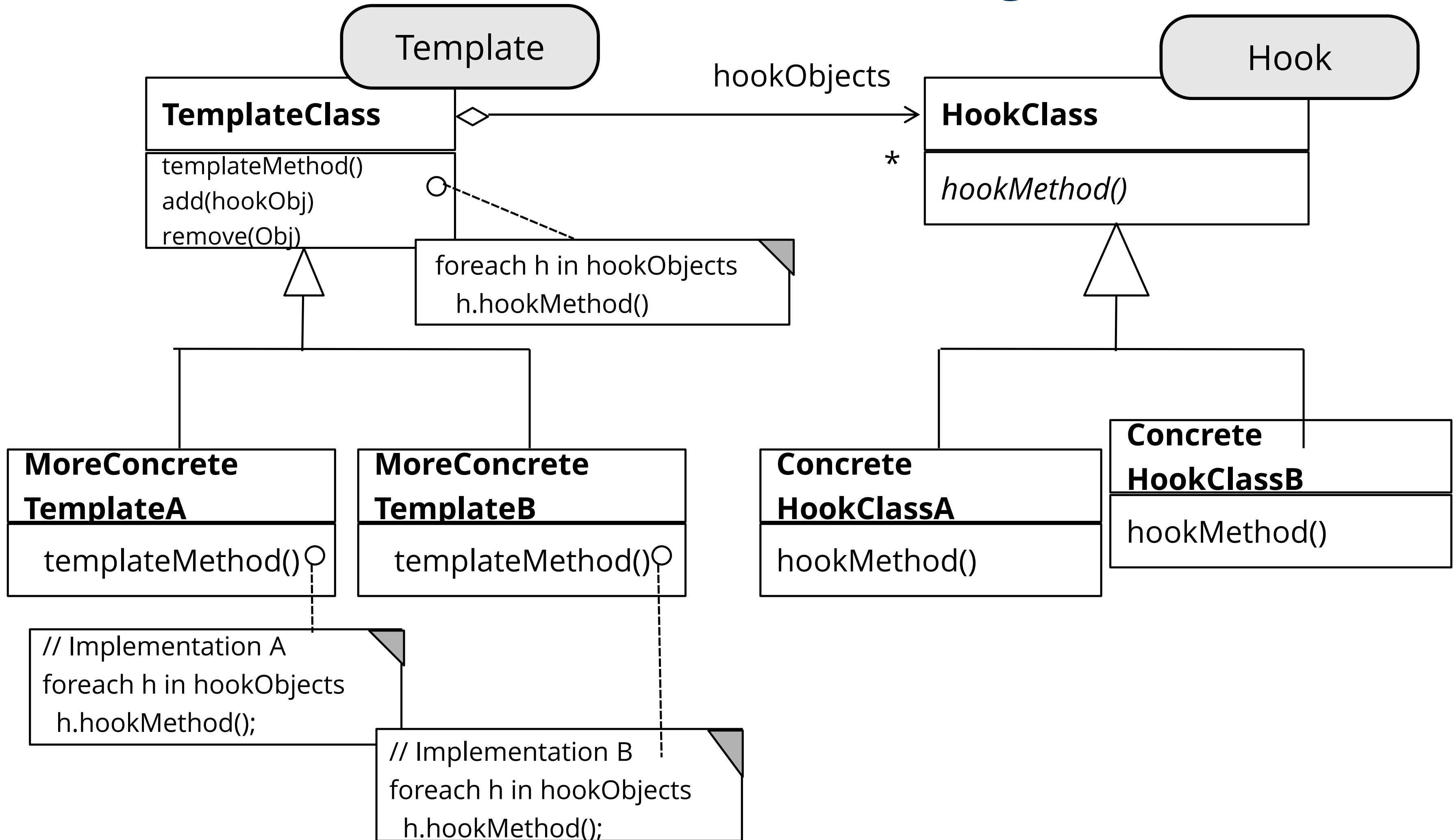
- Overloading of “->” access operation
  - C++, Ada and other languages allow for overloading access
  - Then, a proxy can intervene, but is invisible
- Overloading access can be built in into the language
  - There are languages that offer proxy objects
  - *Modula-3* offers SmartPointers
  - *Gilgul* offers proxy objects

Proxy vs Decorator vs Chain



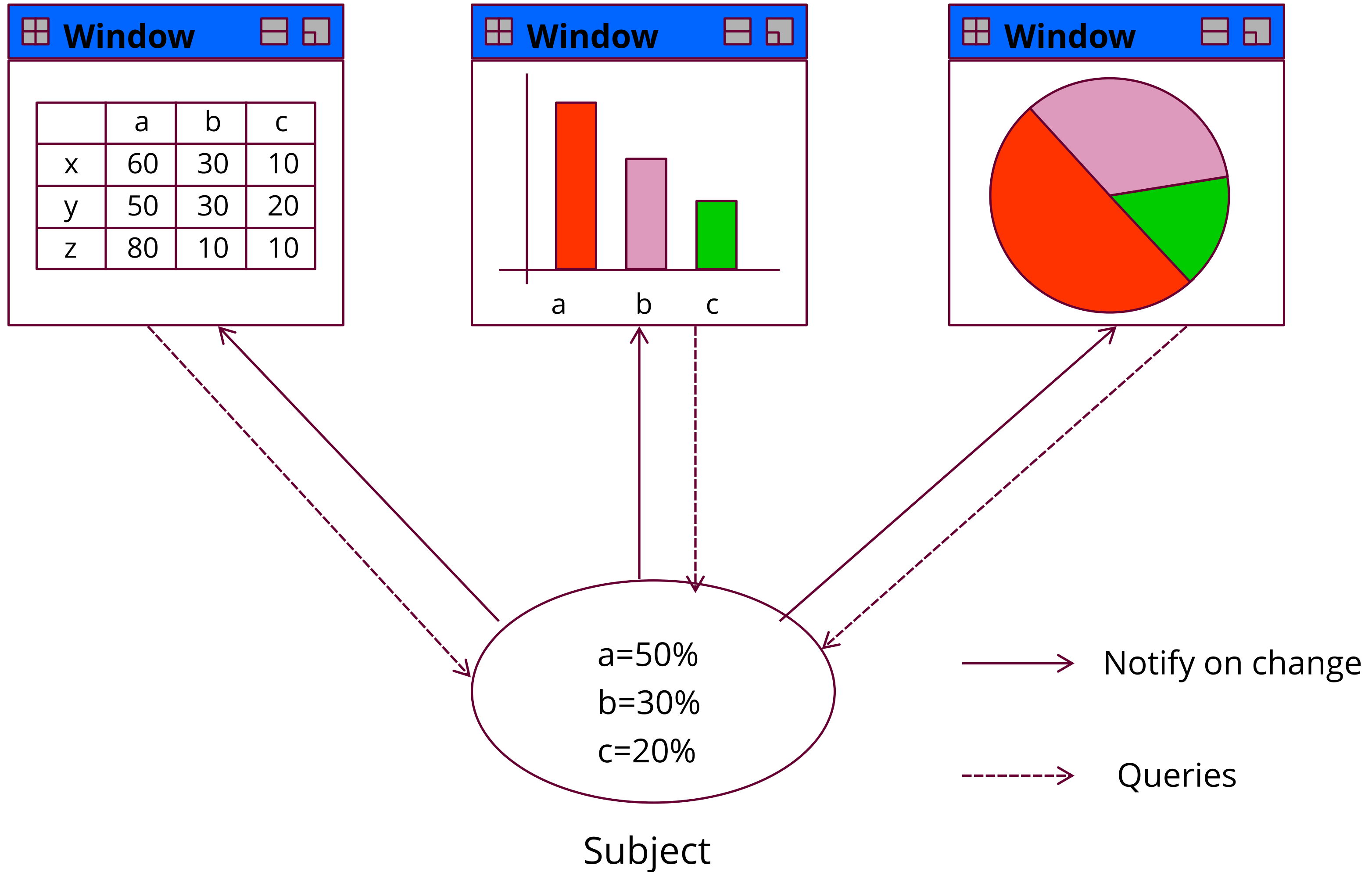
3.2.2 Star-Bridge (*-Bridge)

Extensibility Pattern *DimensionalClassHierarchies (*Bridge)

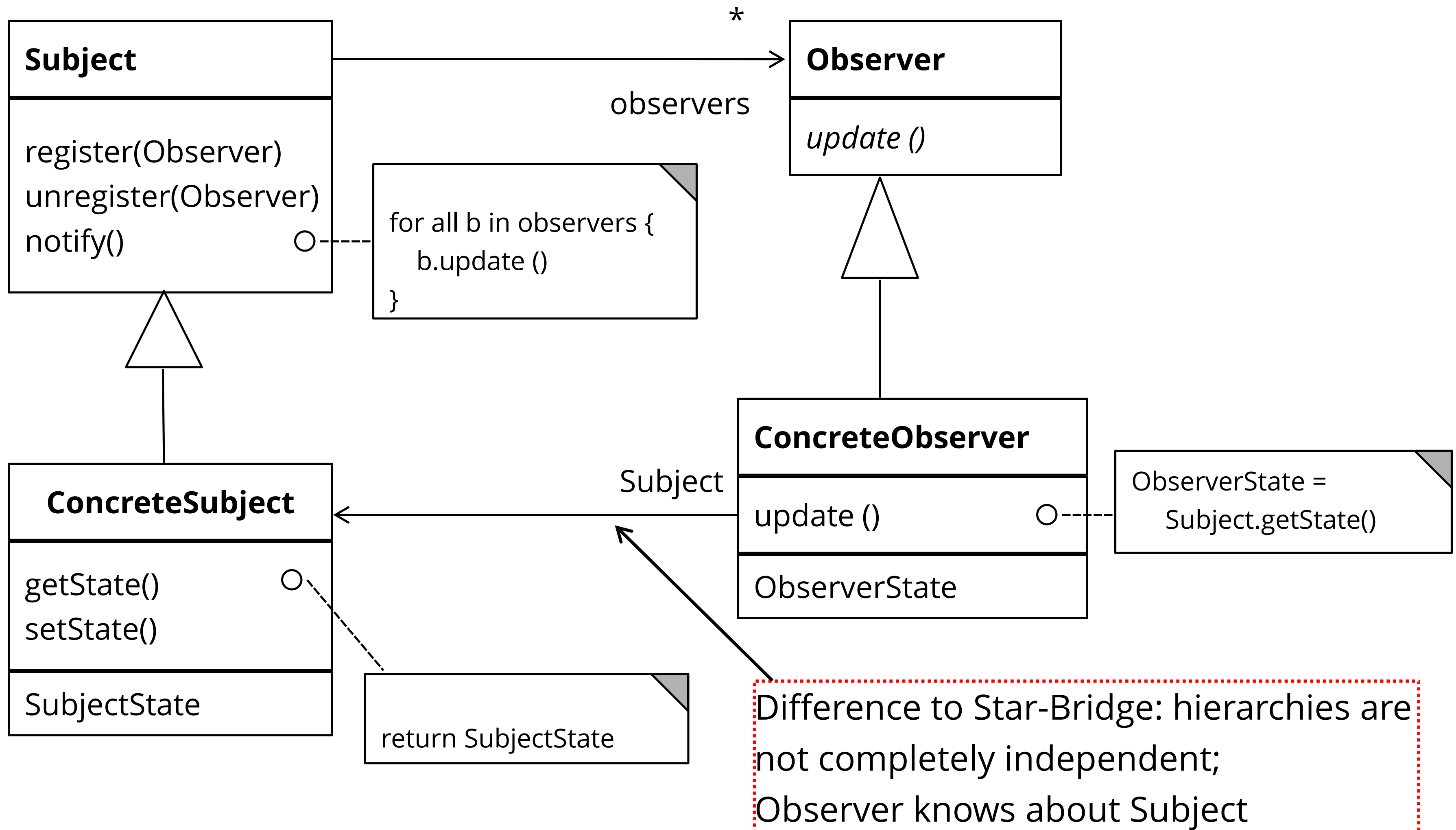


3.2.3 Observer (Event Bridge)

Observer (Publisher/Subscriber, Event Bridge)

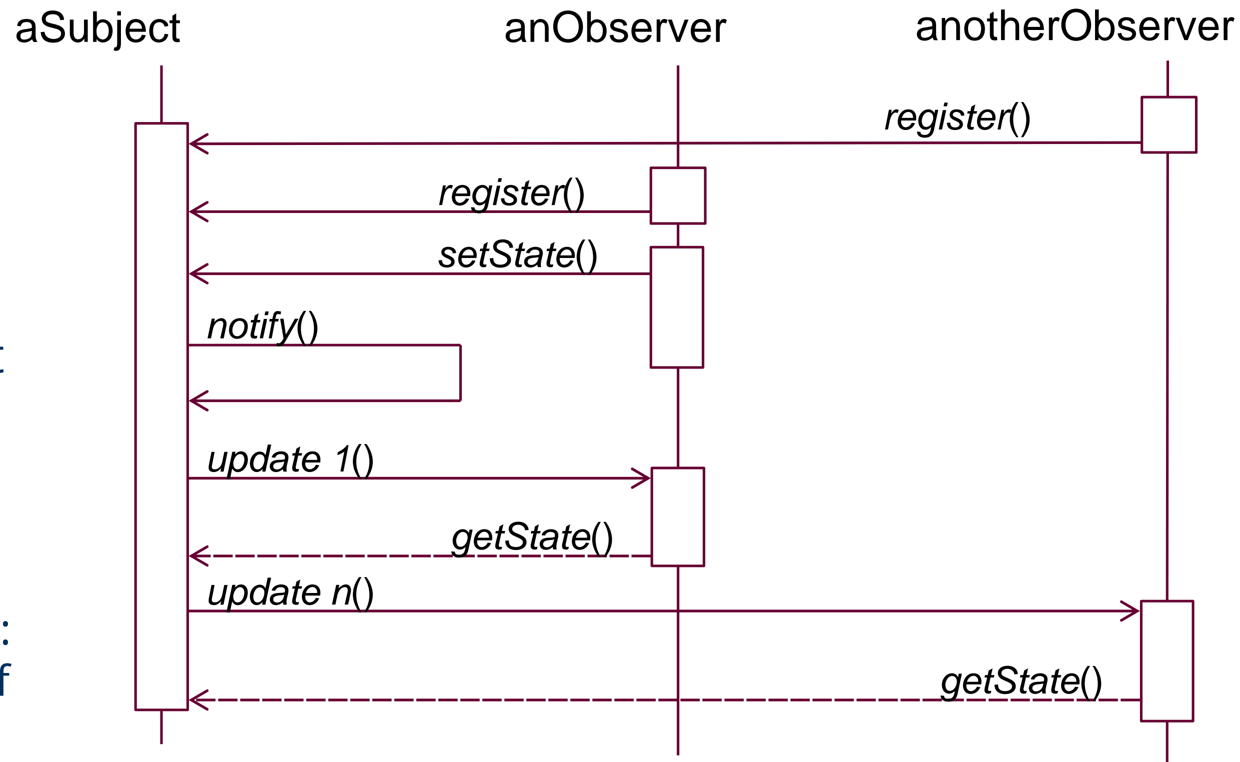


Structure Observer



Sequence Diagram Observer

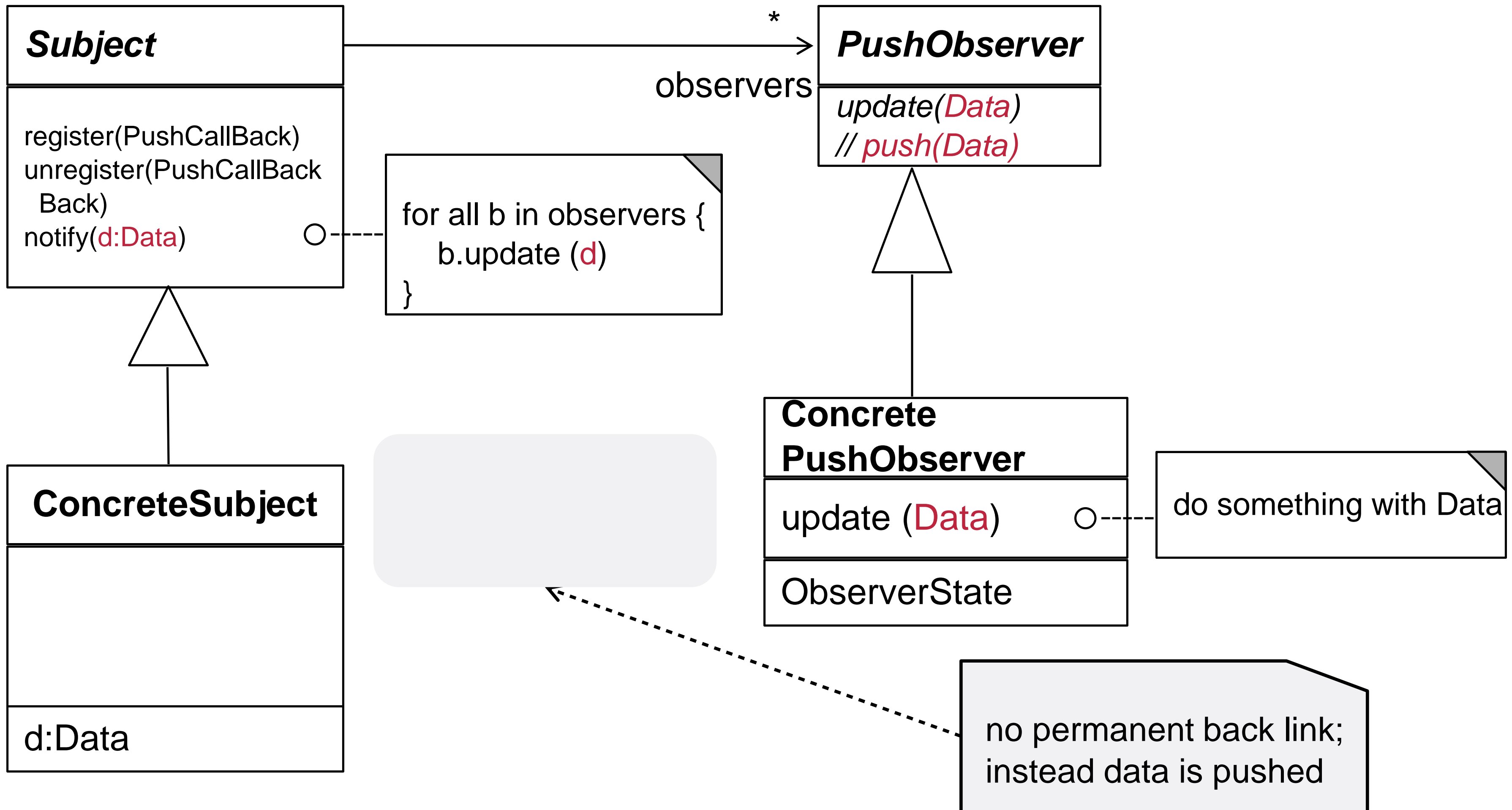
- Update() does not transfer data, only an event (anonymous communication possible)
- Observer pulls data out itself
  - Due to pull of data, subject does not care nor know, which observers are involved: subject independent of observer



Observer Variants

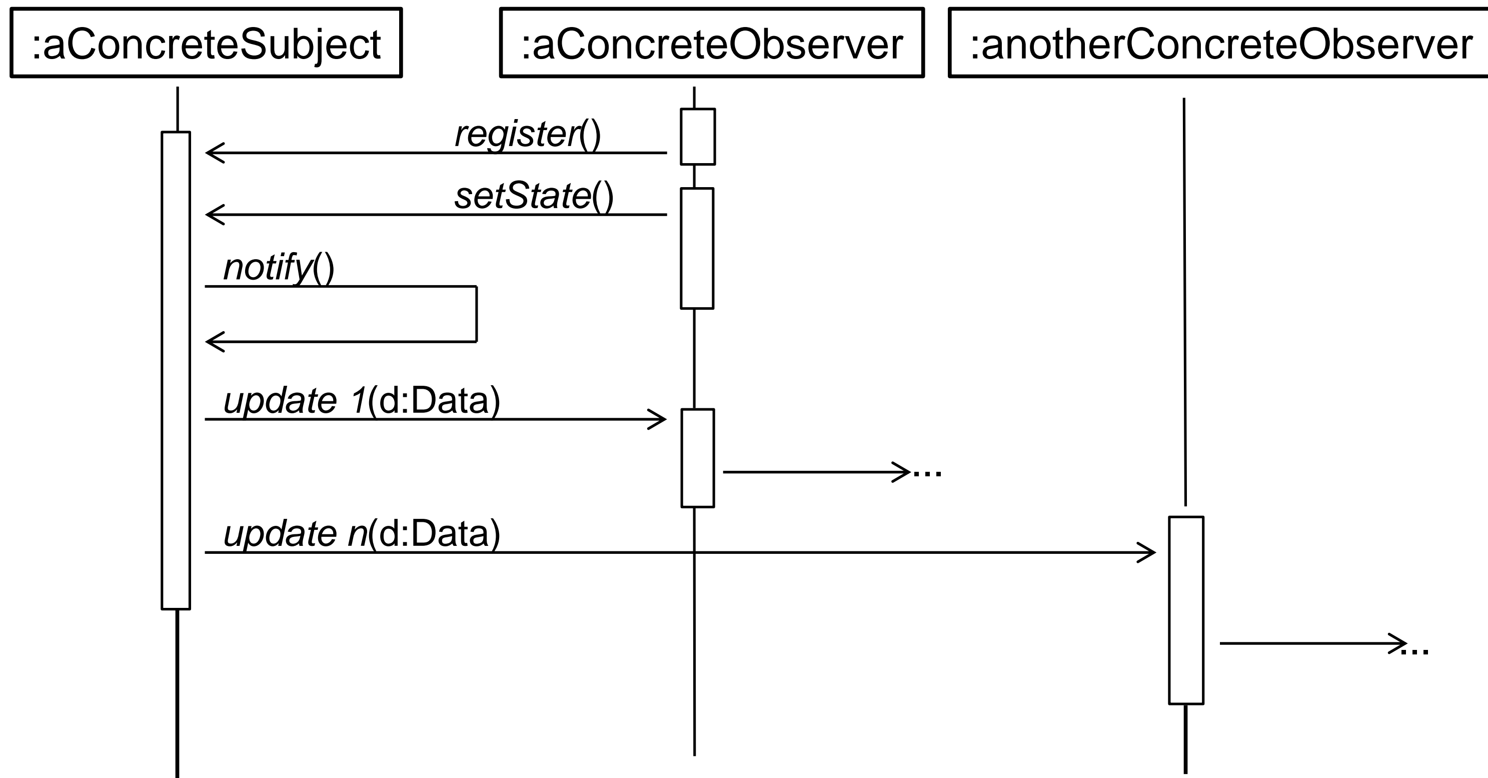
- **Multiple subjects:**
  - If there is more than one subject,
    send Subject as Parameter of `update(Subject s)`.
- **Push model:** subject sends data in notify()
  - The default is the pull model: observer fetches data itself
- **Change manager**

Structure Data-Pushing-Observer



Sequence Diagram Data-Push-Observer

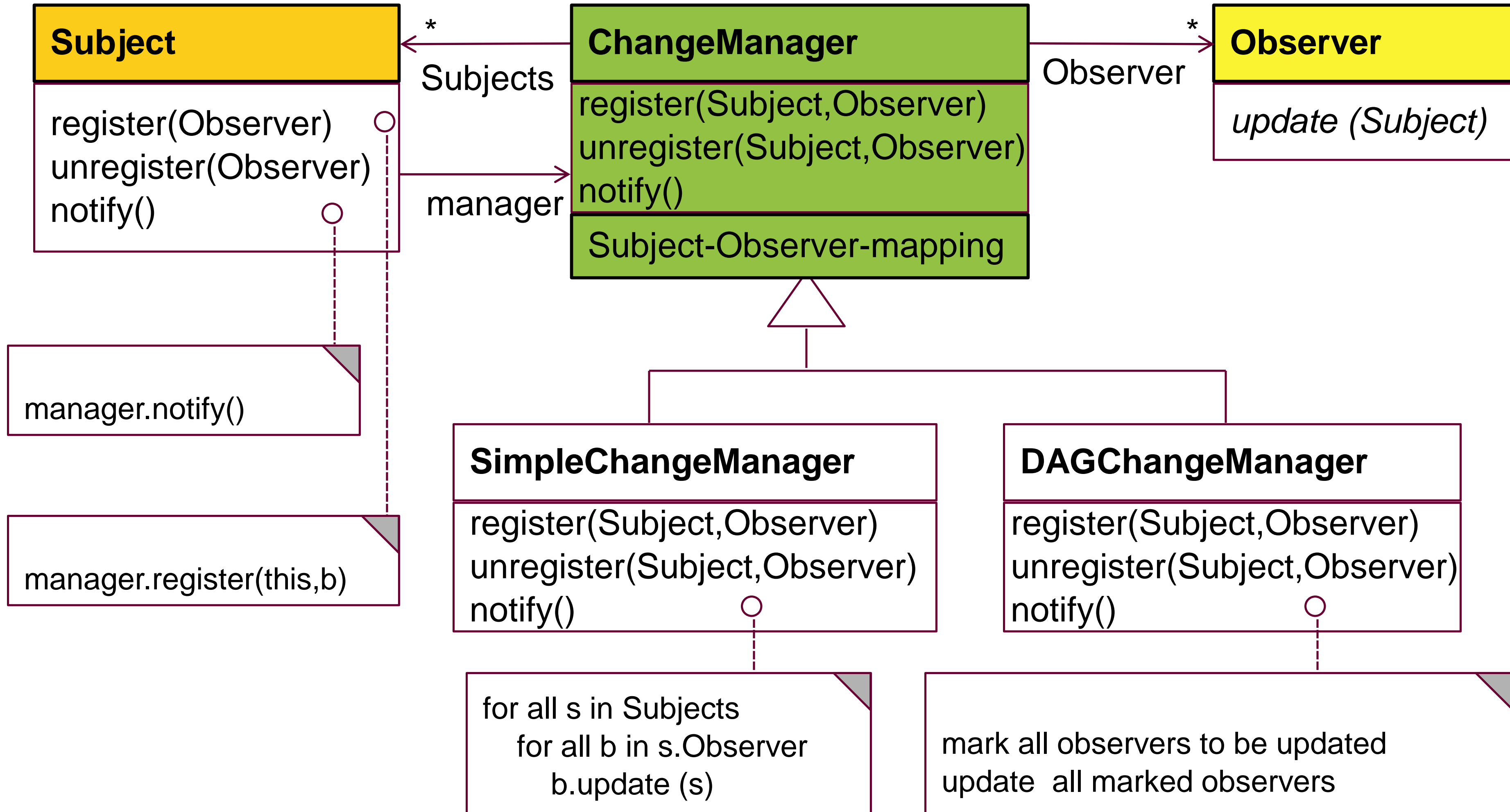
- Update() transfers Data to Observer (push)



Observer - Applications

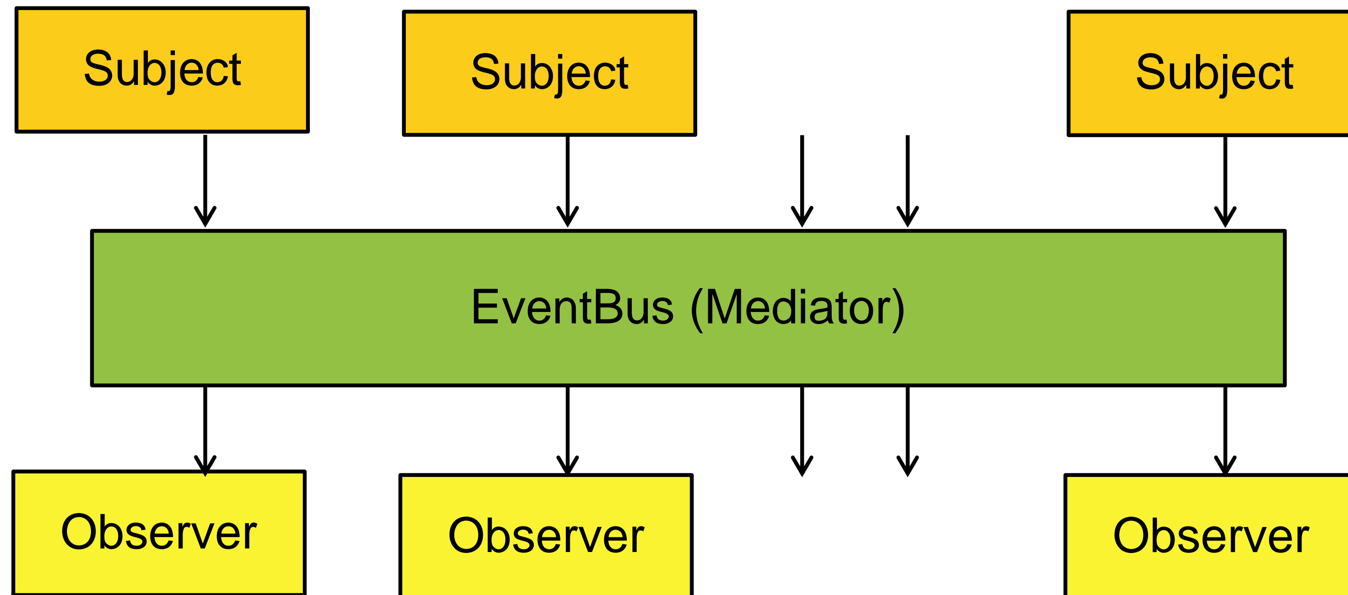
- Loose coupling in communication
  - Observers decide what happens
- Dynamic change of communication
  - Anonymous communication
  - Multi-cast and broadcast communication
  - Cascading communication if observers are chained (stacked)
- Communication of core and observing aspect
  - Observers are a simple way to implement aspect-orientation by hand
  - If an abstraction has two aspects and one of them depends on the other, the observer can implement the aspect that listens and reacts on the core

Observer with ChangeManager (Mediator)



ChangeManager is also Called Eventbus

Basis of many interactive application frameworks (Xwindows, Java AWT, Java InfoBus, ...)



Relations Extensibility Patterns

Unconstrained Patterns

Proxy

Visitor

Decorator

Bridge

*-Bridge

ObjectRecursion

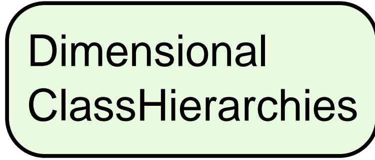
Chain

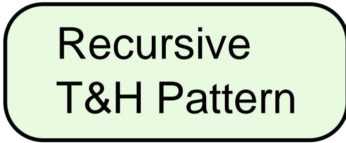
Observer

unconstraining

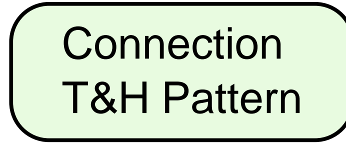
Composite

unconstraining





Framework Patterns obeying T&H role model



Summary

- Most often, extensibility patterns rely on ObjectRecursion
  - An aggregation to the superclass

- This allows for constructing runtime nets: lists, sets, and graphs
  - And hence, for dynamic extension
  - The common superclass ensures a common contract of all objects in the runtime net

The End