Chapter 4
Simple Patterns for Extensibility

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1) Object Recursion
2) Composite
3) Decorator
4) Chain of Responsibility
5) Proxy
6) *-Bridge
7) 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, www.citeseer.org

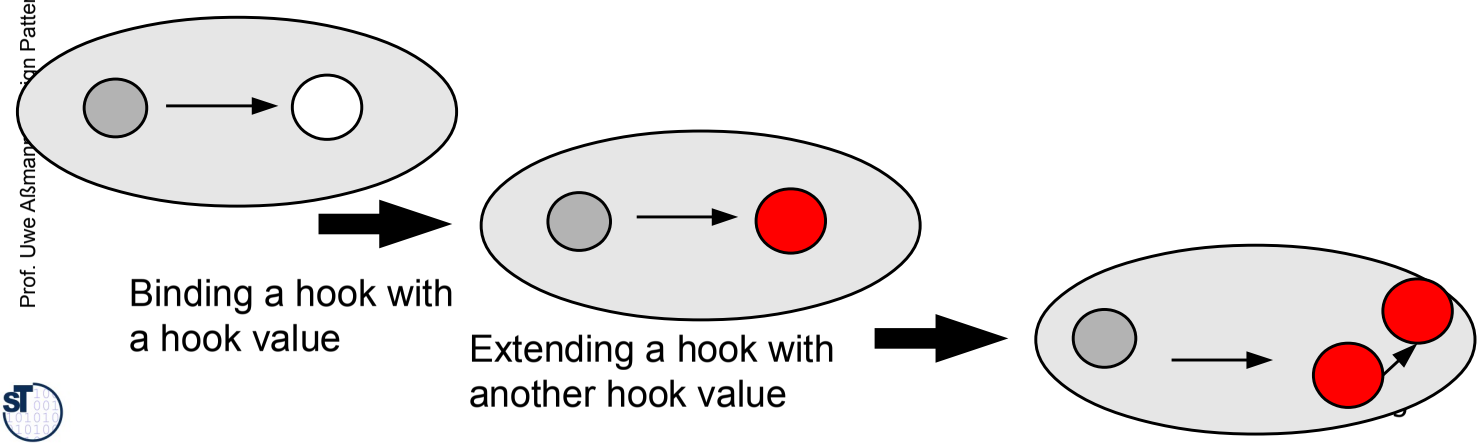
Goal

- 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)
- Understand facets as non-partitioned subset hierarchies
- Layered frameworks as a means to structure large systems, based on facets

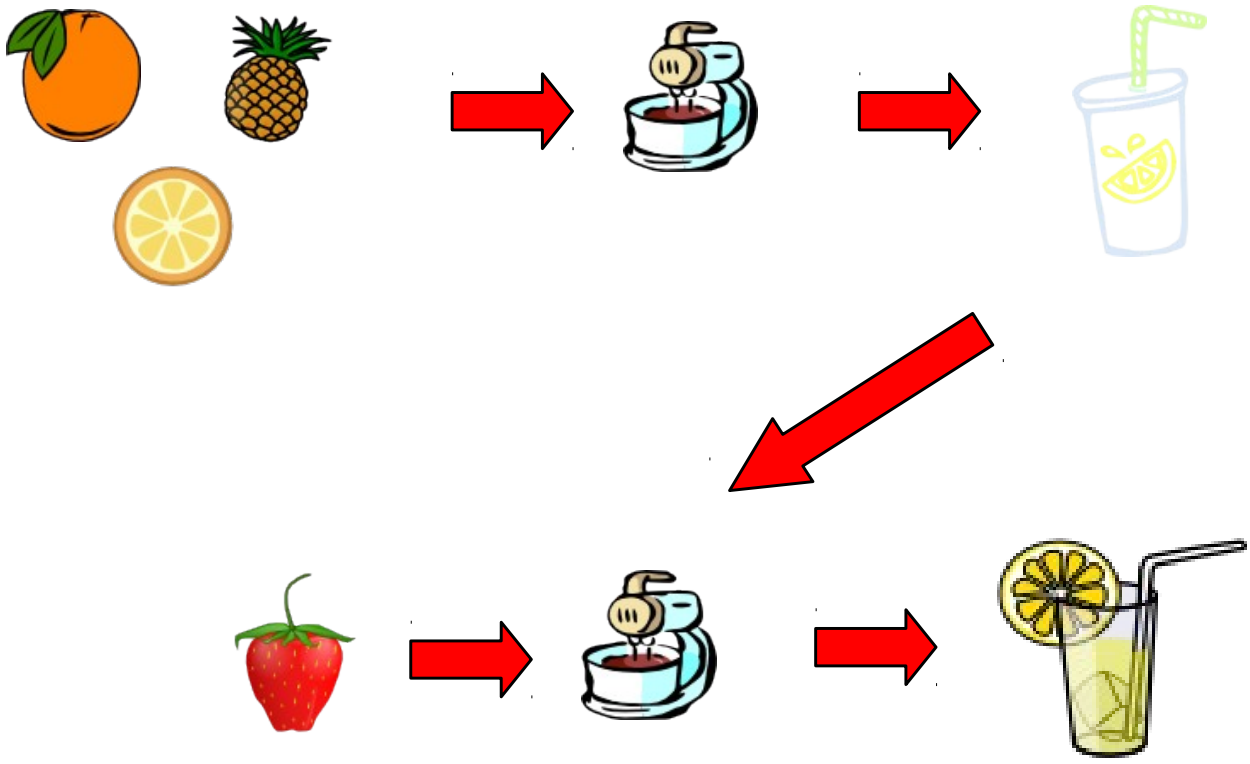
Static and Dynamic Extensibility

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



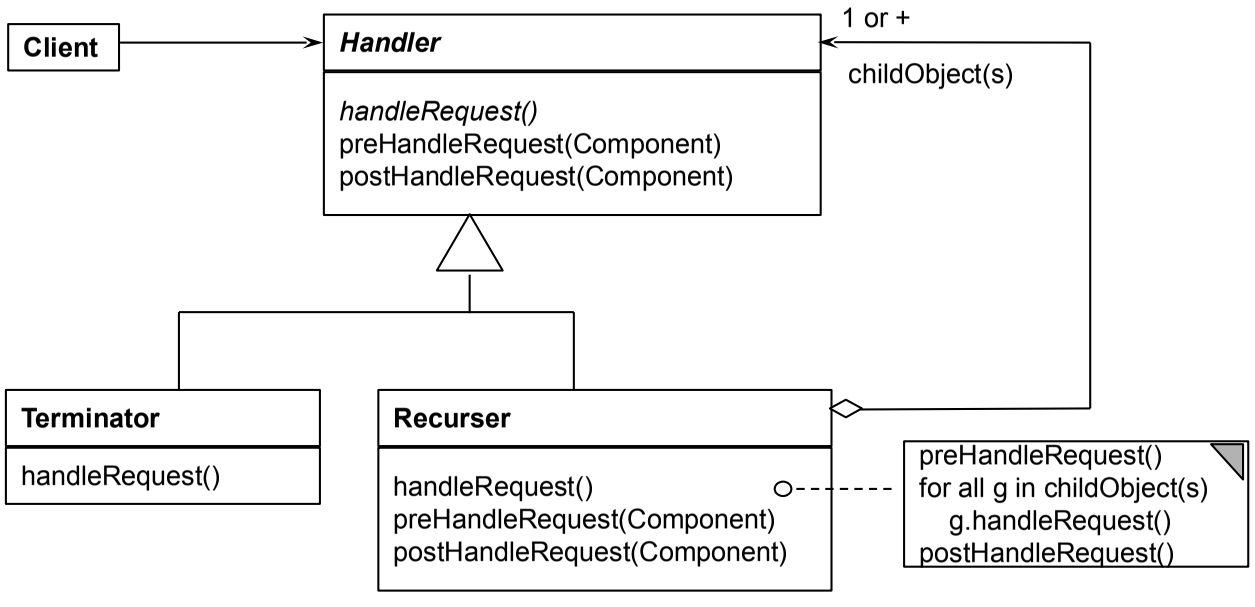
Software Cocktail Mixers



3.1 Object Recursion Pattern

Object Recursion

- Similar to the 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 or 1:n (1-Recursion, n-Recursion)

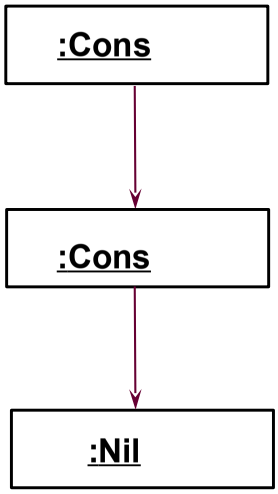


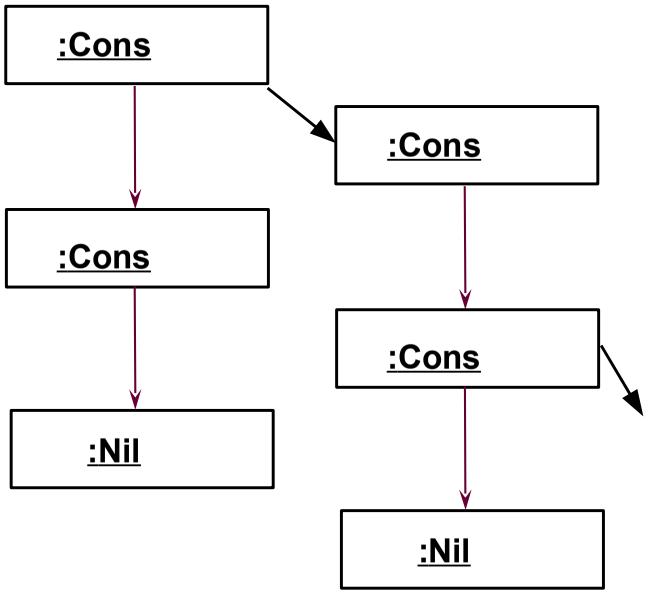
Incentive

- 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 fulfil 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 and graphs



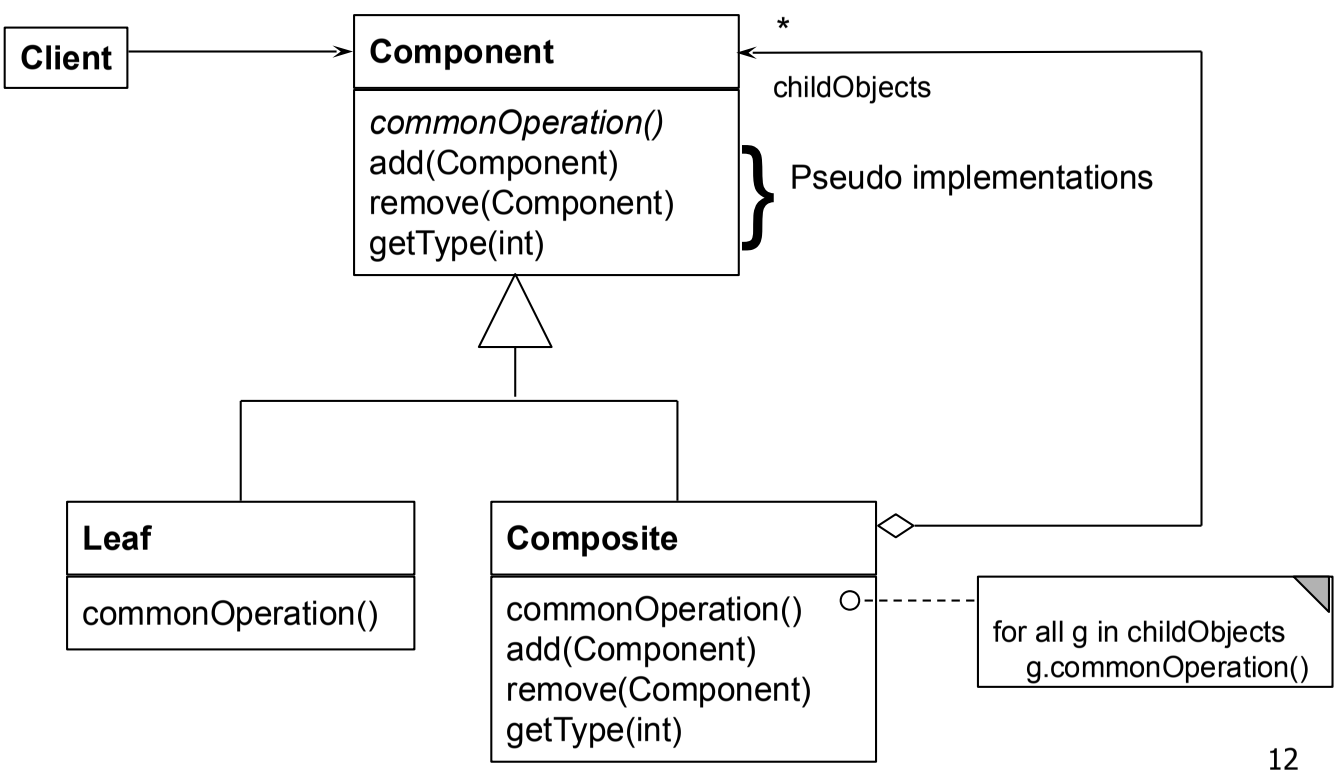


The recursion allows for building up runtime nets

3.2 Composite

Structure Composite

- Composite can be seen as instance of n-ObjectRecursion



Piece Lists in Production Data

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

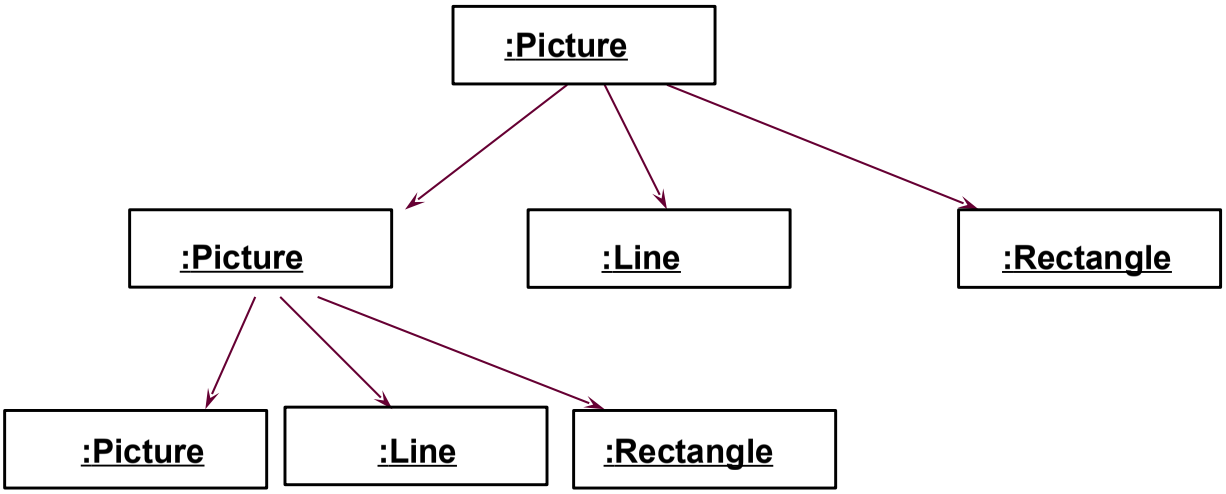
```
class Screw extends CarPart {
    int myCost = 10;
    int calculateCost() {
        return  myCost;
    }
   void addPart(CarPart c) {
        /// impossible, dont do anything
   }
}

// 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 fulfil 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 need not know whether it works on a leaf or 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

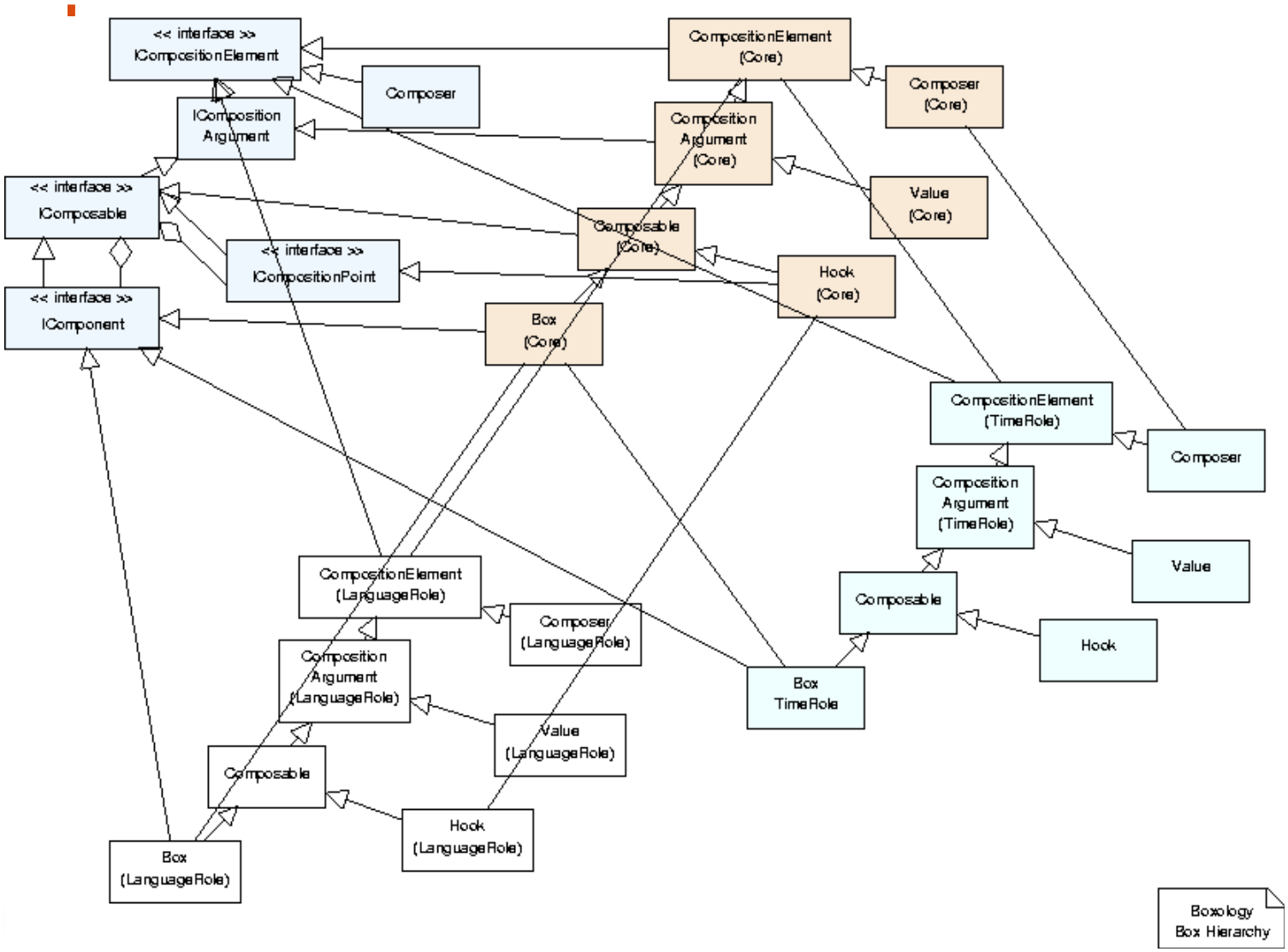
- Part/Whole hierarchies, e.g., nested graphic objects



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

Dynamic 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
- Problems:
  - Pattern is hard to employ when it sits on top of a complex inheritance hierarchy
    - Then, use interfaces only or mixin-based inheritance (not available in most languages)



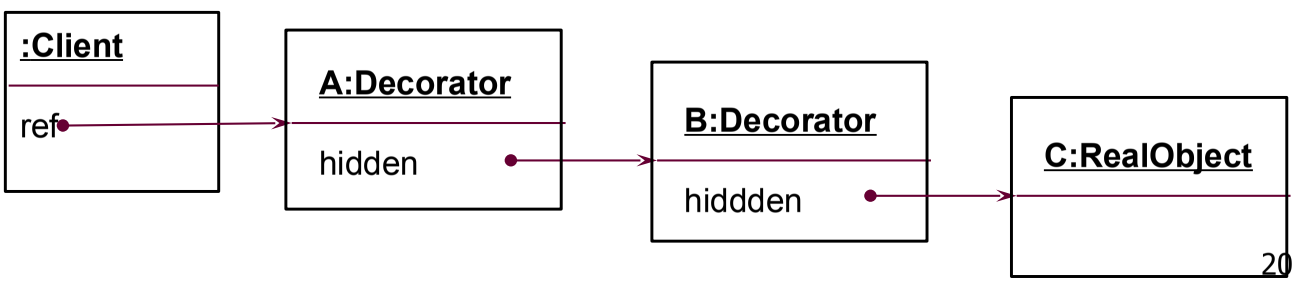
Relations of Composite to Other Programming Domains

- 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...)
    - Barbed wire (homo- and other morphisms)
- The Composite is also the heart of attributed trees and attribute grammars
  - Ordered AG are constraint systems that generate iterators and skeletons [CompilerConstruction]
- Adaptive Programming [Lieberherr] is a generalization of Composite with Iterators [Component-Based Software Engineering (CBSE)]

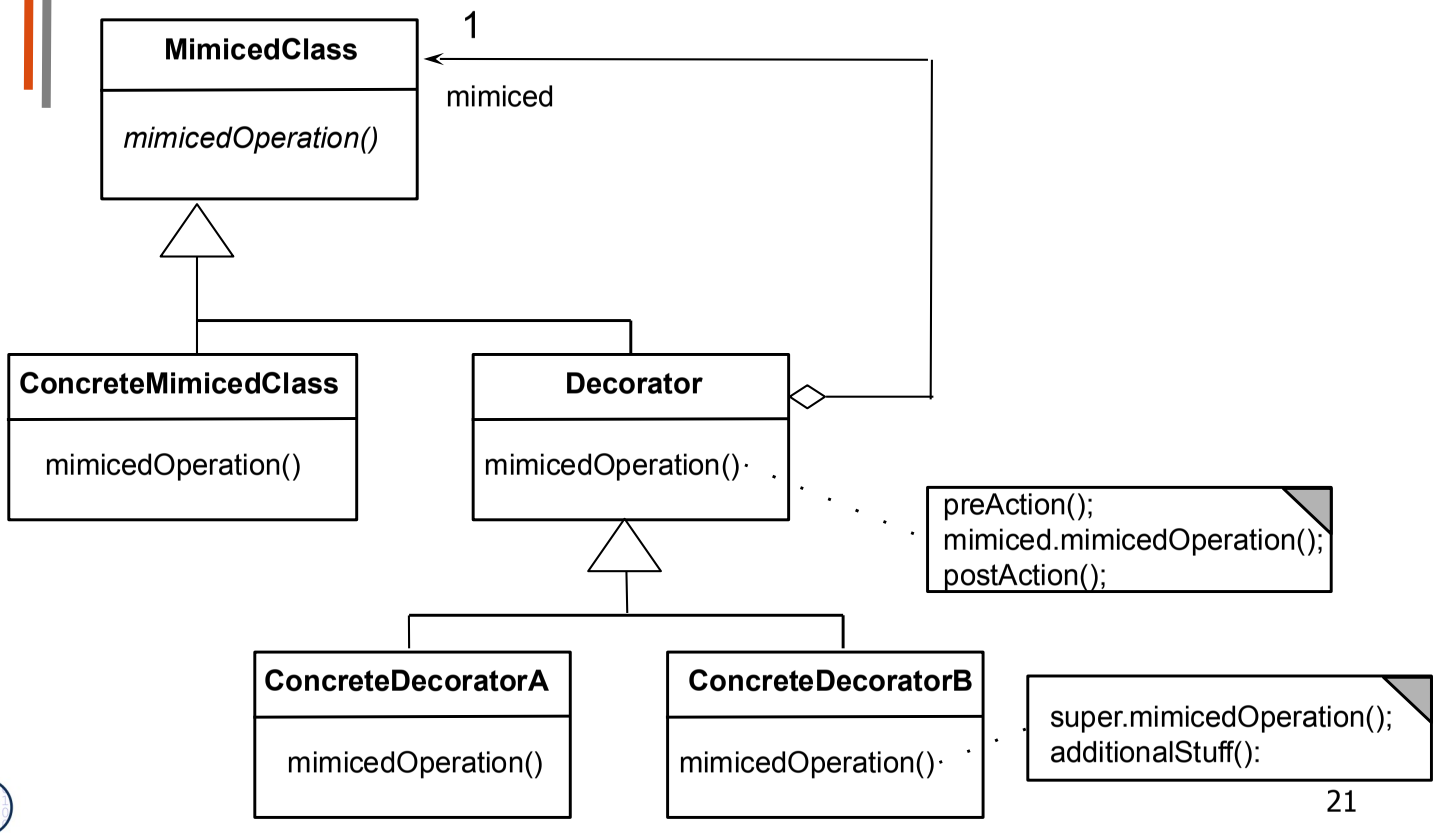
3.3 Decorator as a Variant of ObjectRecursion and Composite

Decorator Pattern

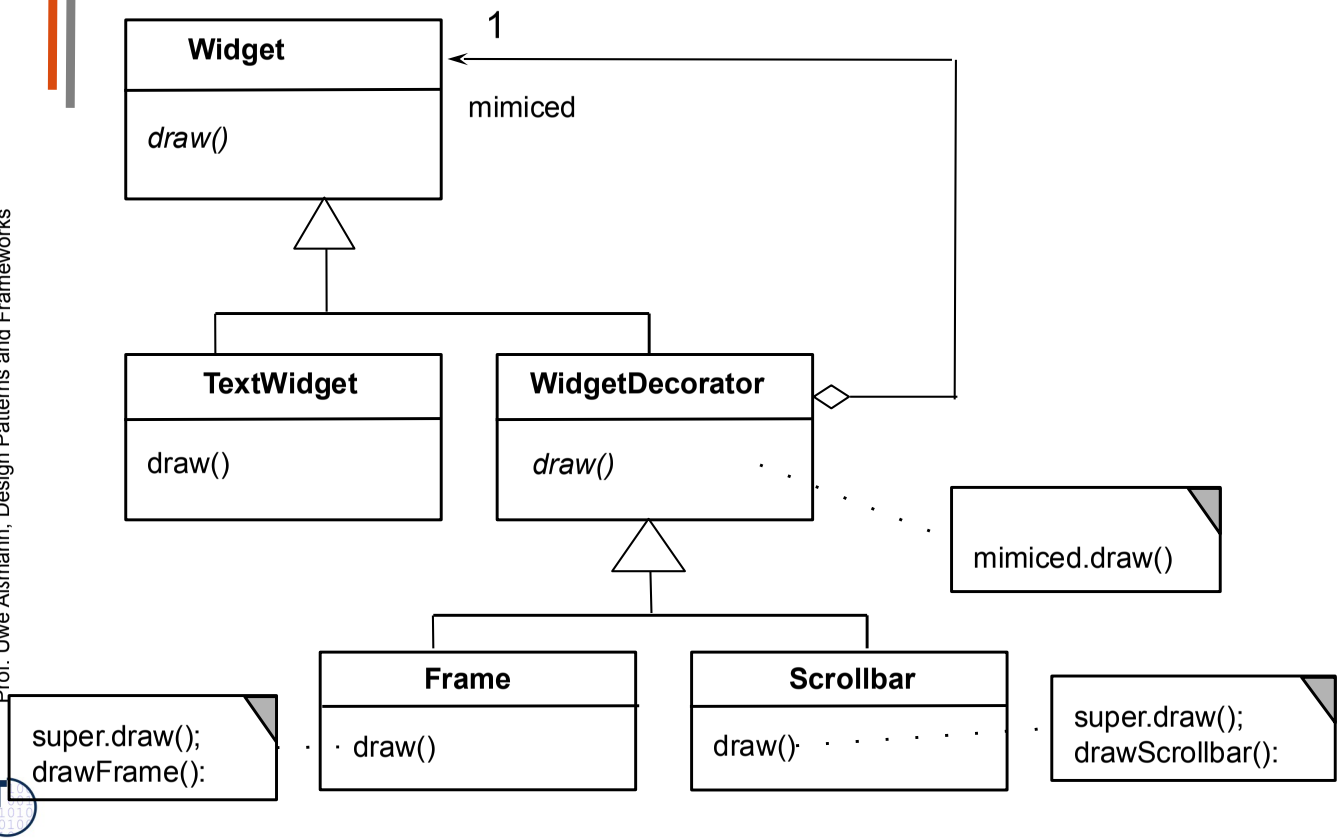
- A Decorator is a *skin* of another object
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
  - Combines inheritance with aggregation
- Similar to ObjectRecursion and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



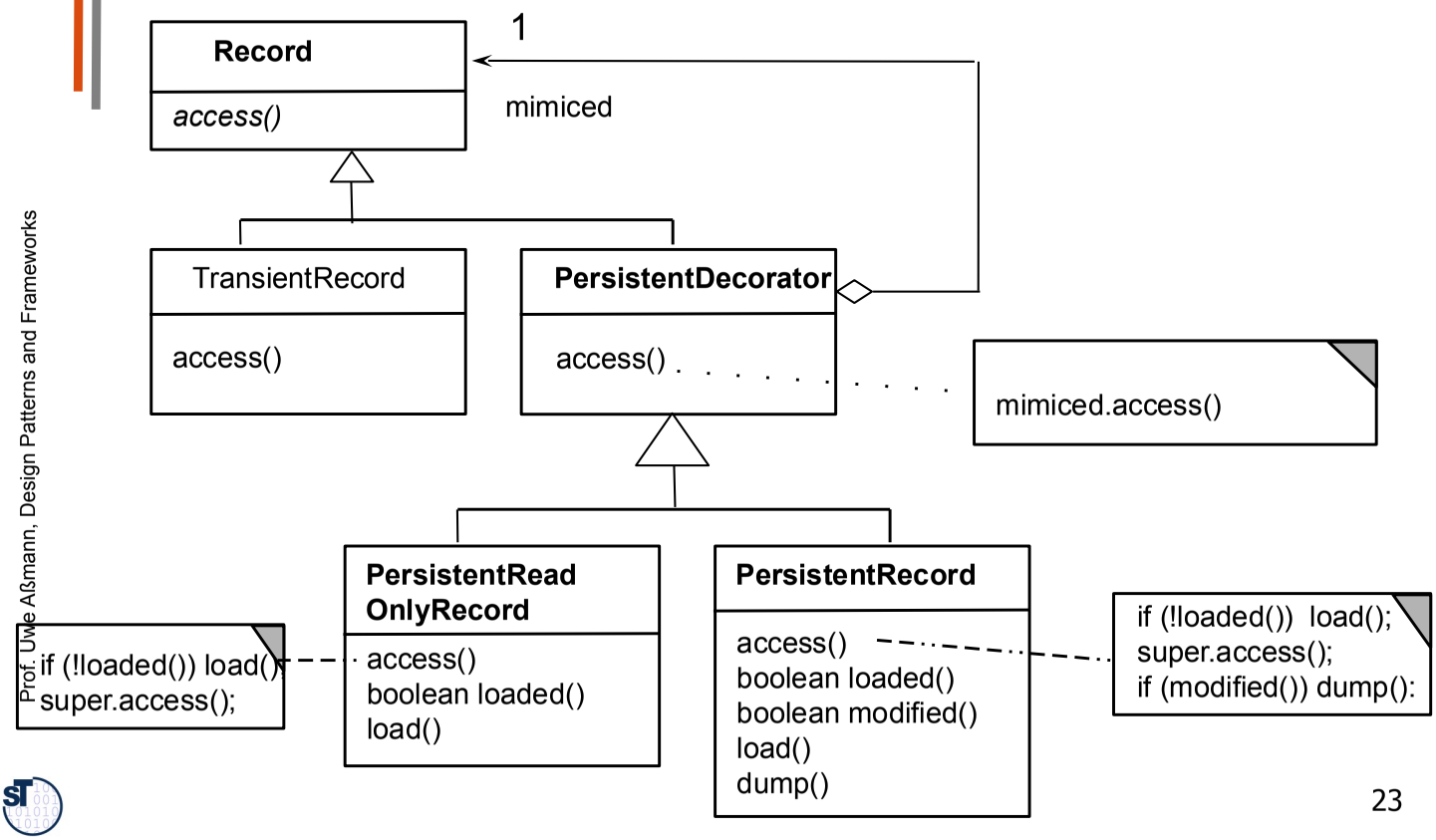
Decorator – Structure Diagram



Decorator for Widgets

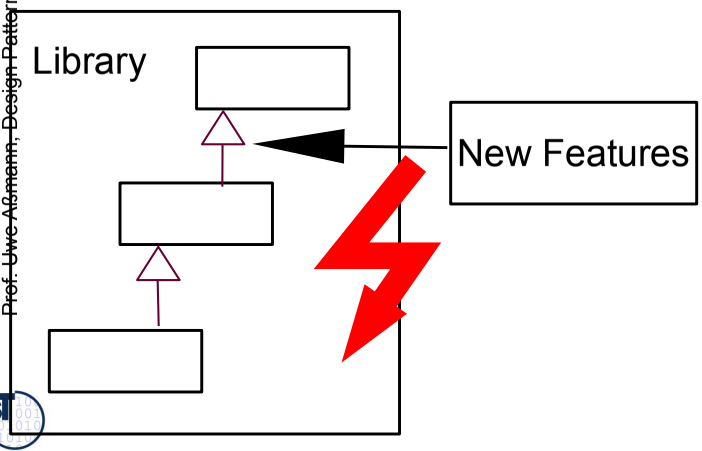


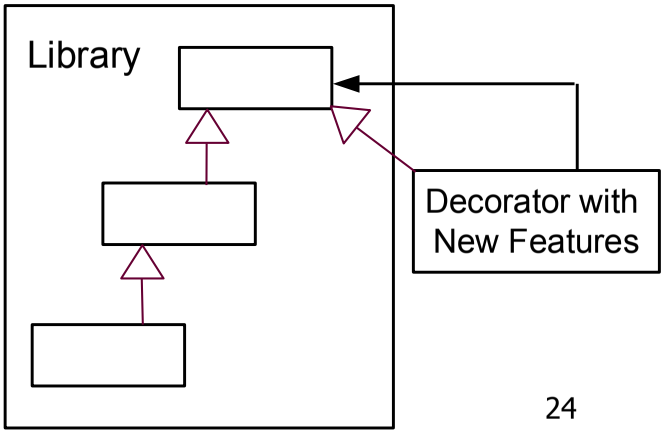
Decorator for Persistent Objects



Purpose Decorator

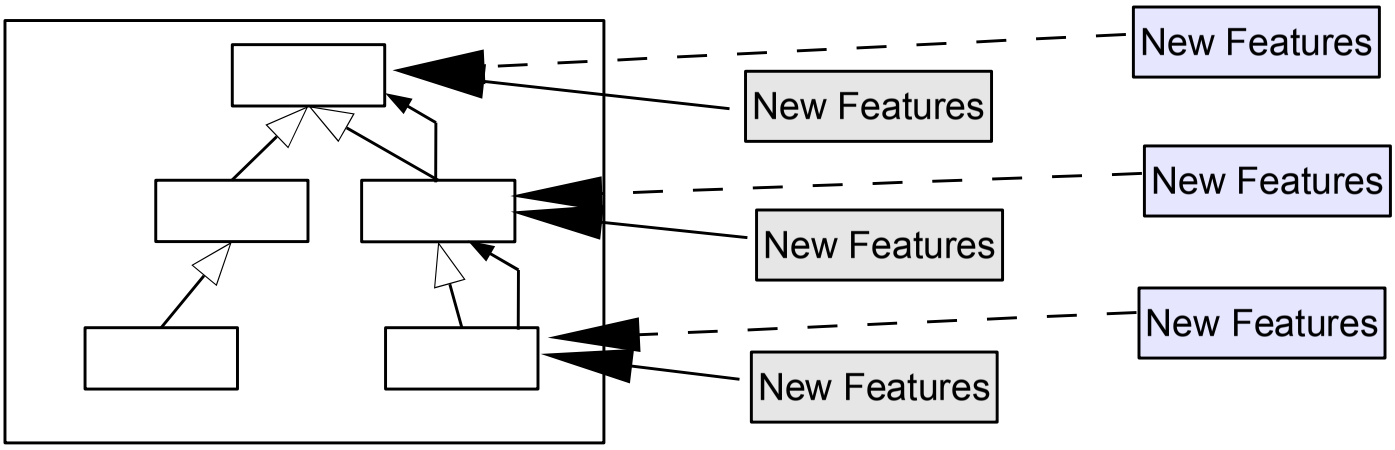
- For extensible objects (i.e., decorating objects)
  - Extension of new features at runtime
  - Removal possible
- Instead of putting the extension into the inheritance hierarchy
  - If that would become too complex
  - If that is not possible since it is hidden in a library





Variants of Decorators

- If only one extension is planned, the abstract superclass Decorator can be saved; a concrete decorator is sufficient
- **Decorator family:** If several decorators decorate a hierarchy, they can follow a common style and can be exchanged together

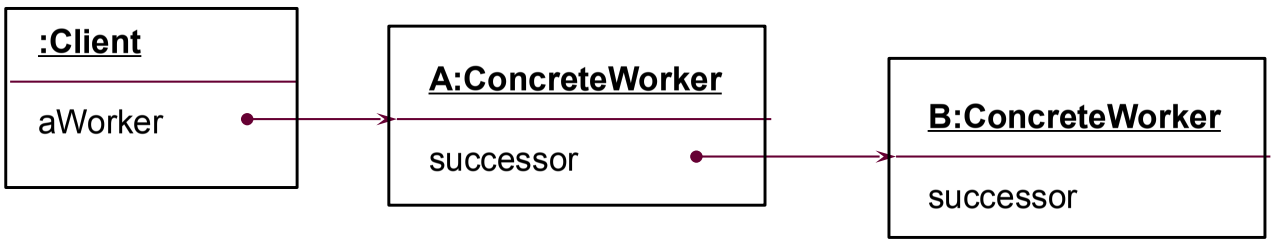


3.4 Chain of Responsibility

Chain of Responsibility

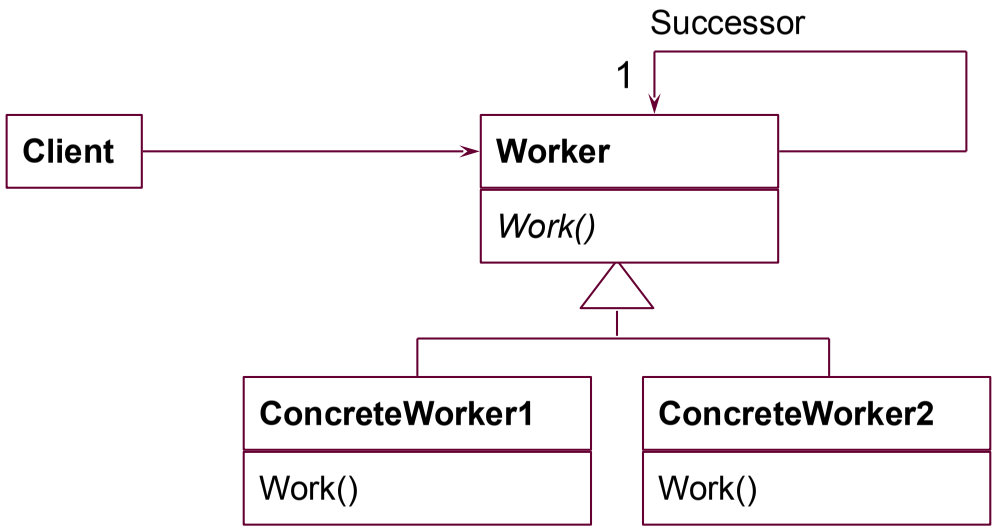
- Delegate an action to a list of delegatees
  - That attempt to solve the problem one after the other
  - Or delegate further on, down the chain
  - “daisy chain” principle

ObjectStructure:



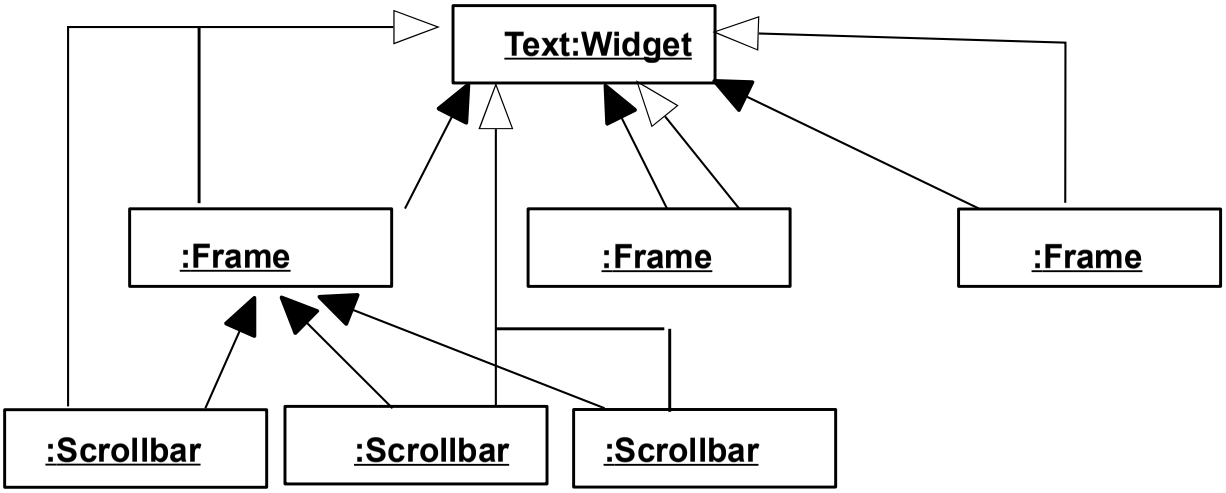
Structure for ChainOfResponsibility

- 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)

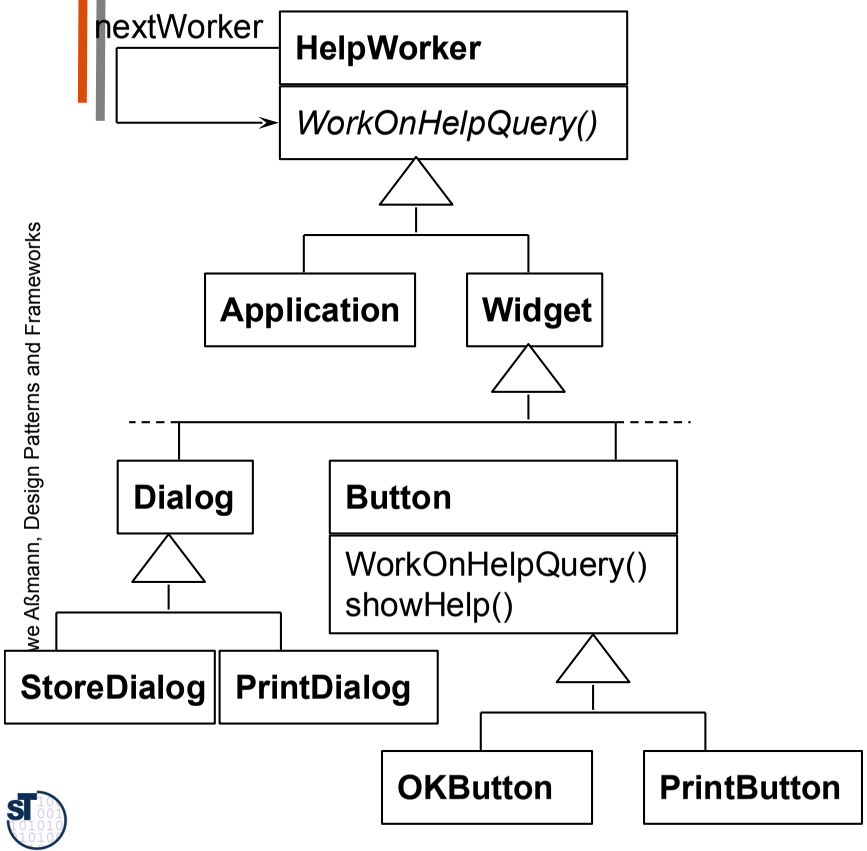


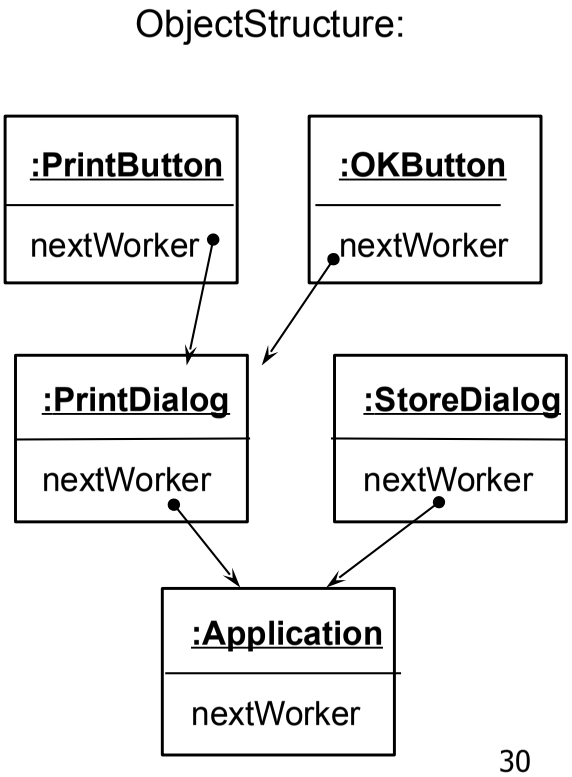
Chains in Runtime Trees

- 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





Help System with Chain

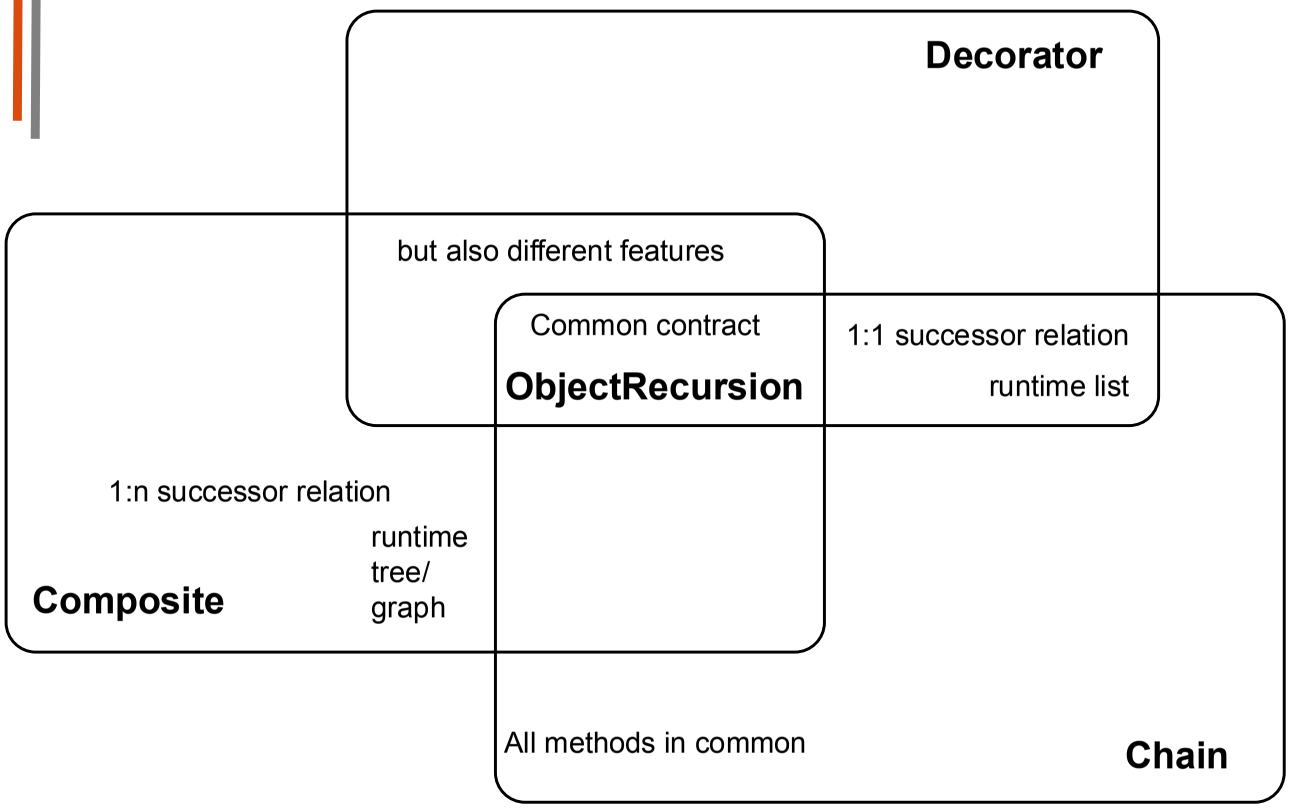
```
abstract class HelpWorker {
   HelpWorker nextWorker;  // here is the 1-
    recursion
    void workOnHelpQuery() {
    if (nextWorker)
     nextWorker.workOnHelpQuery();
    }  else { /* no help available */ }
}
class Widget extends HelpWorker {
    // this class can contain fixing code
}
class 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 not known compile-time
  - Nor at allocation time (polymorphism)
  - But dynamically
  - 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

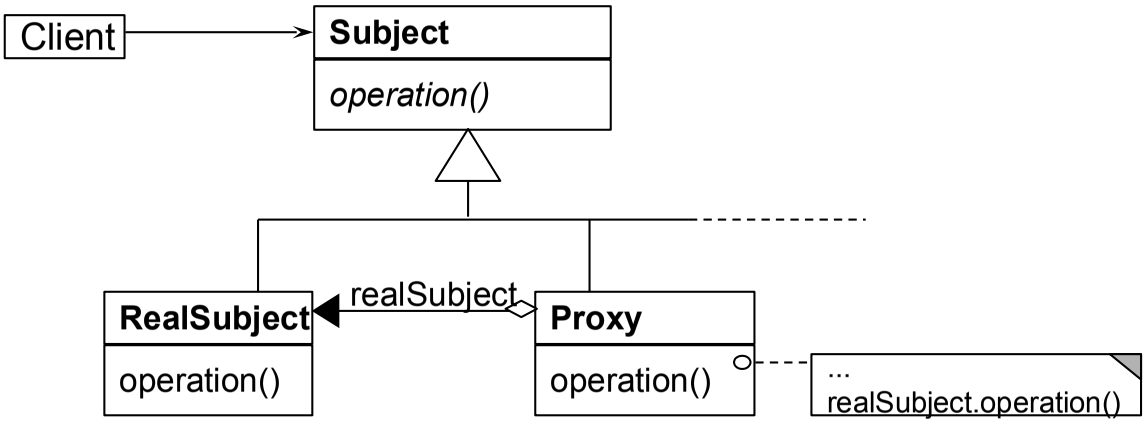
Composite vs Decorator vs Chain



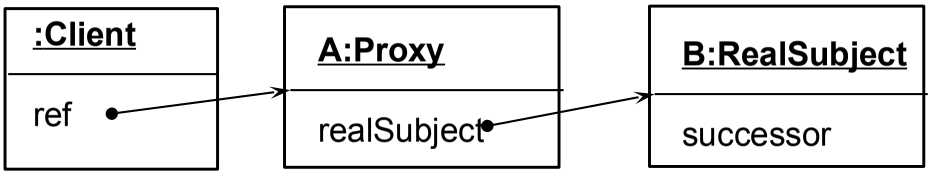
3.5 Proxy

Proxy

- Hide the access to a real subject by a representant



Object Structure:



Proxy

- The proxy object is a representant of an object
  - The Proxy is similar to Decorator, but it is not derived from ObjectRecursion
  - 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.

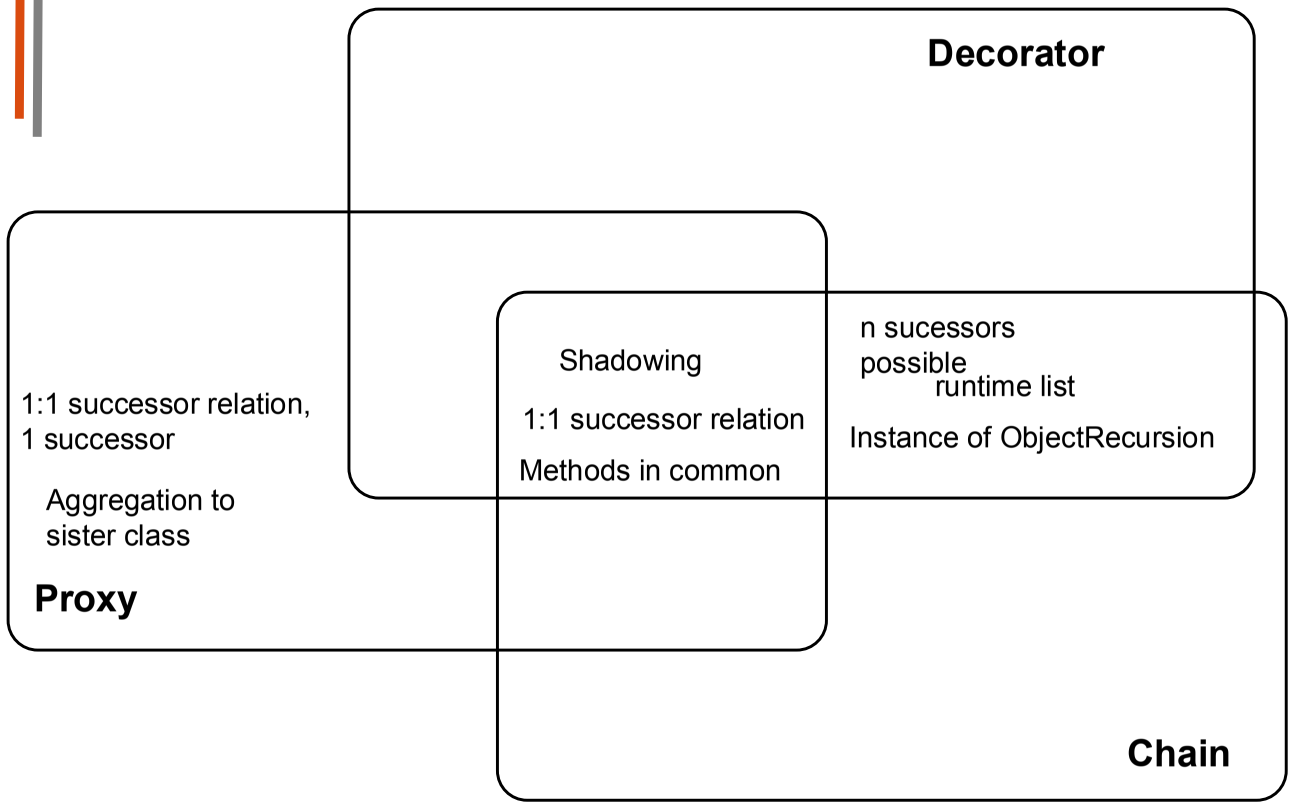
Proxy Variants

- *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:* representant 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++ and other languages allow for overloading access
  - Then, a proxy can invervene
- Built in into the language
  - There are languages that offer proxy objects
  - Modula-3 offers SmartPointers
  - Gilgul offers proxy objects

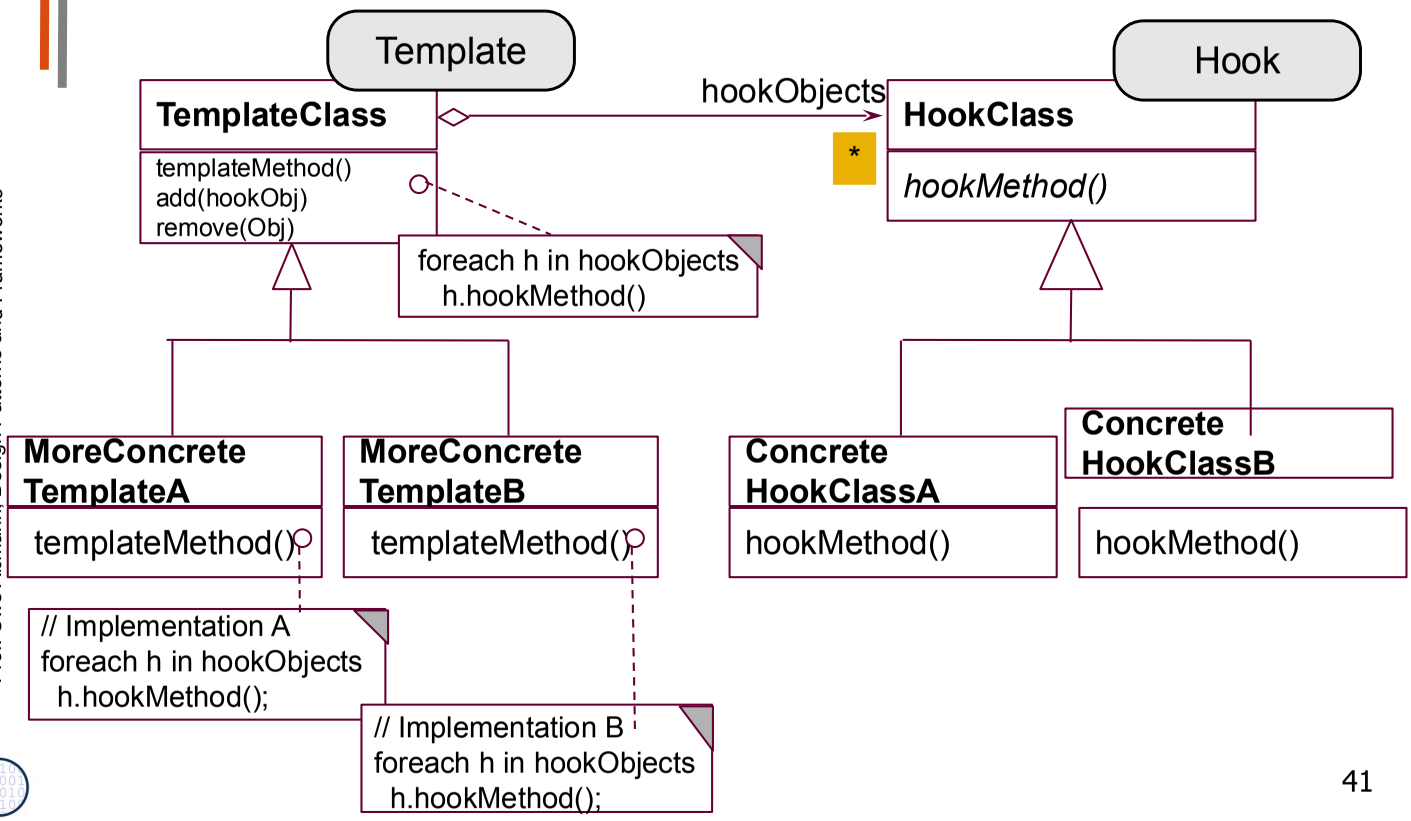
Proxy vs Decorator vs Chain



3.6 *-Bridge

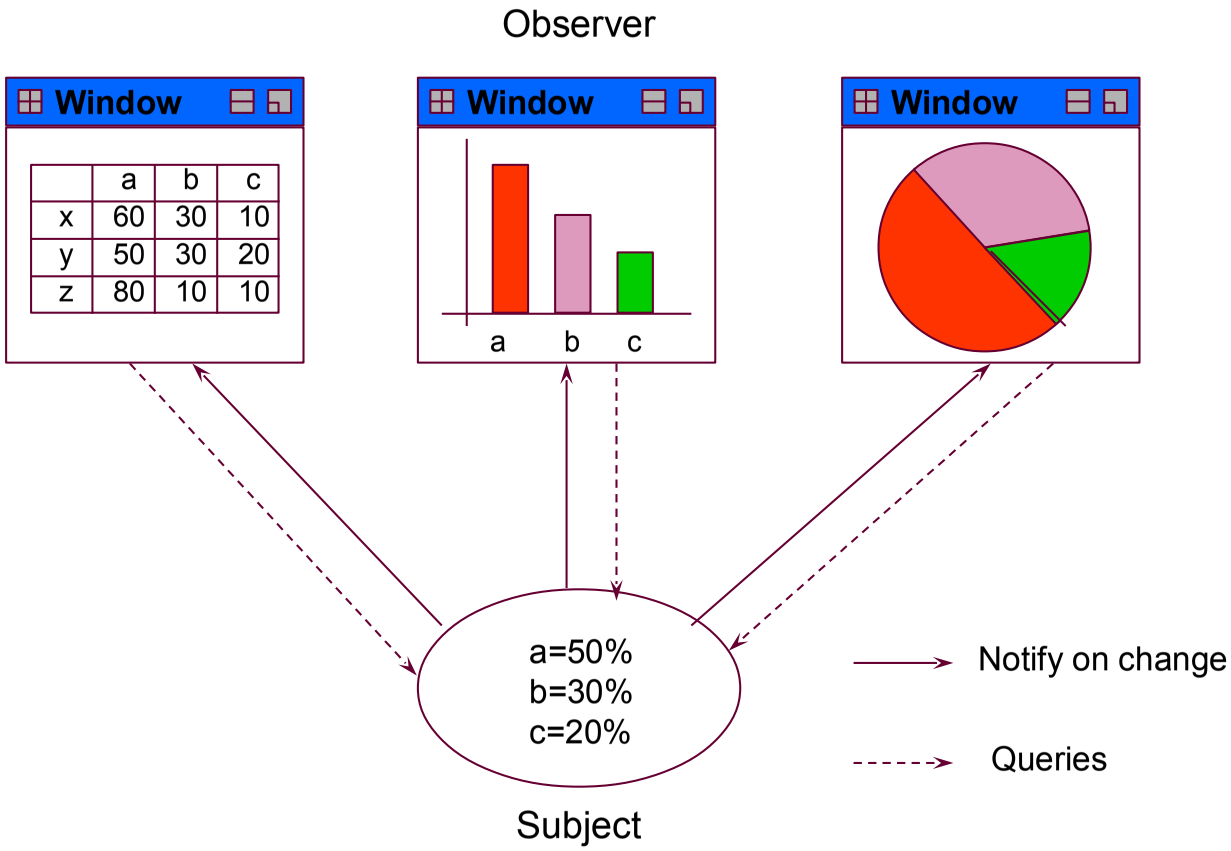
Extensibility Pattern *DimensionalClassHierarchies (*Bridge)

- A bridge with a collection



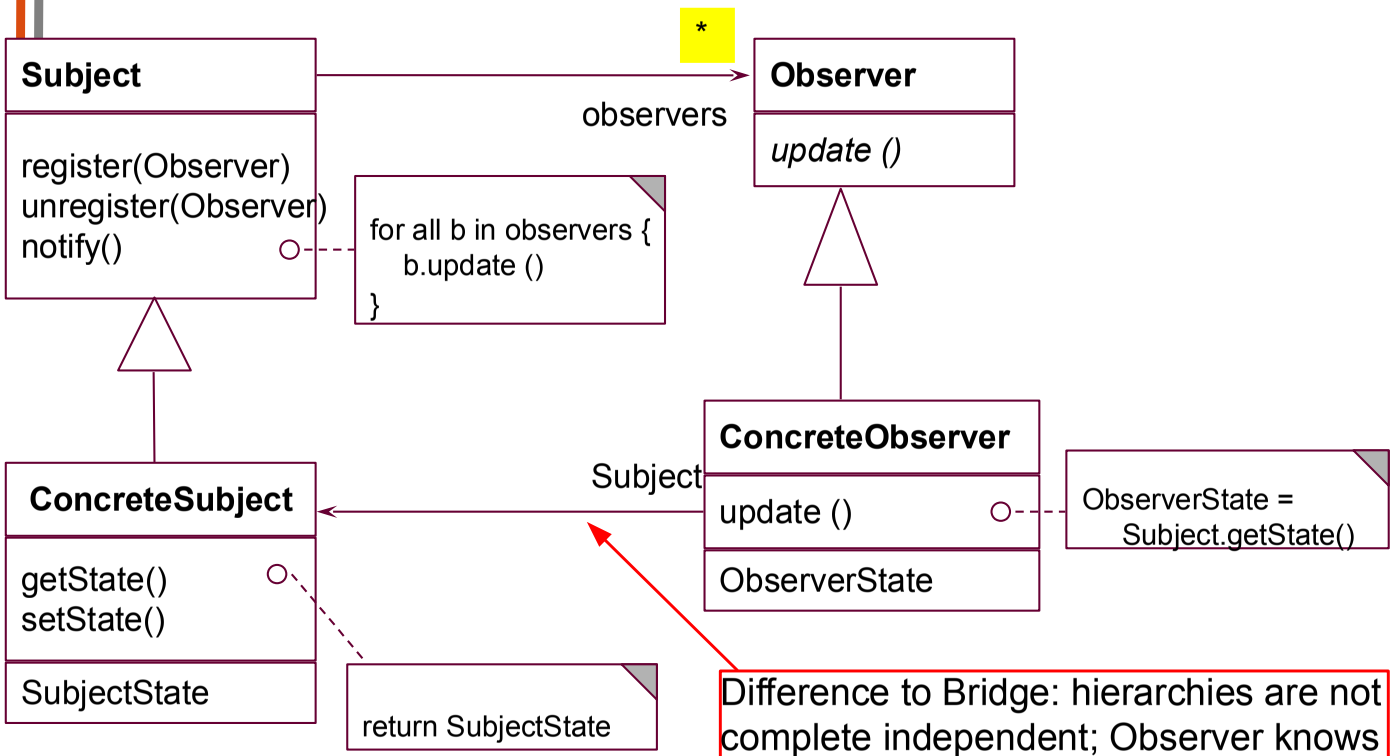
3.7 Observer – (Event Bridge)

Observer (Publisher/Subscriber, Event Bridge)



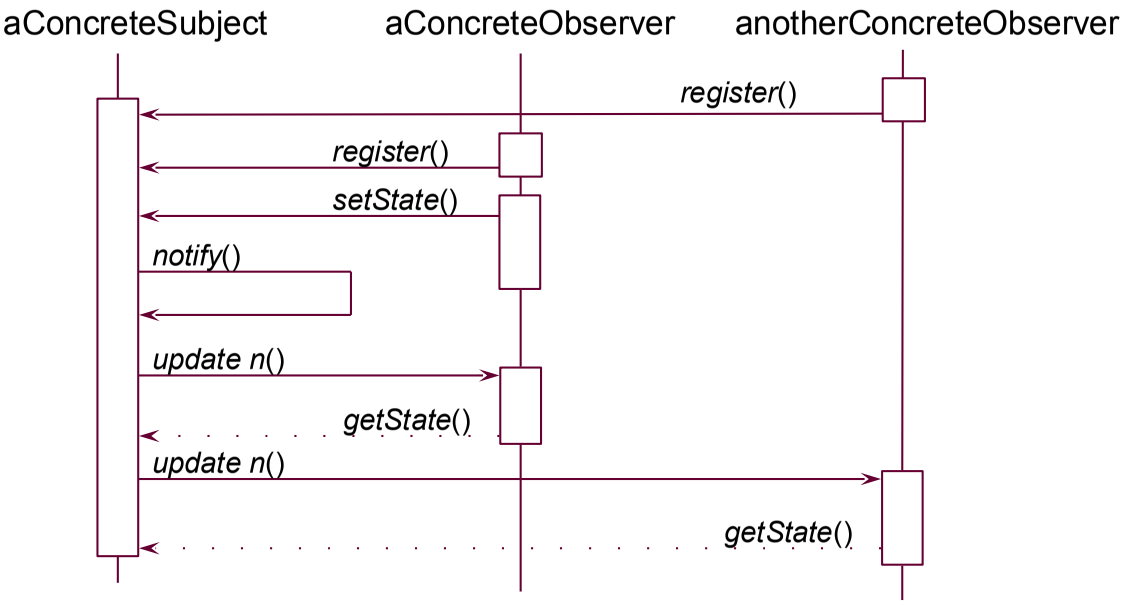
Structure Observer

- Extension of *-Bridge



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 - Applications

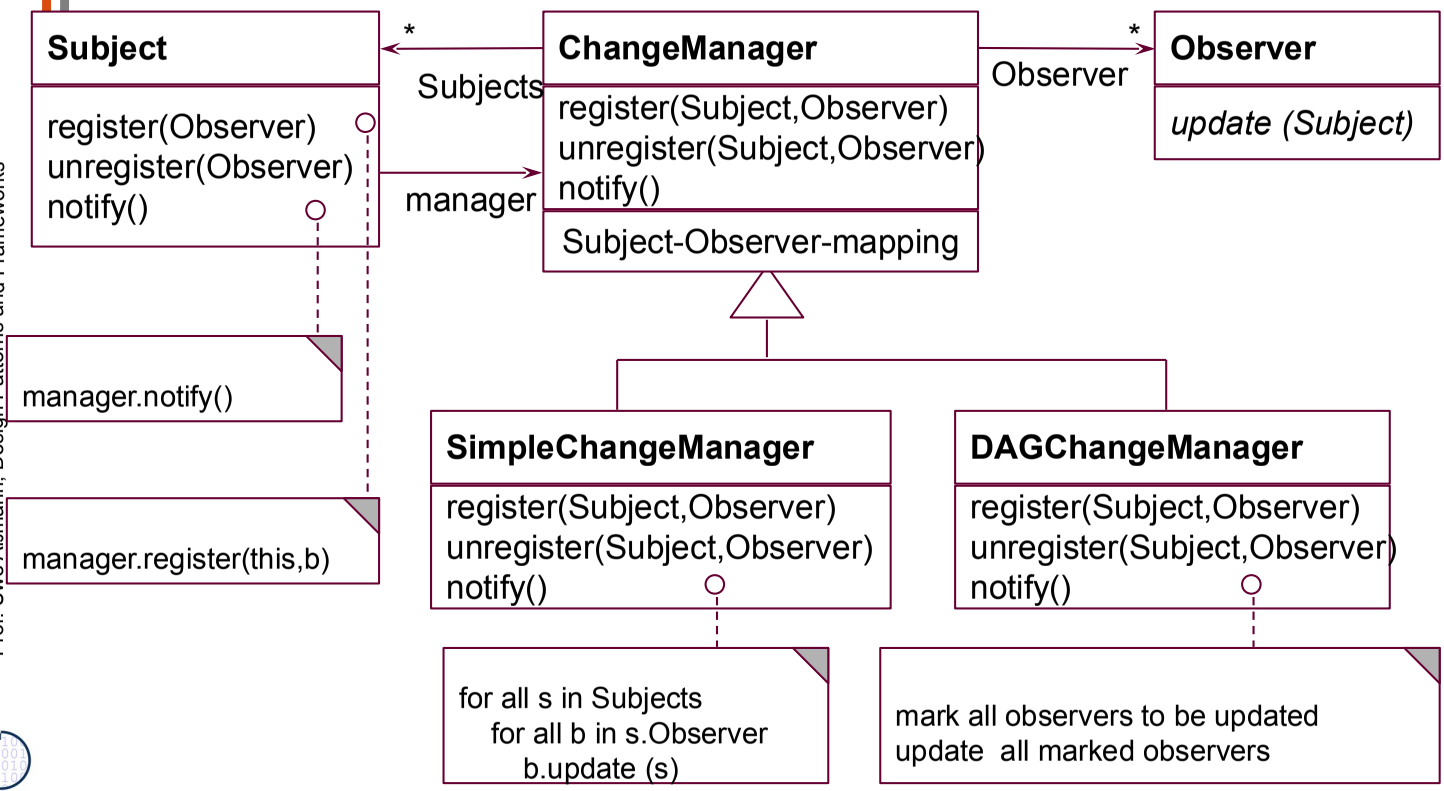
- Loose coupling in communication
  - Observers decide what happens
- Dynamic change of communication
  - Anonymous communication
  - Multi-cast and broadcast communication
  - Cascading communication if observers are chained (stacked)
- Communication of core and aspect
  - If an abstraction has two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

Observer Variants

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

Observer with ChangeManager (Mediator)

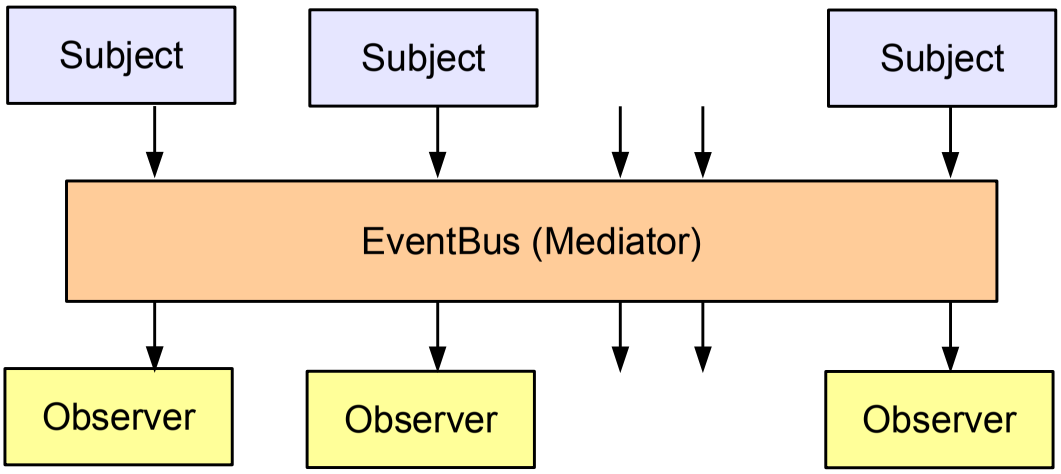
- Mediator between subjects and observer:
  - May filter events, stop cascaded propagations



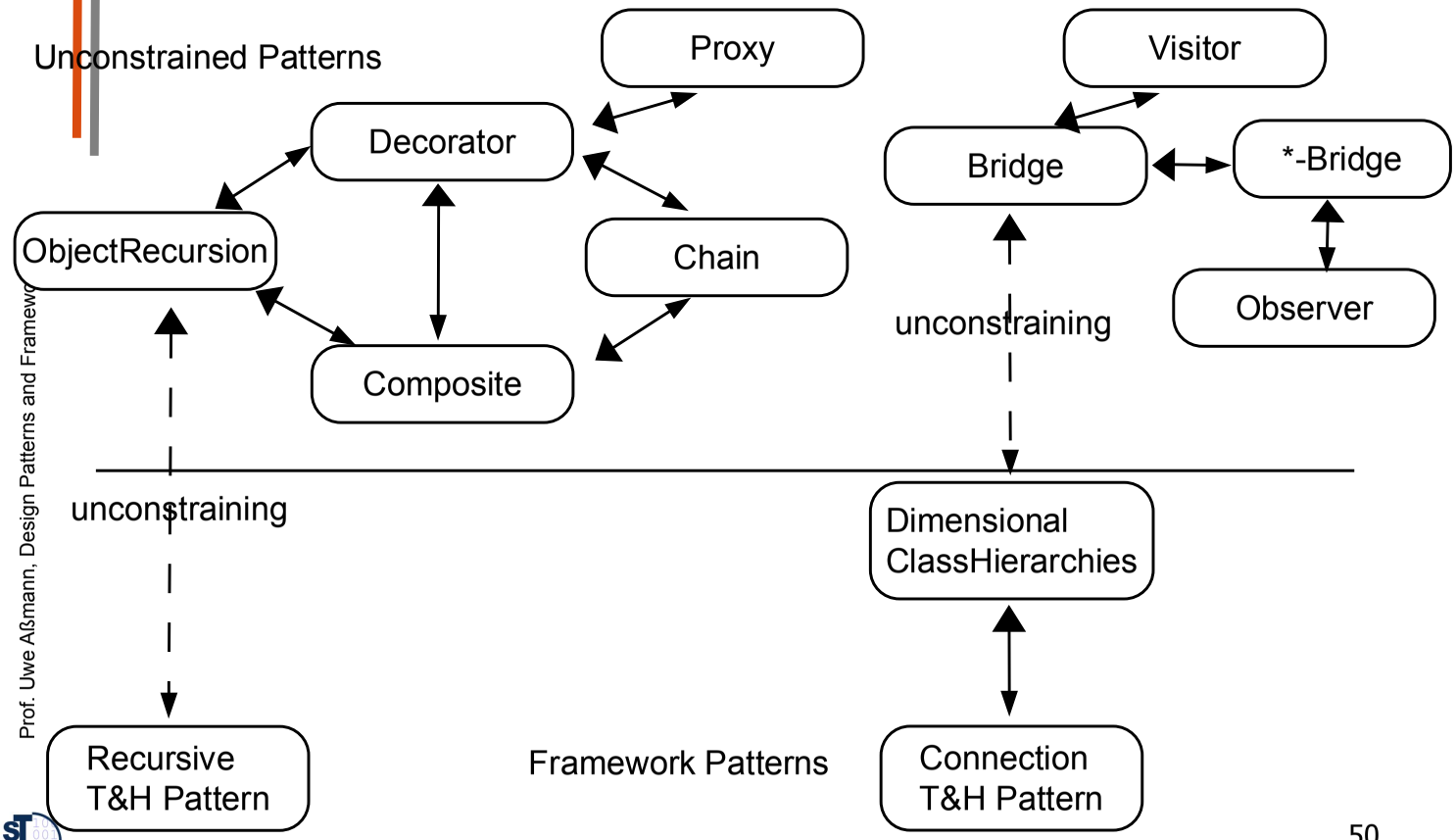
Prof. Uwe Aßmann, Design Patterns and Frameworks

ChangeManager is also Called Eventbus

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



Relations Extensibility Patterns



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
- Layered systems can be implemented with dimensional class hierarchies (Bridges)
- Layered frameworks are product families for systems with layered architectures

The End