24. Entwurfsmuster für Produktfamilien

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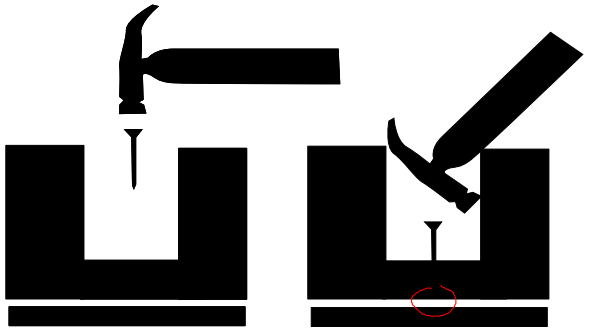
1) Patterns for Variability
2) Patterns for Extensibility
3) Patterns for Glue
4) Other Patterns
5) Patterns in AWT

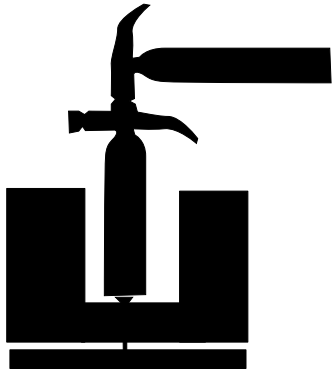
DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Achtung: Dieser Foliensatz ist teilweise in Englisch gefasst, weil das Thema in der Englisch-sprachigen Kurs “Design Patterns and Frameworks” wiederkehrt.
Mit der Bitte um Verständnis.

Obligatory Literature

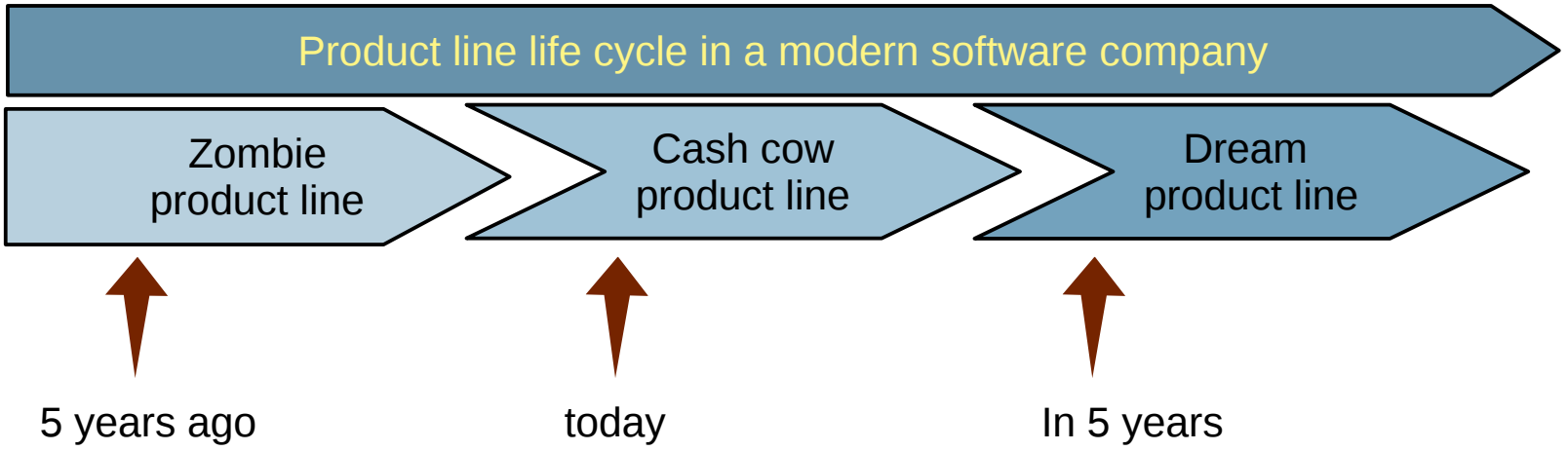
- ST für Einsteiger, Kap. Objektentwurf: Wiederverwendung von Mustern
- also: Chap. 8, Bernd Brügge, Allen H. Dutoit. Objektorientierte Softwaretechnik mit UML, Entwurfsmustern und Java. Pearson.





Standard Problems to Be Solved By *Product Line Patterns*

- **Product Line Patterns** are specific design patterns about:
- **Variability**
  - Exchanging parts easily
  - Variation, variability, complex parameterization
  - Static and dynamic
  - For product lines, framework-based development
- **Extensibility**
  - Software must change
- **Glue** (adaptation overcoming architectural mismatches)
  - Coupling software that was not built for each other

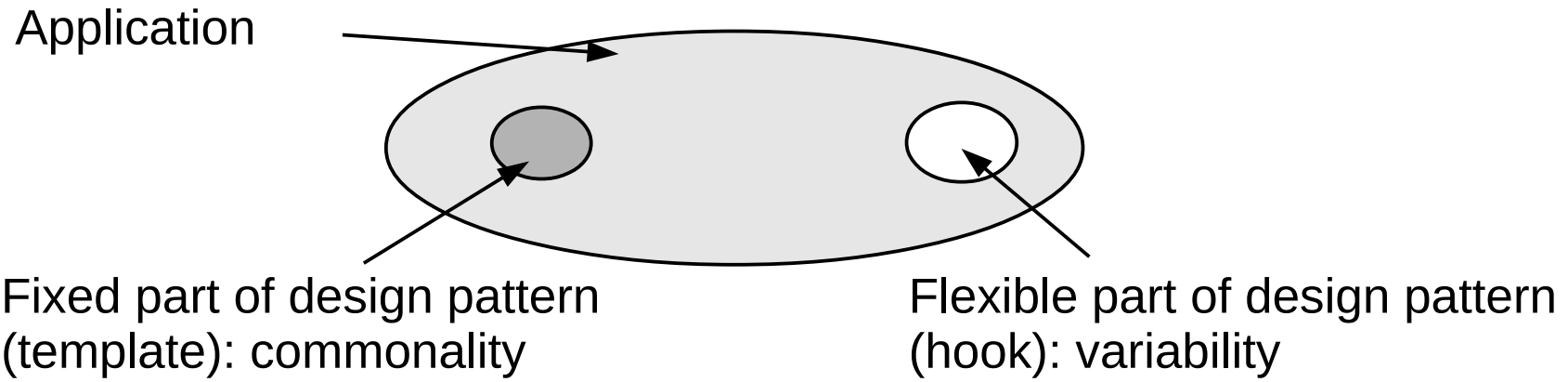


24.1) Patterns for Variability

Variability Pattern	# Run-time objects	Key feature
TemplateMethod	1	
FactoryMethod	1	
TemplateClass	2	Complex object
Strategy	2	Complex algorithm object
FactoryClass	3	Complex allocation of a family of objects
Bridge (DimensionalClass Hierarchy)	2	Complex object

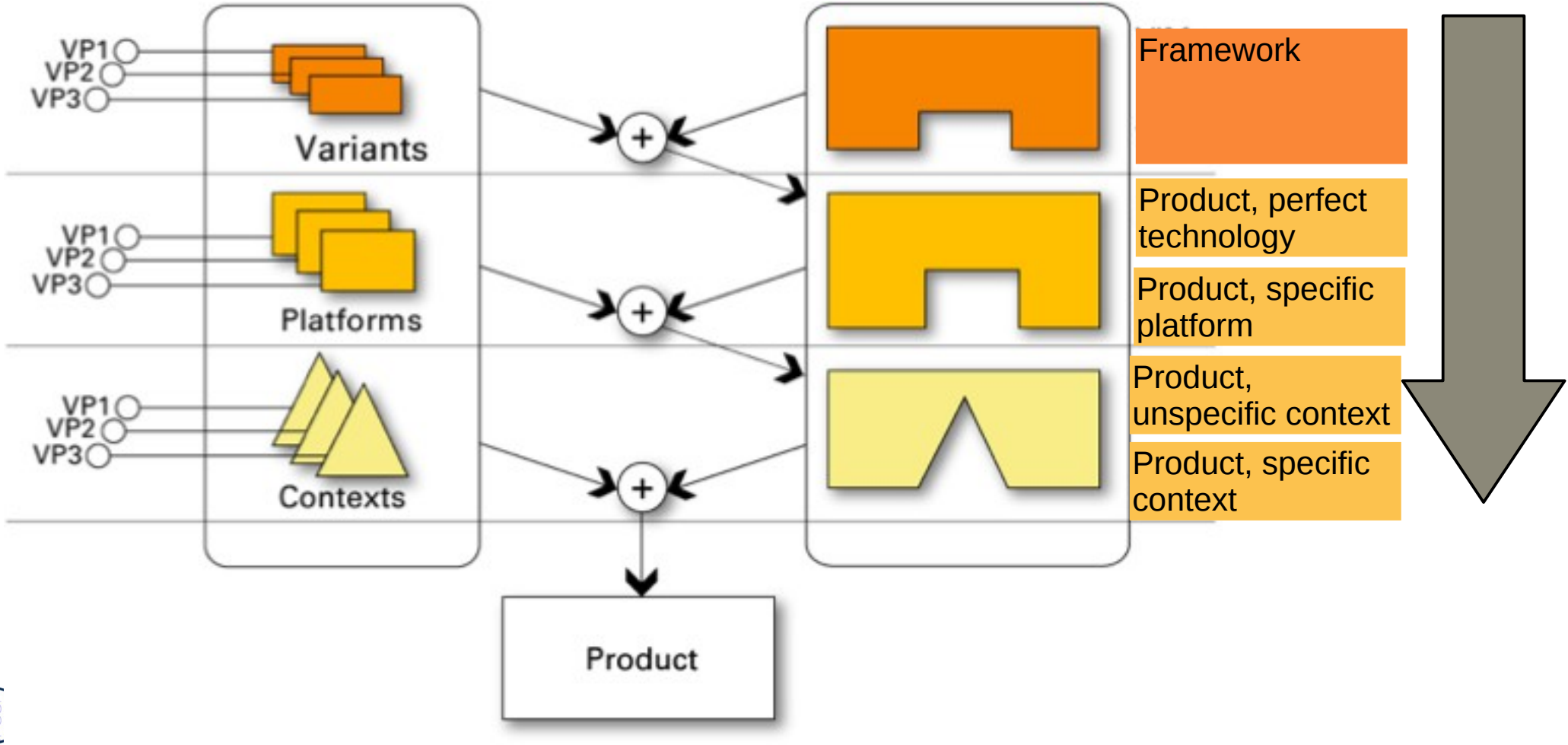
Commonalities and Variabilities

- A variability design pattern describes
  - Code that are *common* to several applications
    - Commonalities lead to *frameworks* of *product lines*
  - Code that are *different or variable* from application to application
    - Variabilities to *products* of a product line
- For capturing the communality/variability knowledge in variability design patterns, Pree invented the *template-and-hook (T&H) concept*
  - *Templates* contain skeleton code (commonality), common for the entire product line
  - *Hooks (hot spots)* are placeholders for the instance-specific code (variability)



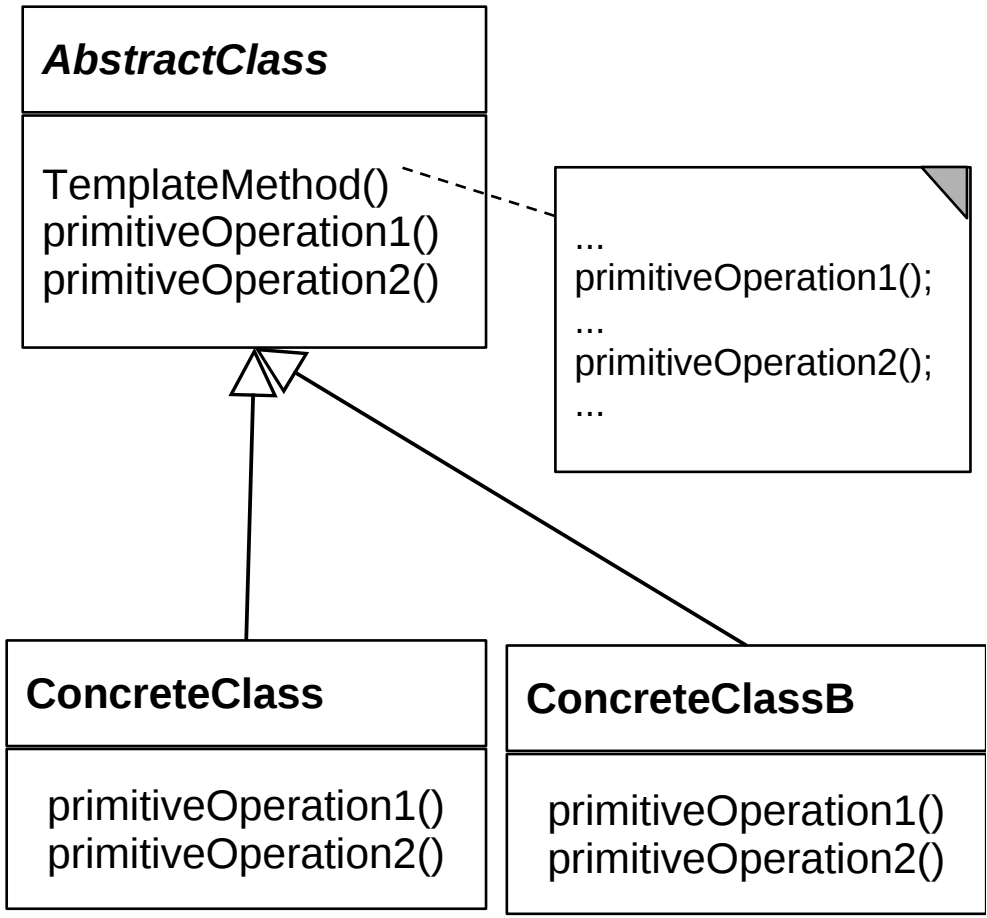
Why Do We Need Variability?

- Functional features, packages (payed vs free use), etc
- Platforms (Hardware, operating system, database, GUI package, etc.)
- Dynamic contexts (personalization, time and location)



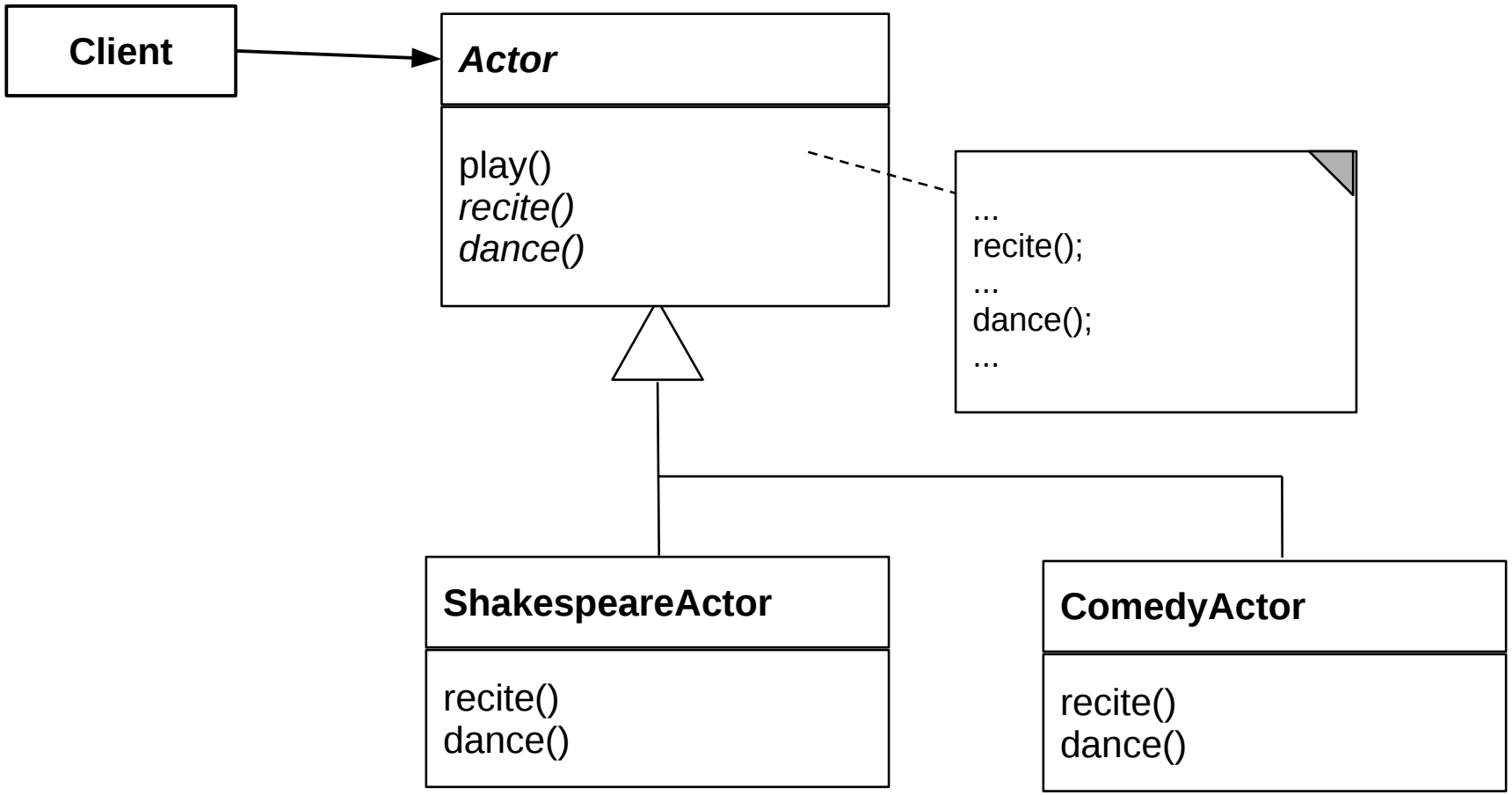
TemplateMethod Pattern is a Variability Design Pattern (Rpt.)

- Define the skeleton of an algorithm (template method)
  - The template method is concrete
- Delegate parts to abstract *hook methods* that are filled by subclasses
- Implements template and hook with the same class, but different methods
- Allows for varying behavior
  - Separate invariant from variant parts of an algorithm
- Example: TestCase in JUnit



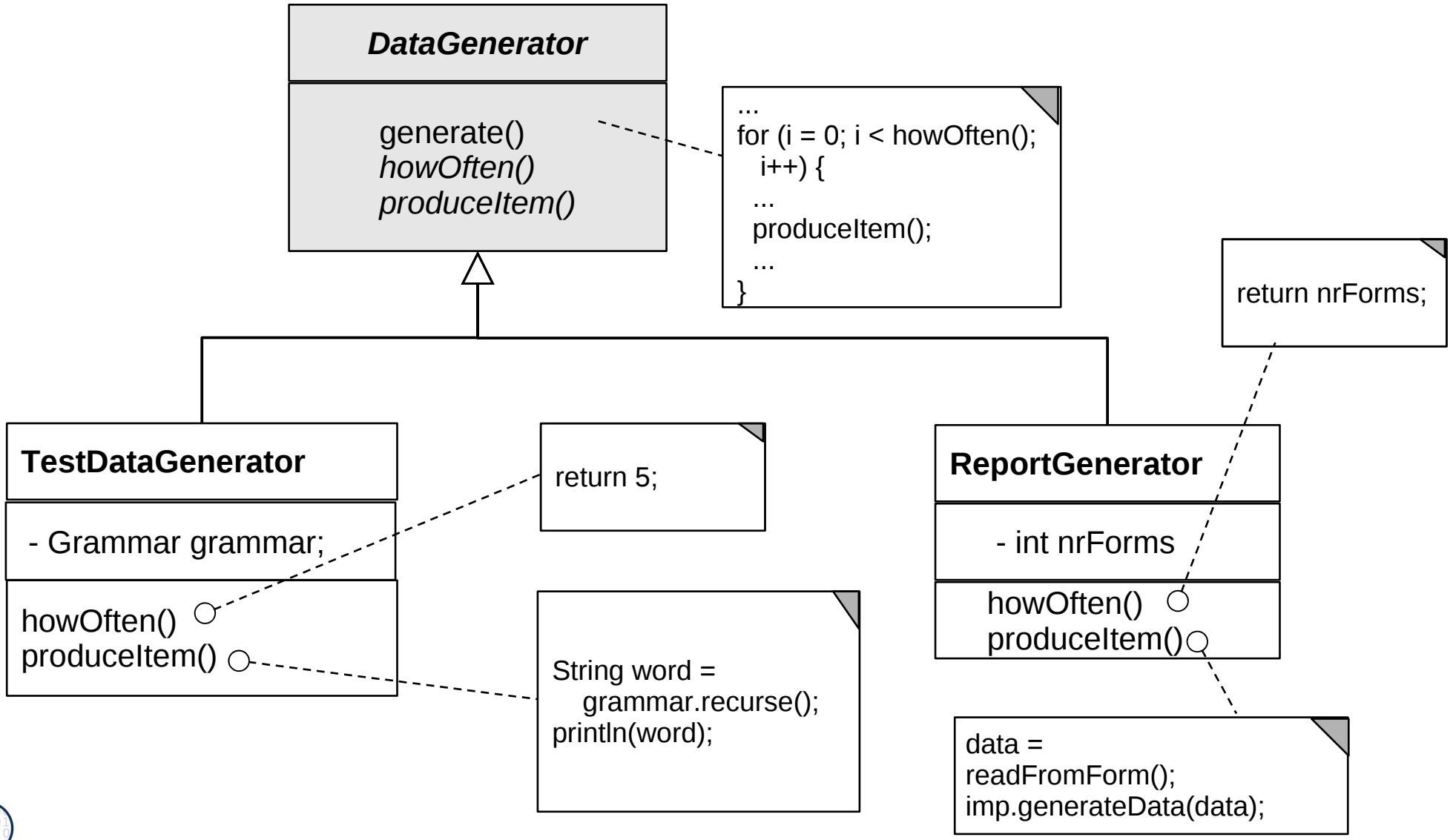
Actors and Genres as Template Method

- Binding an Actor's hook to be a ShakespeareActor *or* a Comedy Actor
- The behavior visible to a client will differ in two aspects, reciting and dancing



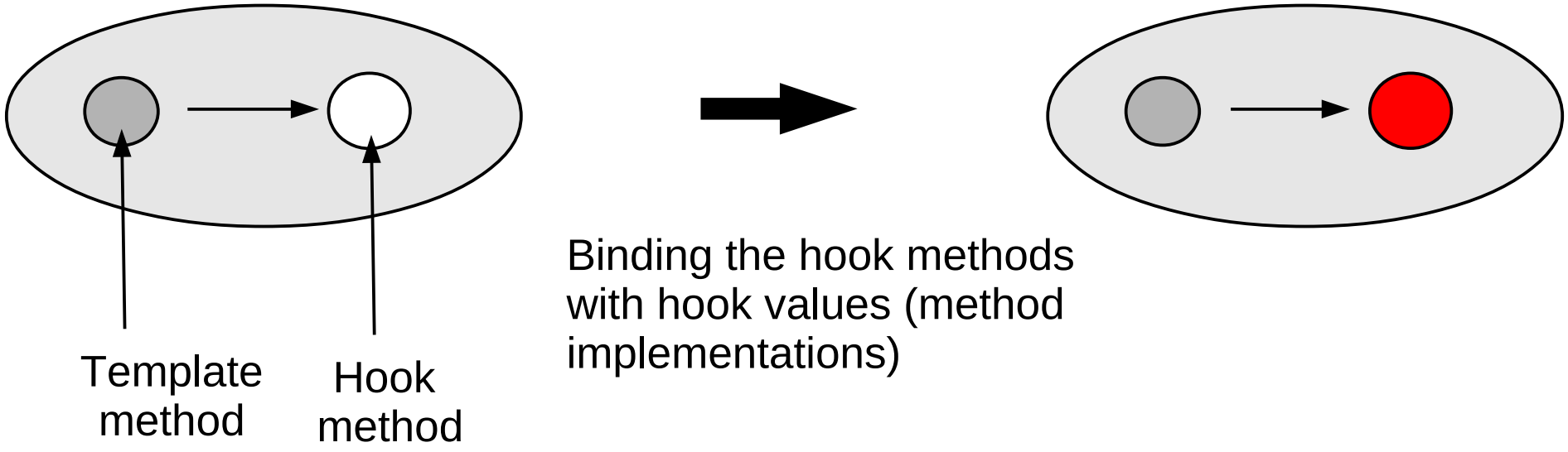
Running Example: A Data Generator

- Parameterizing a data generator by frequency and kind of production



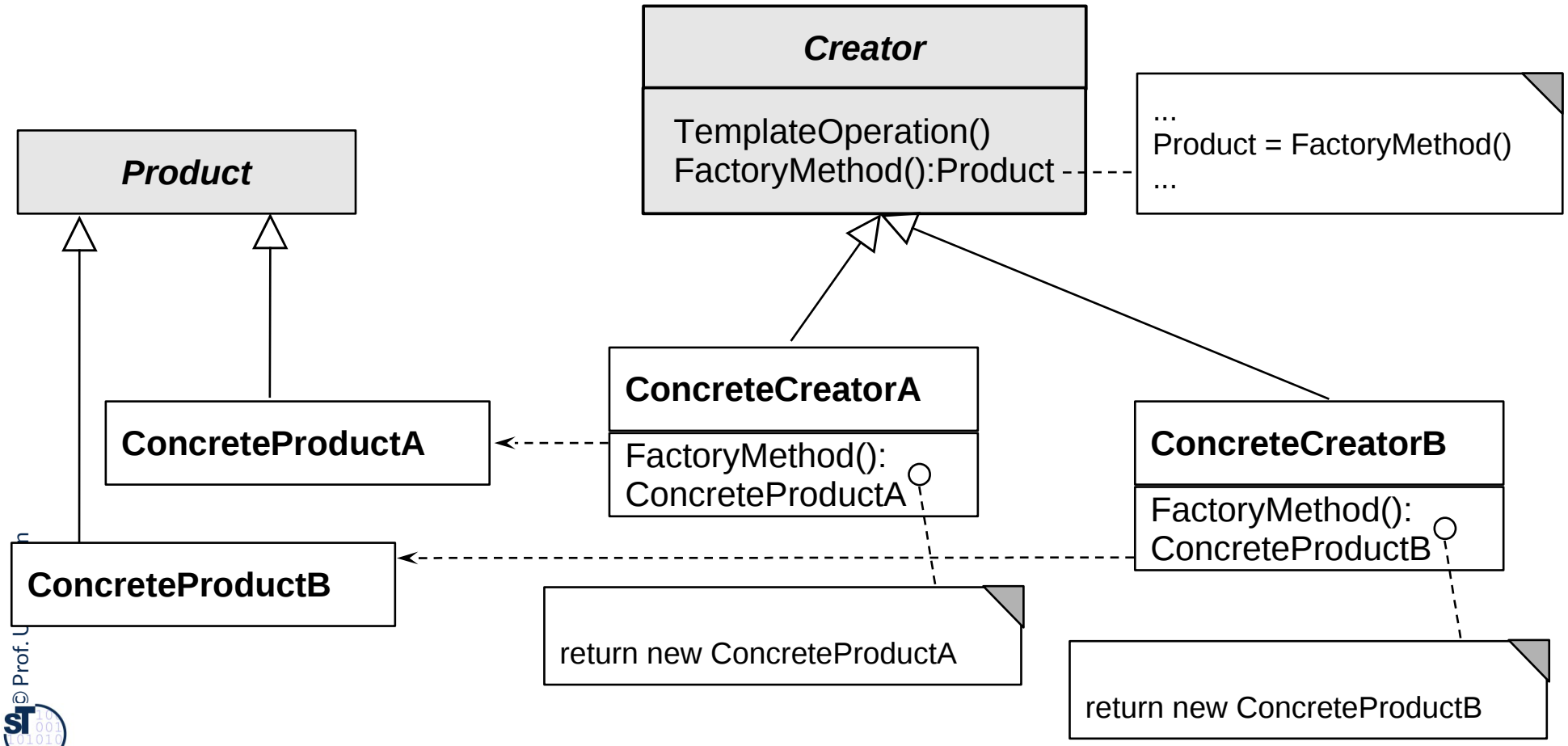
Variability with TemplateMethod

- **Binding the hook method(s)** means to
  - Derive a concrete subclass from the abstract superclass, providing their implementation
- **Controlled variability** by only allowing for binding hook methods, but not overriding template methods



24.1.2 FactoryMethod (Rpt.)

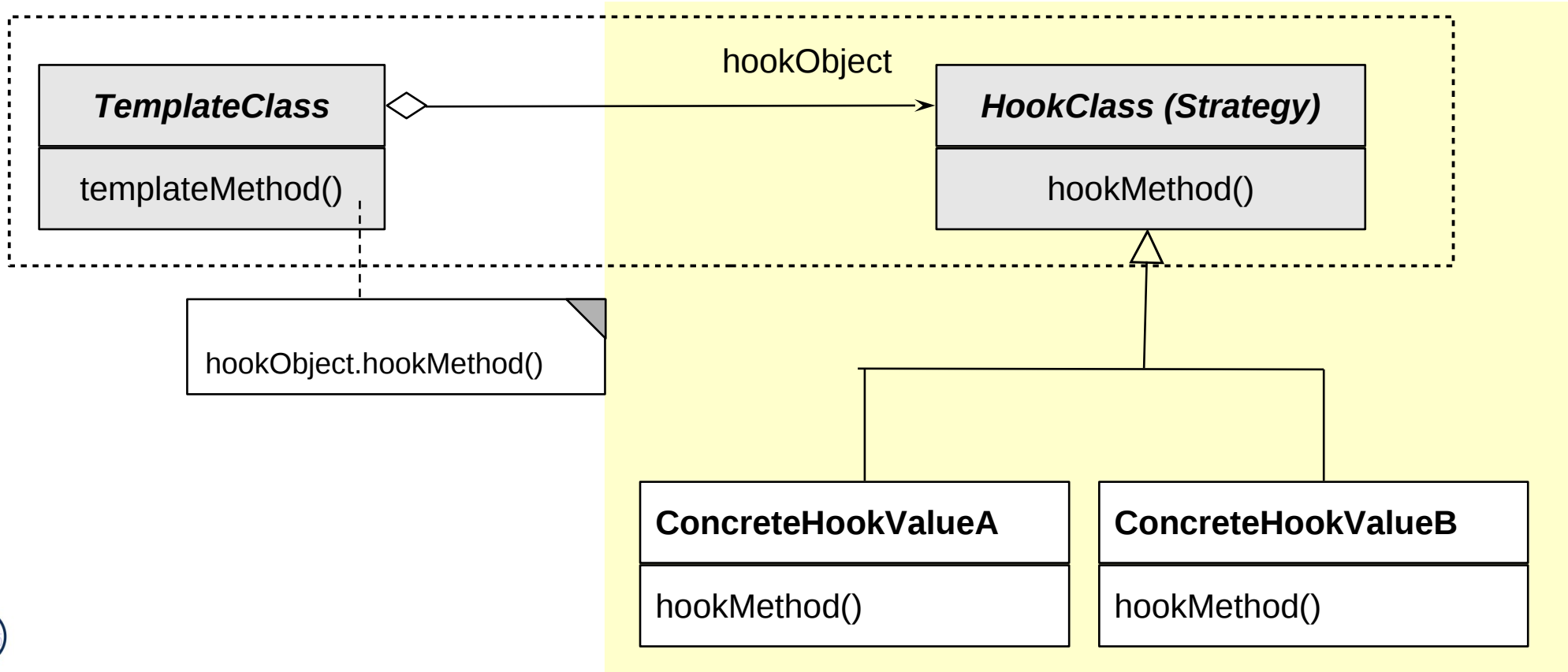
- FactoryMethod is a variant of TemplateMethod
- A FactoryMethod is a polymorphic constructor



24.1.3 Strategy (Template Class)

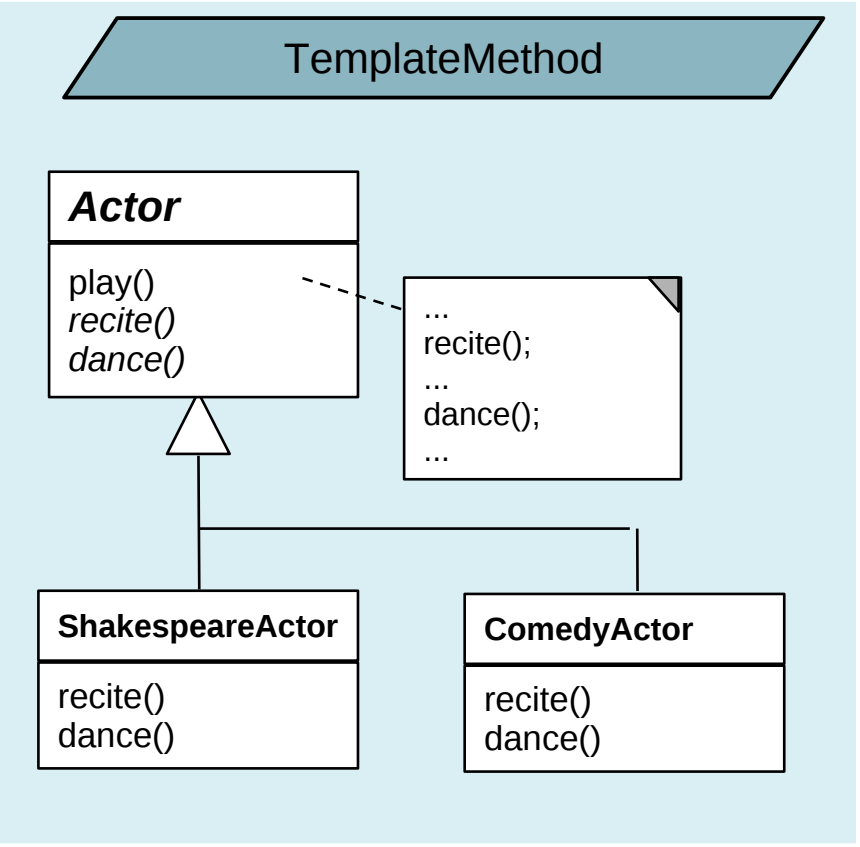
Strategy (also called Template Class)

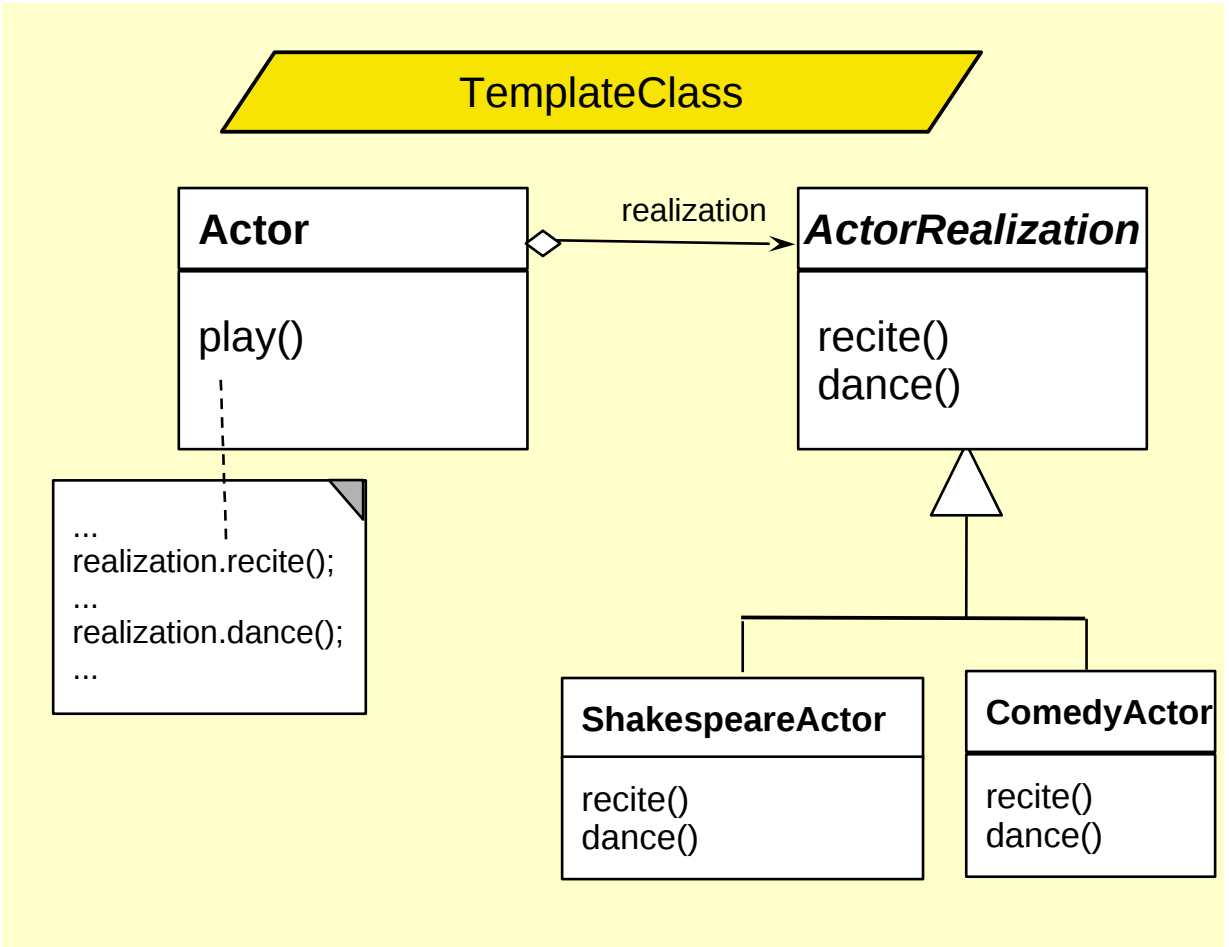
- The template method and the hook method are found in different classes
- Similar to TemplateMethod, but
  - Hook objects and their hook methods can be exchanged at run time
  - Exchanging several methods (a set of methods) at the same time
  - Consistent exchange of several parts of an algorithm, not only one method
- This pattern is basis of Bridge, Builder, Command, Iterator, Observer, Visitor.



Actors as Template Method

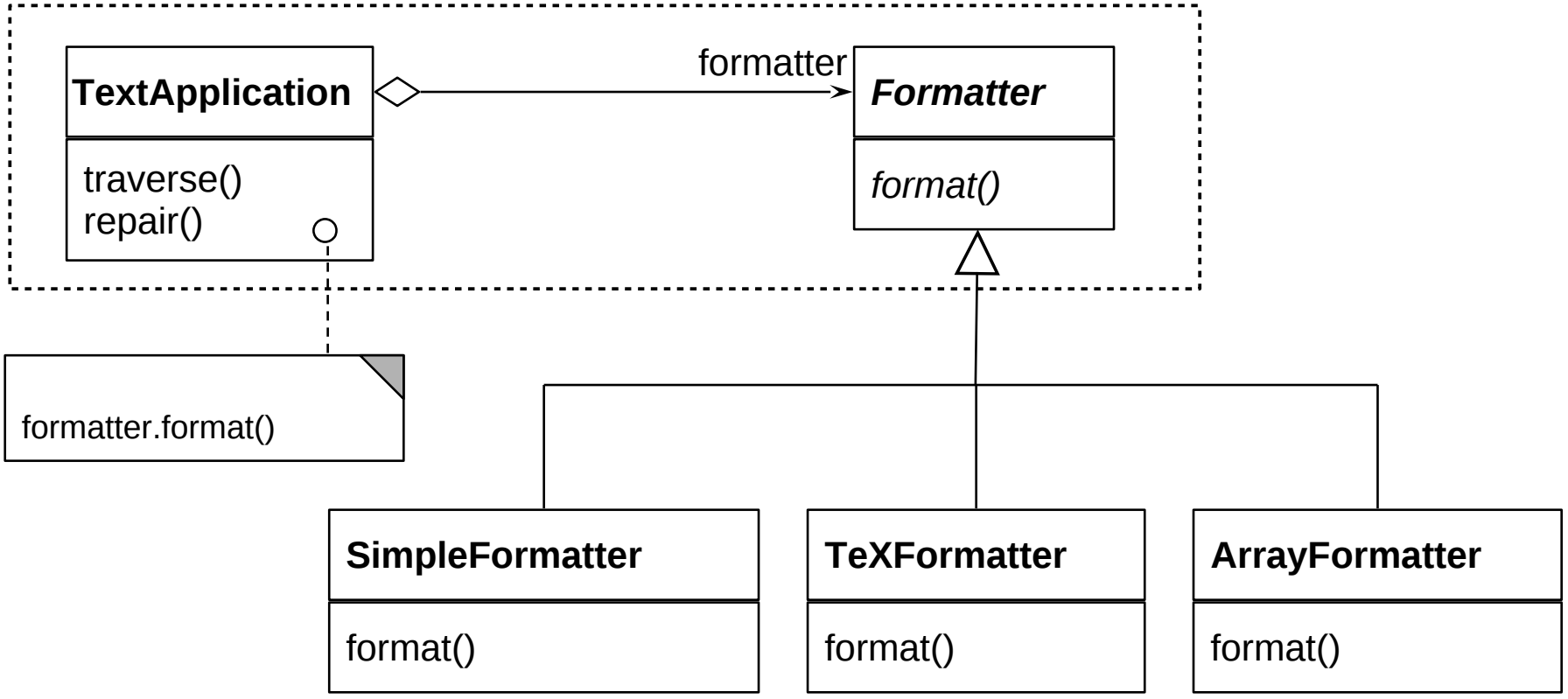
- TemplateMethod creates *one* run-time object; TemplateClass creates *two physical objects belonging to one logical object*





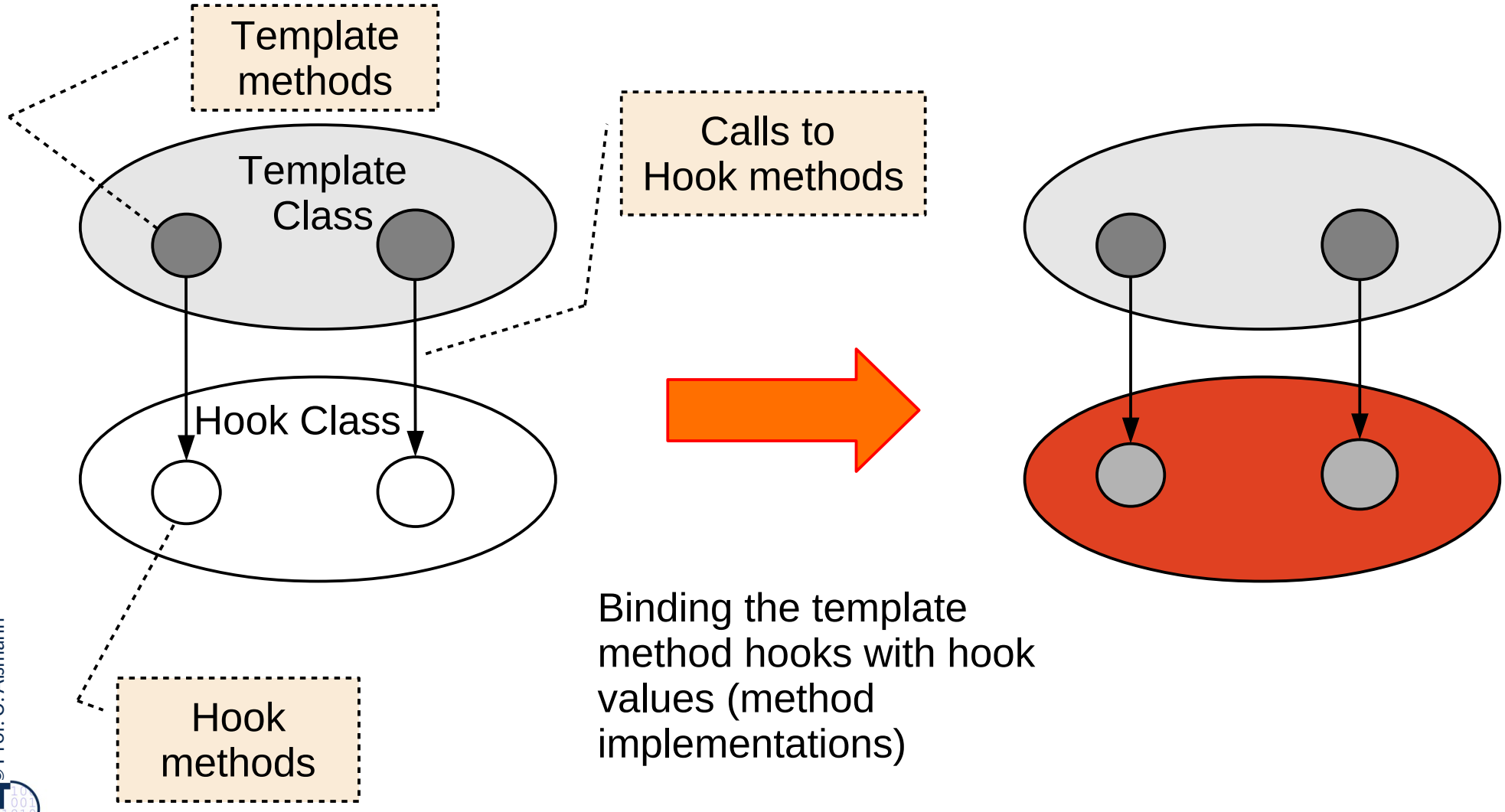
Example for Strategy

- Strategy represents an algorithms as object (but Command calls it `execute()`)
- Ex.: complex formatting algorithm
- Strategy objects are often subobjects of complex objects



Variability with Strategy

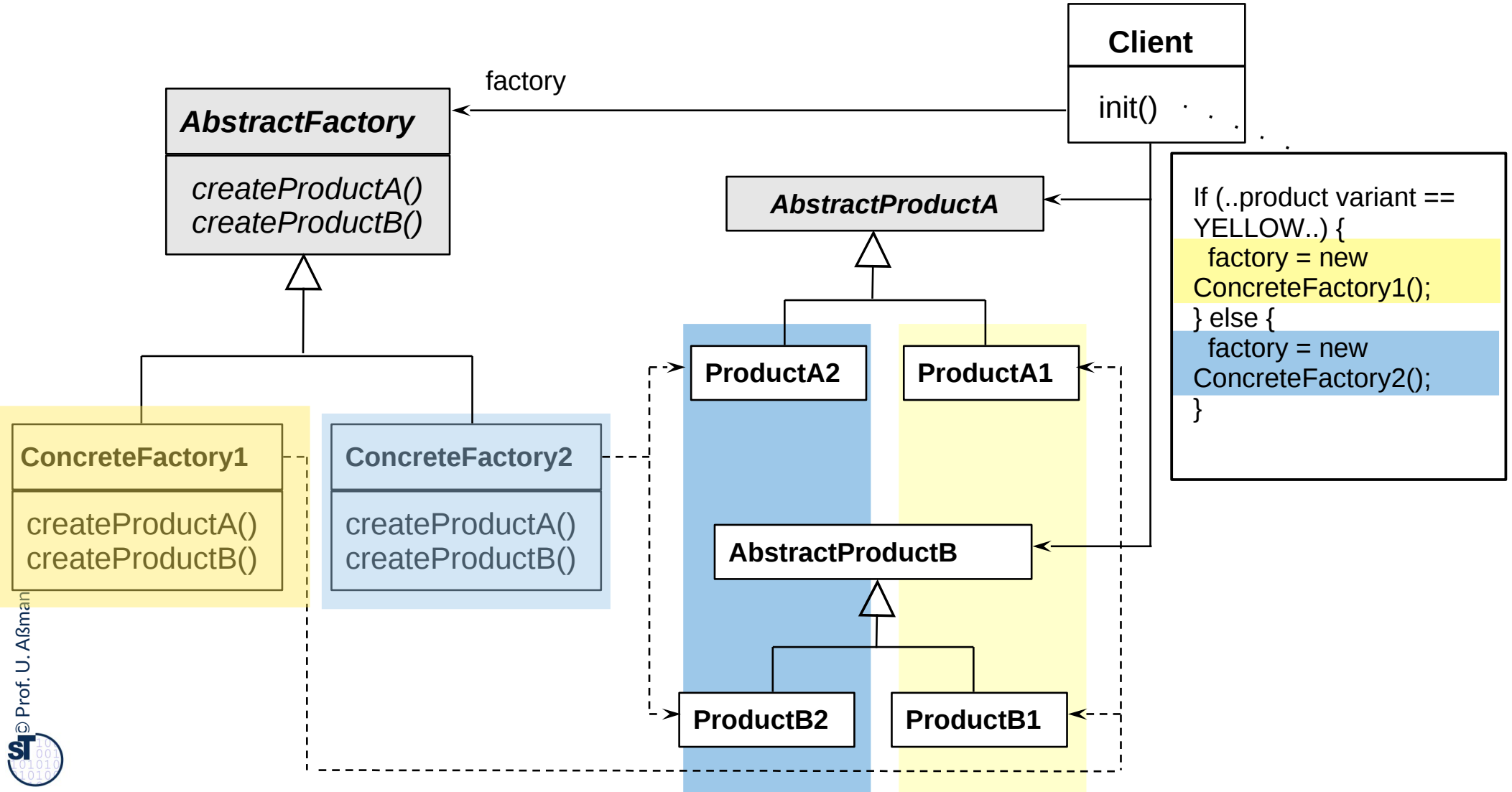
- Binding the hook class of a Strategy means to derive a concrete subclass from the **abstract hook superclass,** providing the implementation of the hook method



24.1.4. Factory Class

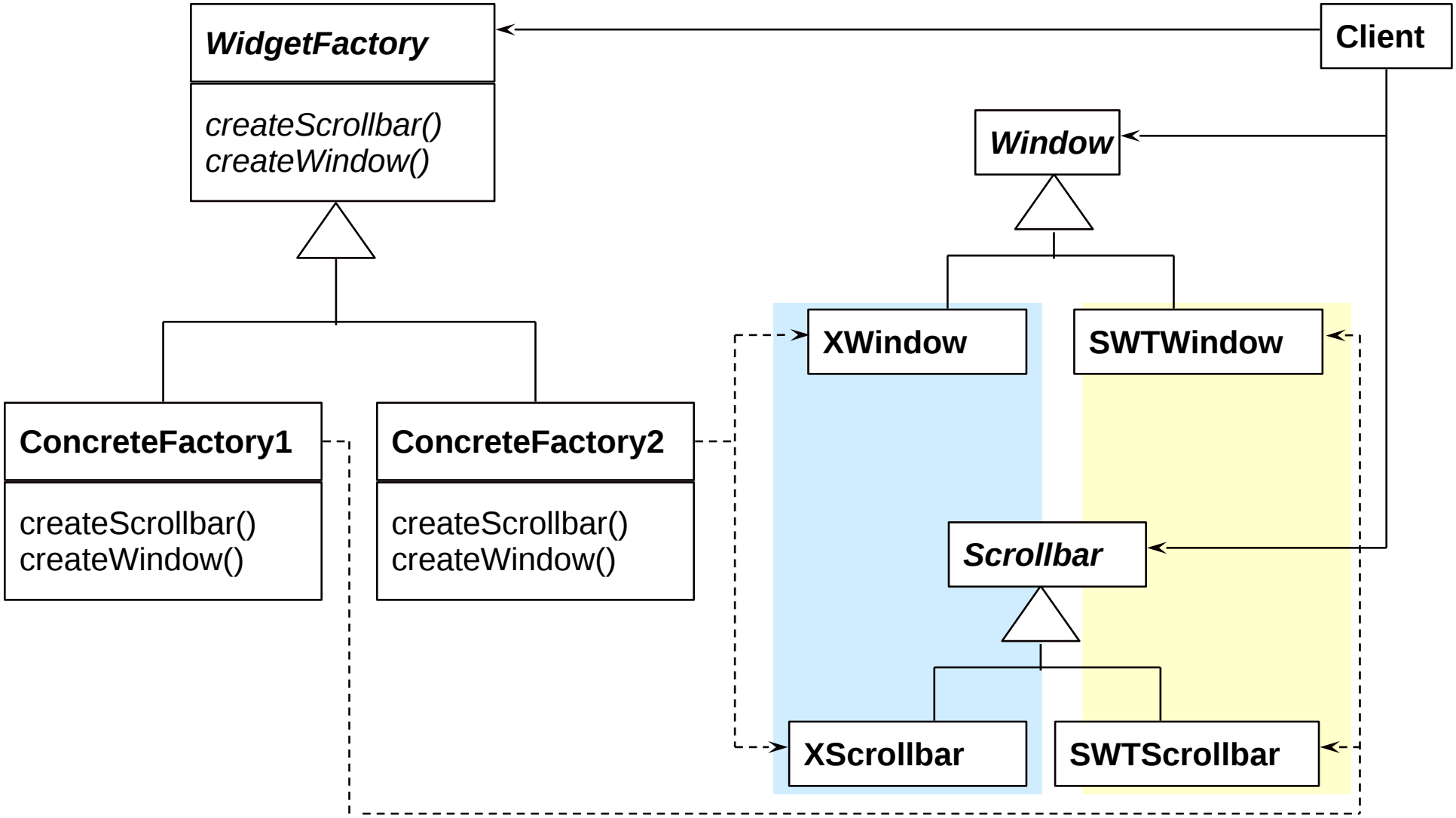
24.1.4 Factory Class (Abstract Factory)

- Allocate a family of products {Ai, Bi, ..} in different "flavors" or "colors" {1, 2, ..}
- Vary consistently by exchange of factory and object families



Example for Factory Class

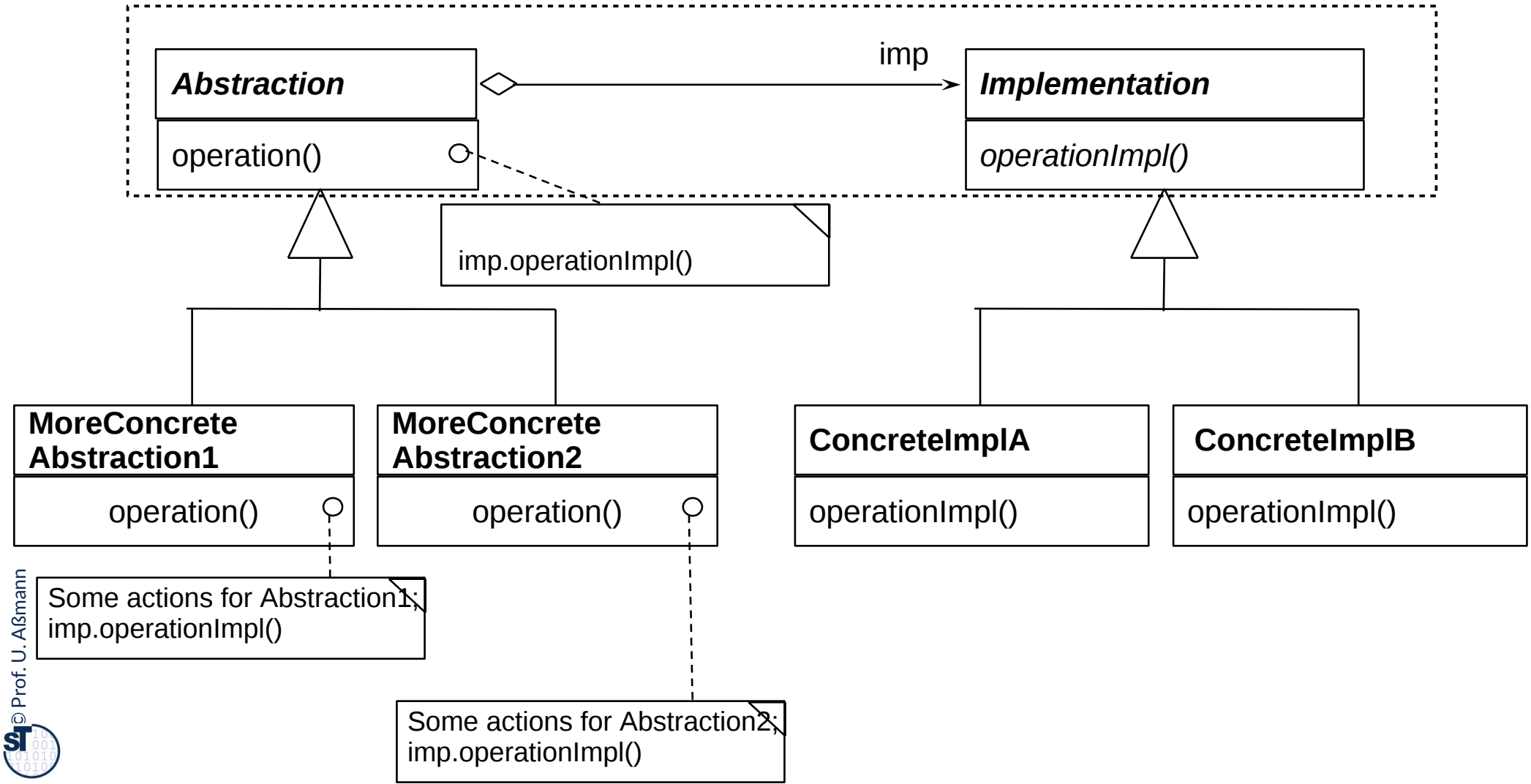
- Consistently varying a family of widgets



24.1.5 Bridge (Dimensional Class Hierarchies)

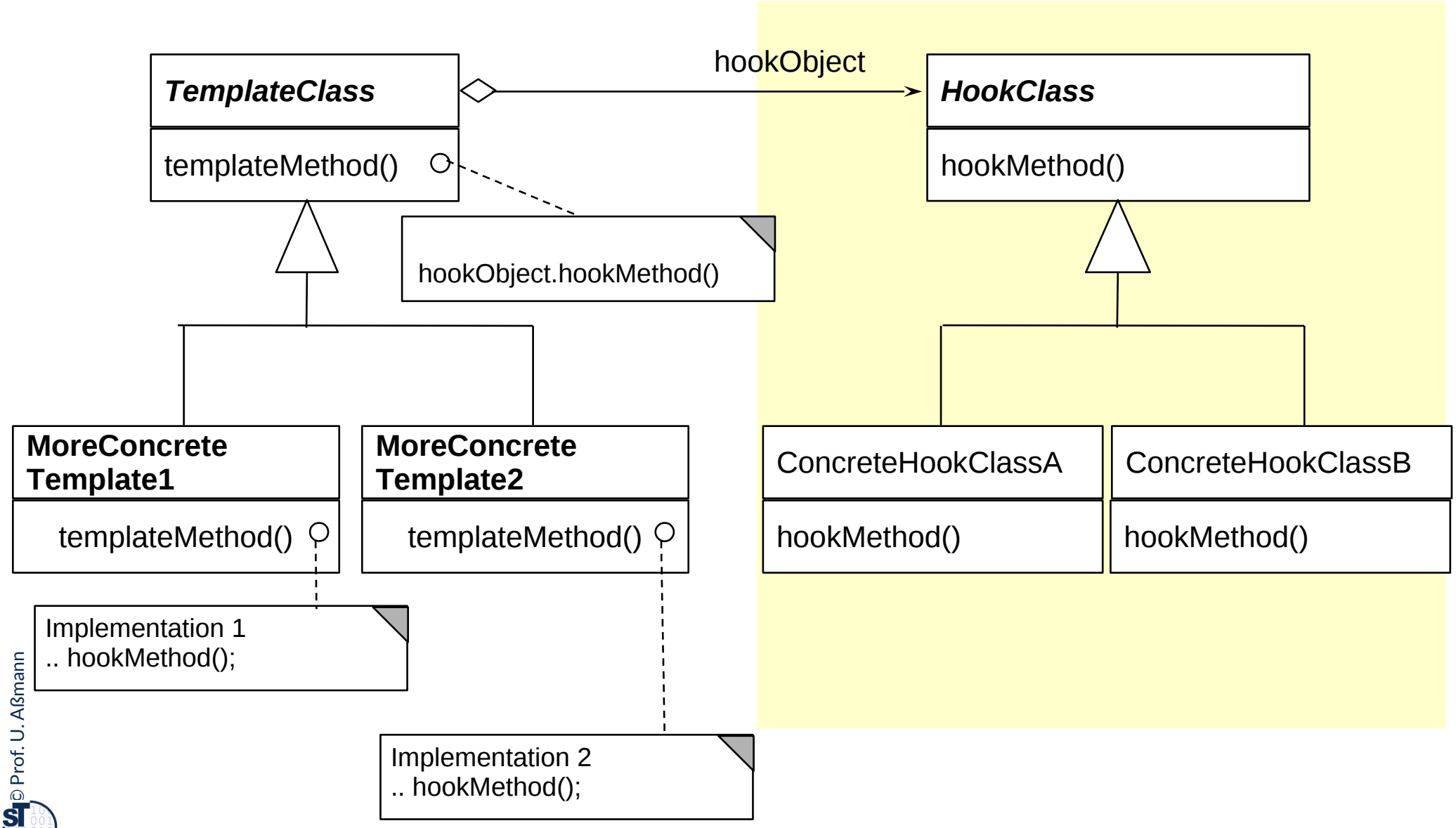
Bridge for Complex Objects (GOF-Version)

- A **Bridge** represents a *complex object* with two layers
- The left hierarchy (upper layer) is called *abstraction hierarchy*, the right hierarchy (lower layer) is called *implementation*

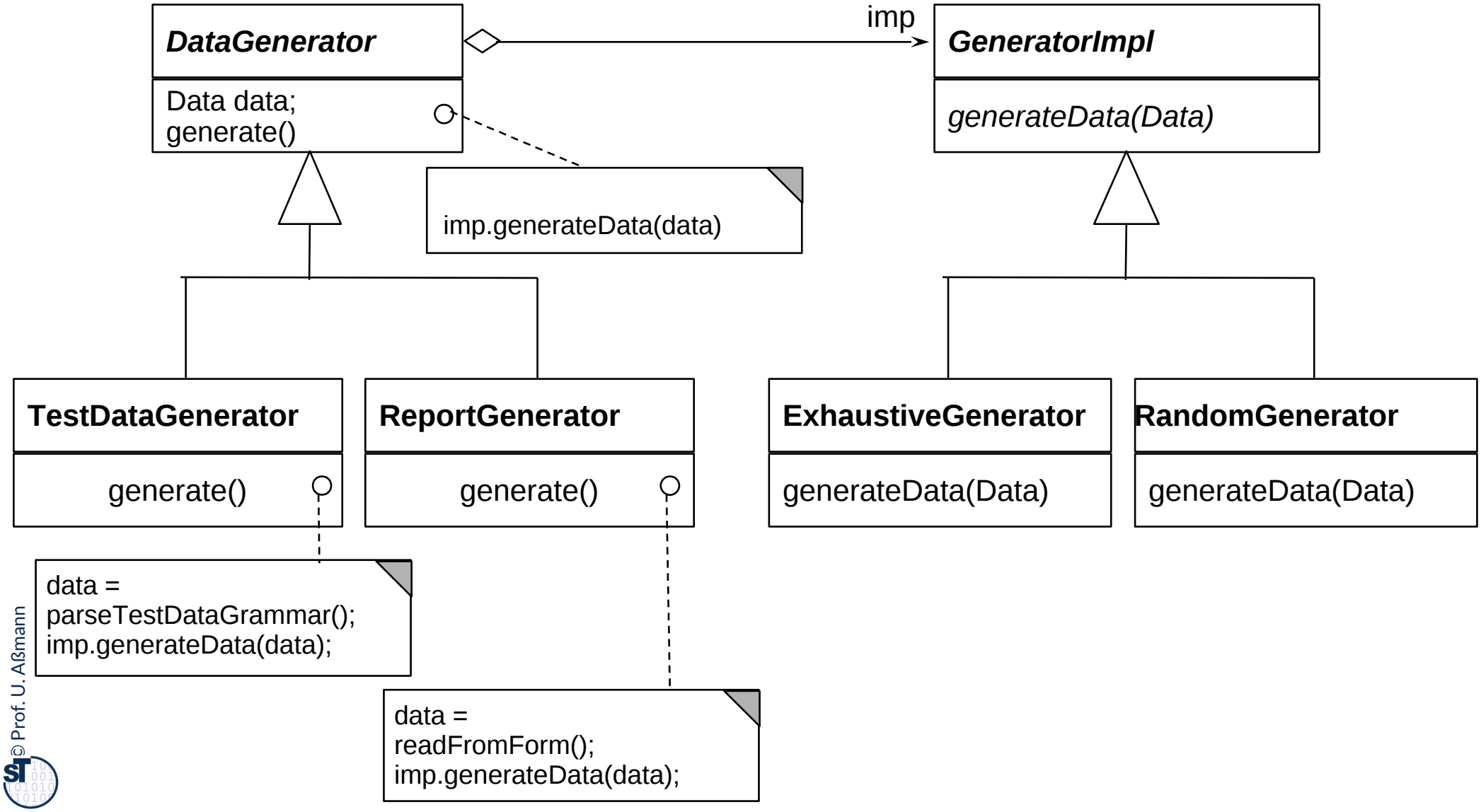


Bridge as Dimensional Class Hierarchies

- Bridge is an extension of TemplateClass

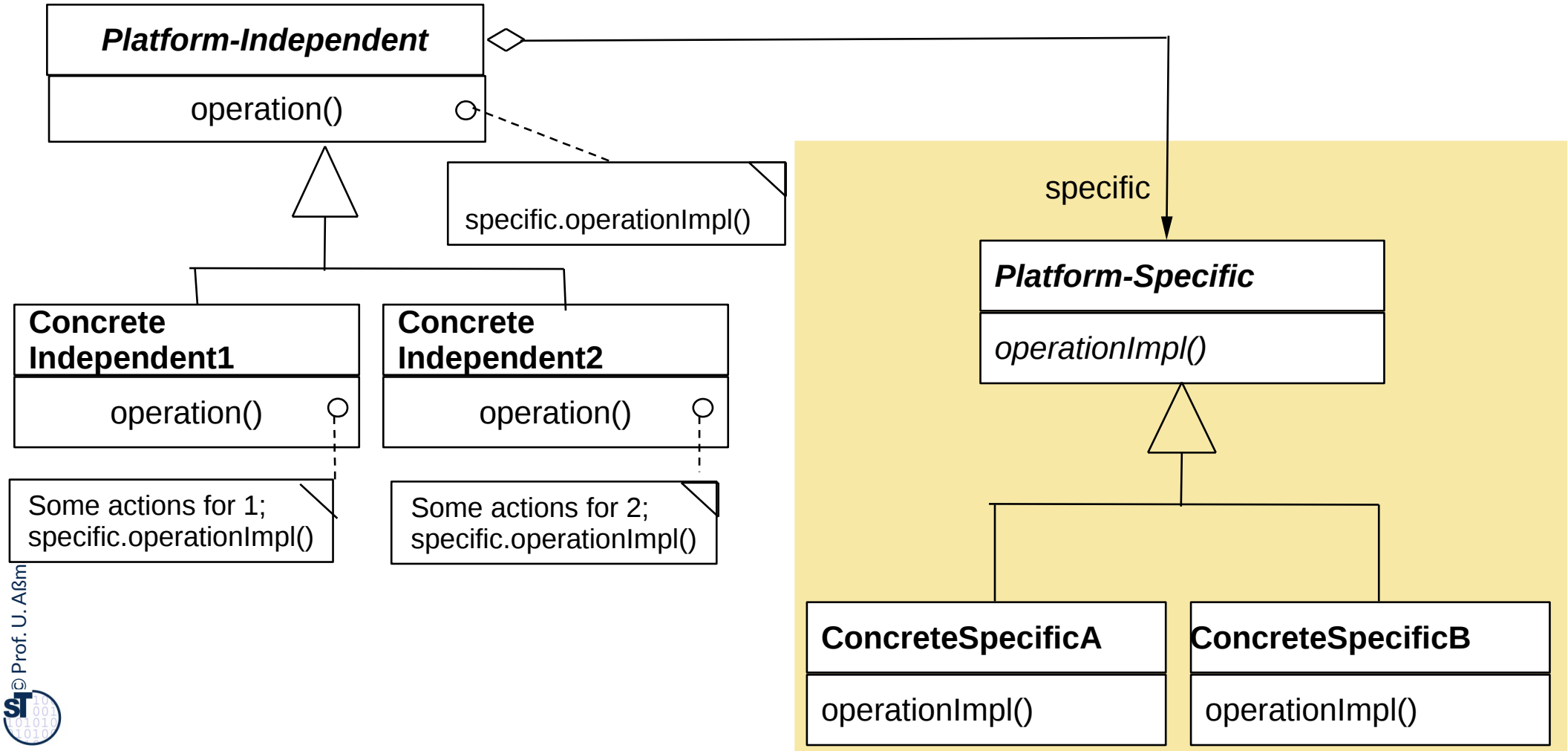


Ex. Complex Object *DataGenerator* as Bridge



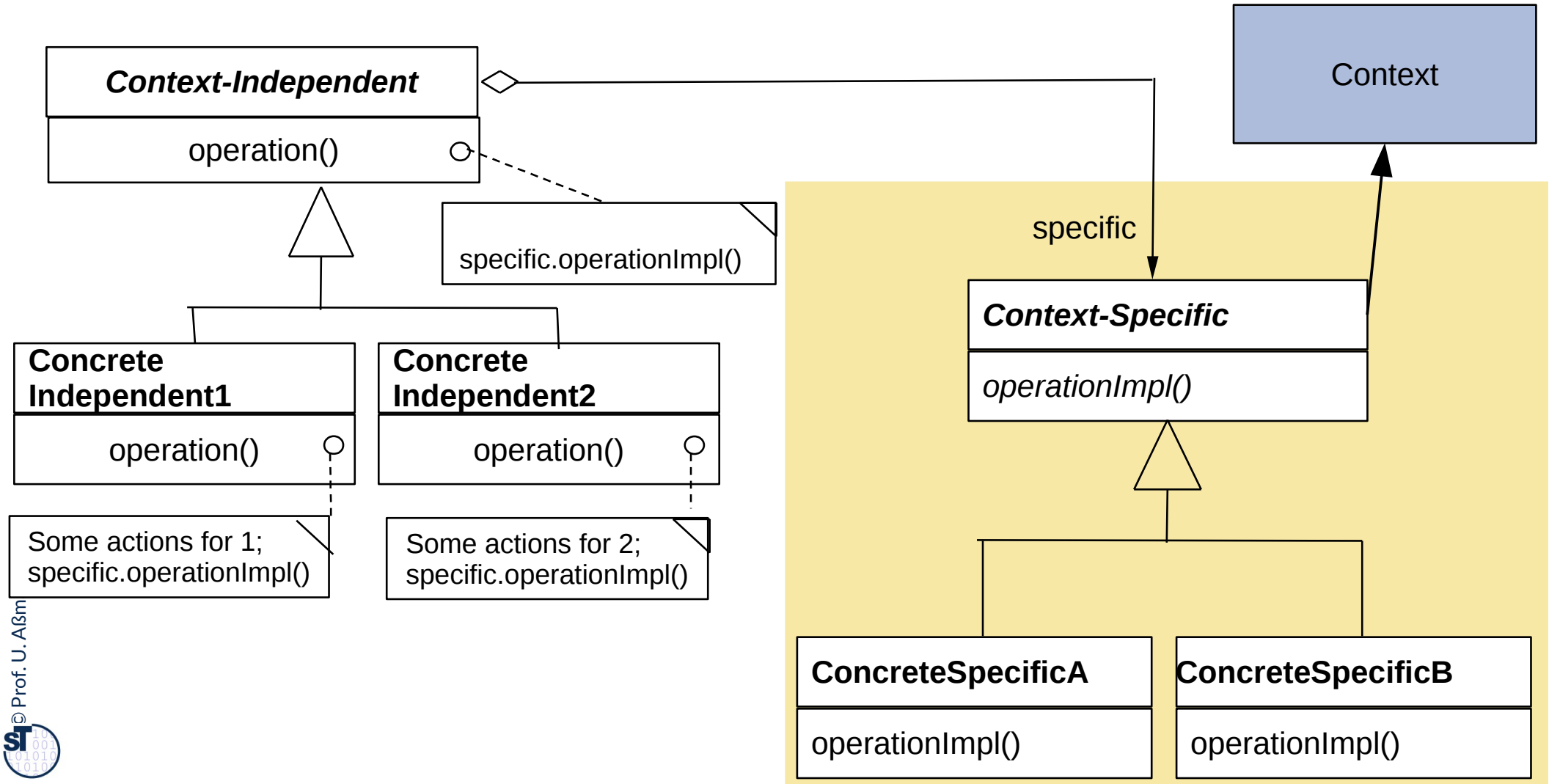
Use of Bridge for Separation of Platform-Independent from Platform-Dependent Code

- Bridge can be used to implement an object with *platform-independent (left/upper hierarchy)* and platform-specific part (lower/right hierarchy)
- For every type of platform, there must be one Bridge



Use of Bridge for Separation of Context-Independent from Context-Dependent Code

- Bridge can be used to implement an object with *context-independent (left/upper hierarchy)* and context-specific part (lower/right hierarchy)
- For every type of context, there must be one Bridge



24.2) Patterns for Extensibility

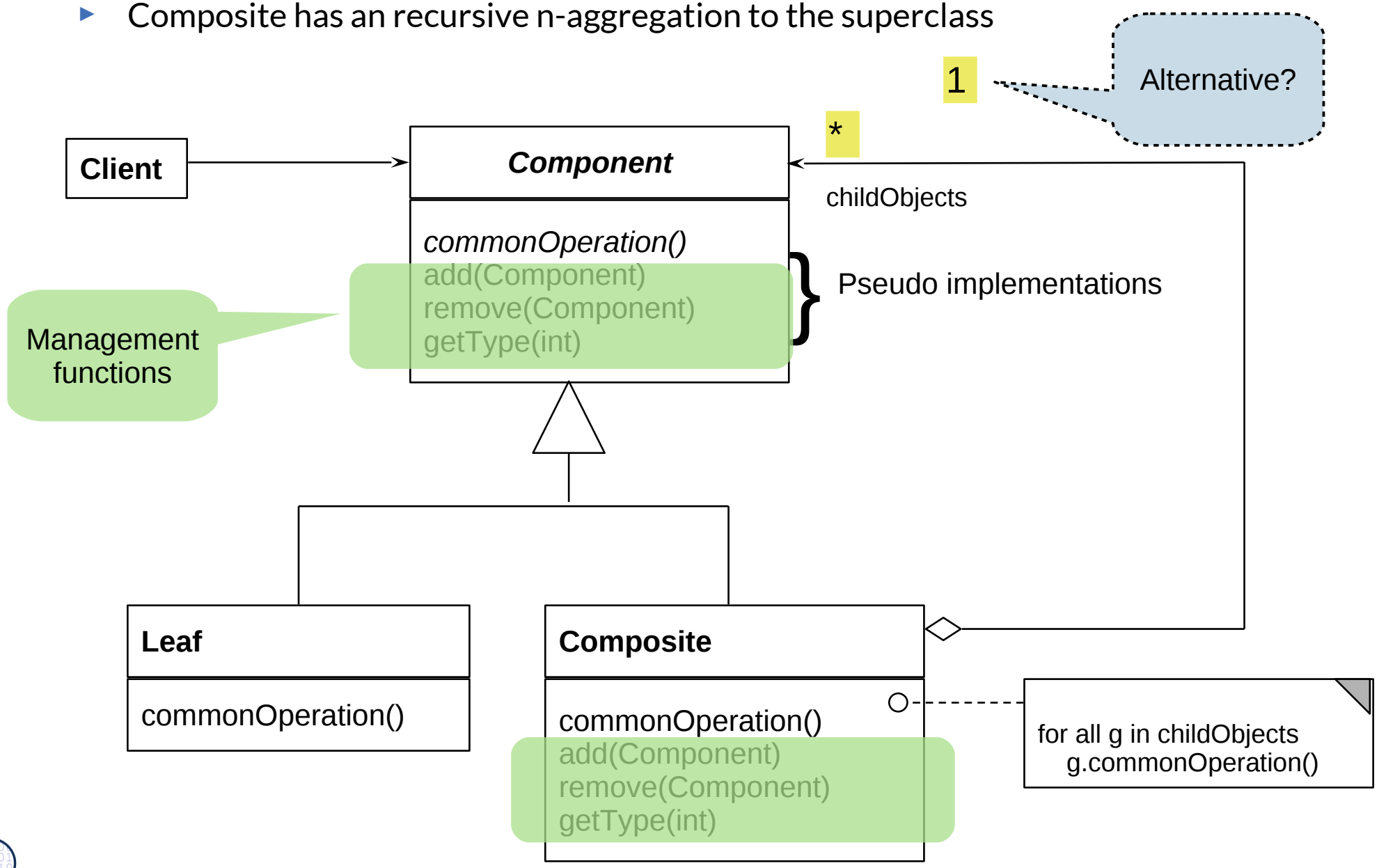
Extensibility patterns describe how to build

plug-ins (complements, extensions) to frameworks

Extensibility Pattern	# Run-time objects	Key feature
Composite	*	Whole/Part hierarchy
Decorator	*	List of skins
Callback	2	Dynamic call
Observer	1+*	Dynamic multi-call
Visitor	2	Extensible algorithms on a data structure
EventBus, Channel	*	Complex dynamic communication infrastructure (Appendix)

24.2.1 Structure Composite (Rpt.)

- Composite has an recursive n-aggregation to the superclass

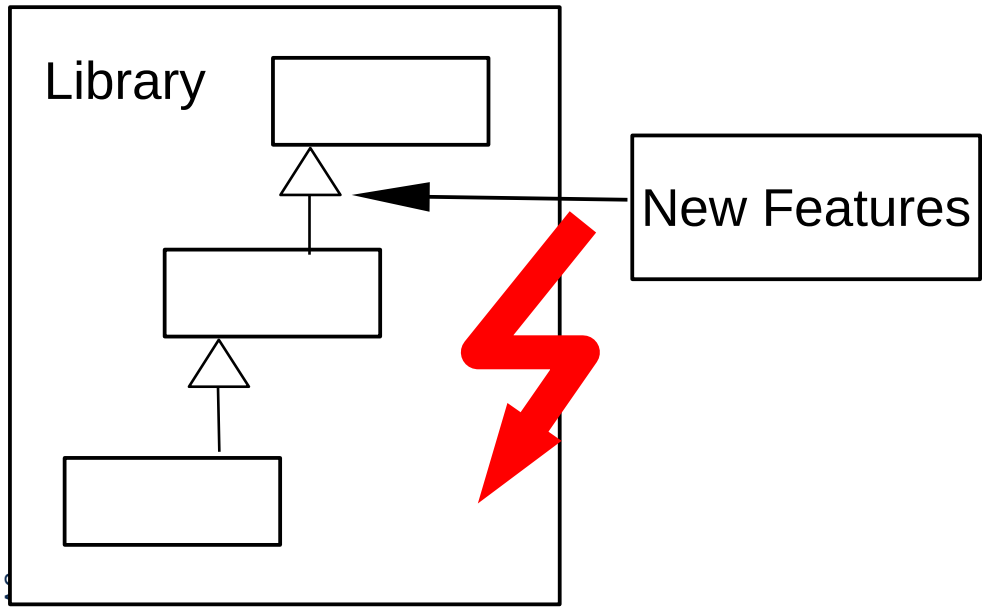


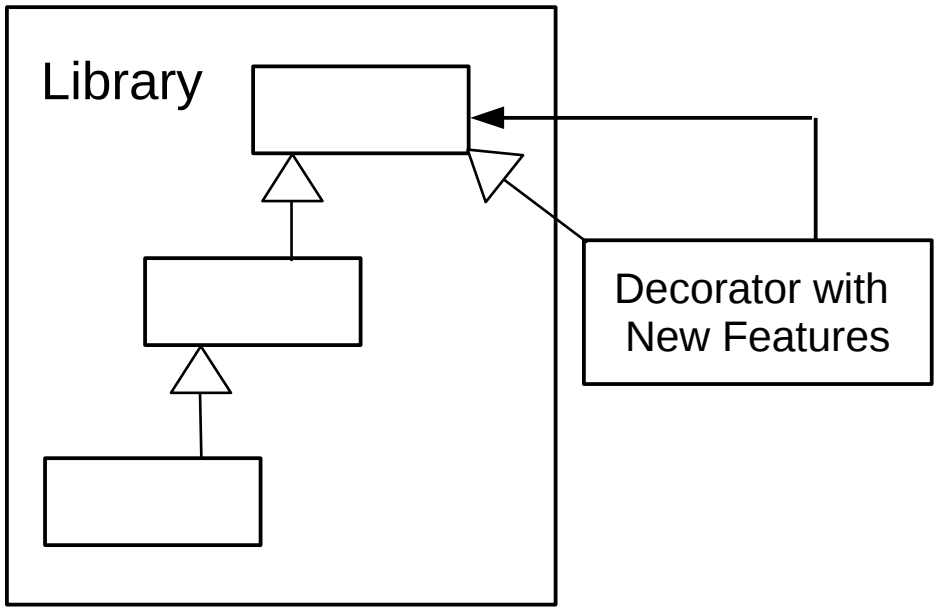
24.2.2. Decorator

- The “sibling” of Composite

Problem

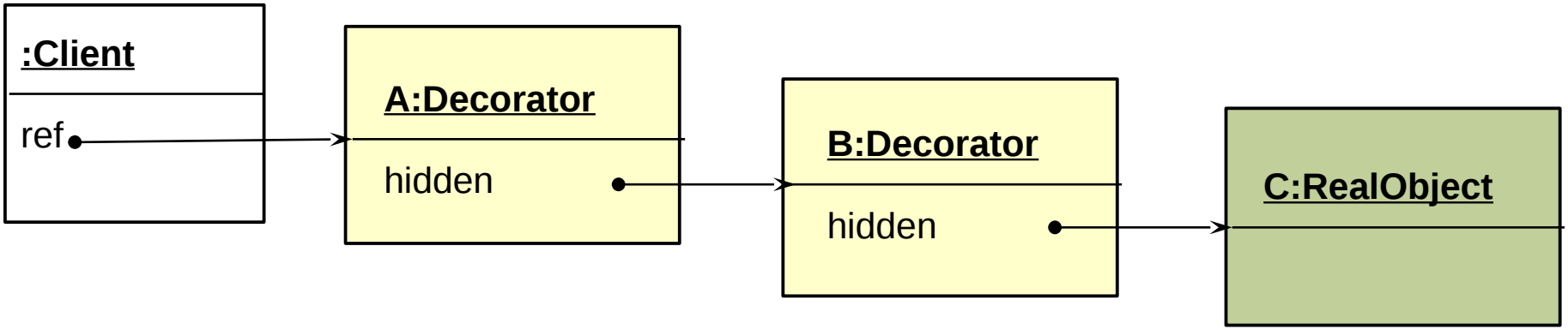
- How to extend an inheritance hierarchy of a library that was bought in binary form?
- How to avoid that an inheritance hierarchy becomes too deep?





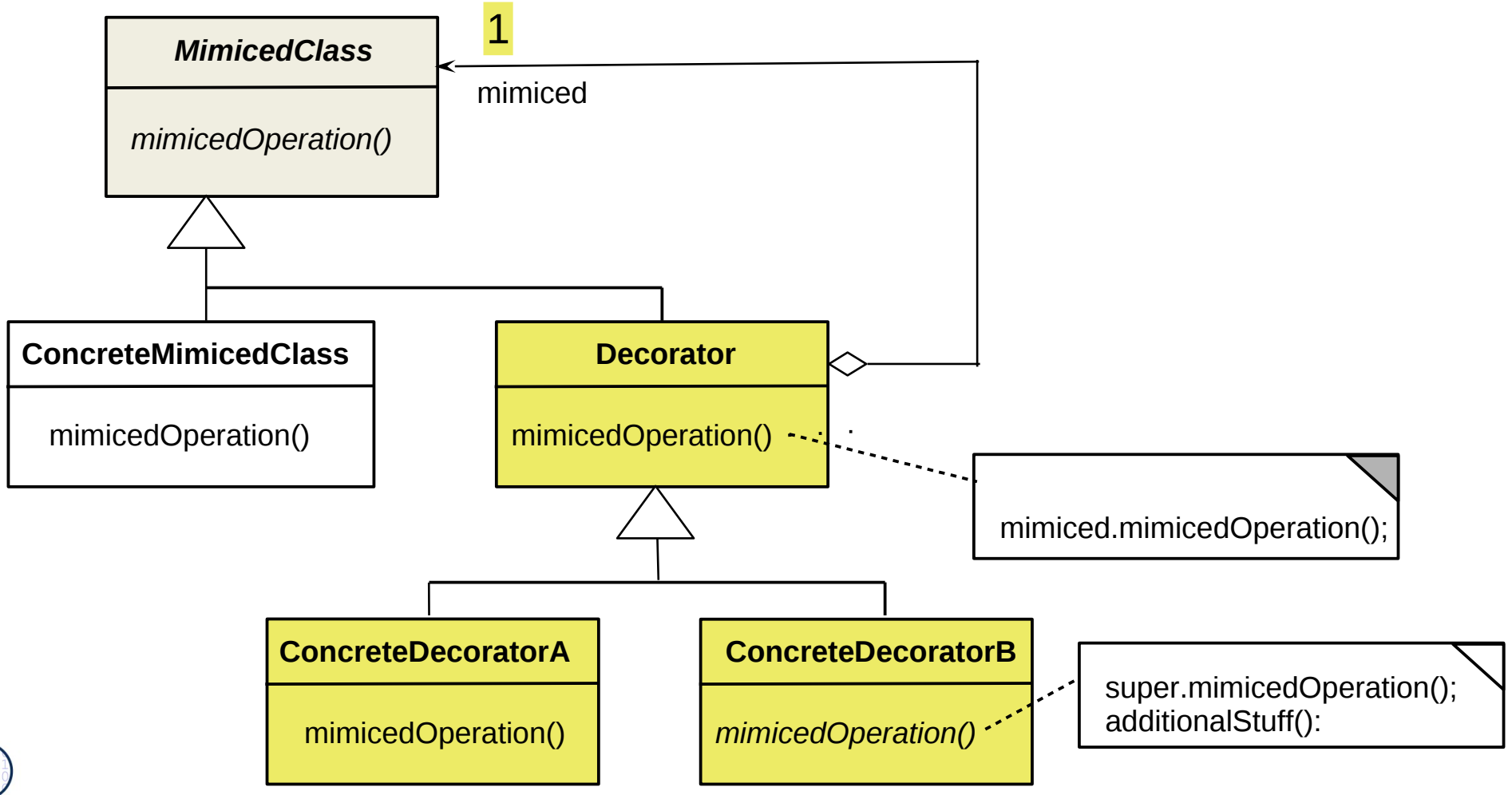
Snapshot of Decorator Pattern

- A Decorator object is a *skin* of another object
- The Decorator class *mimics* a class

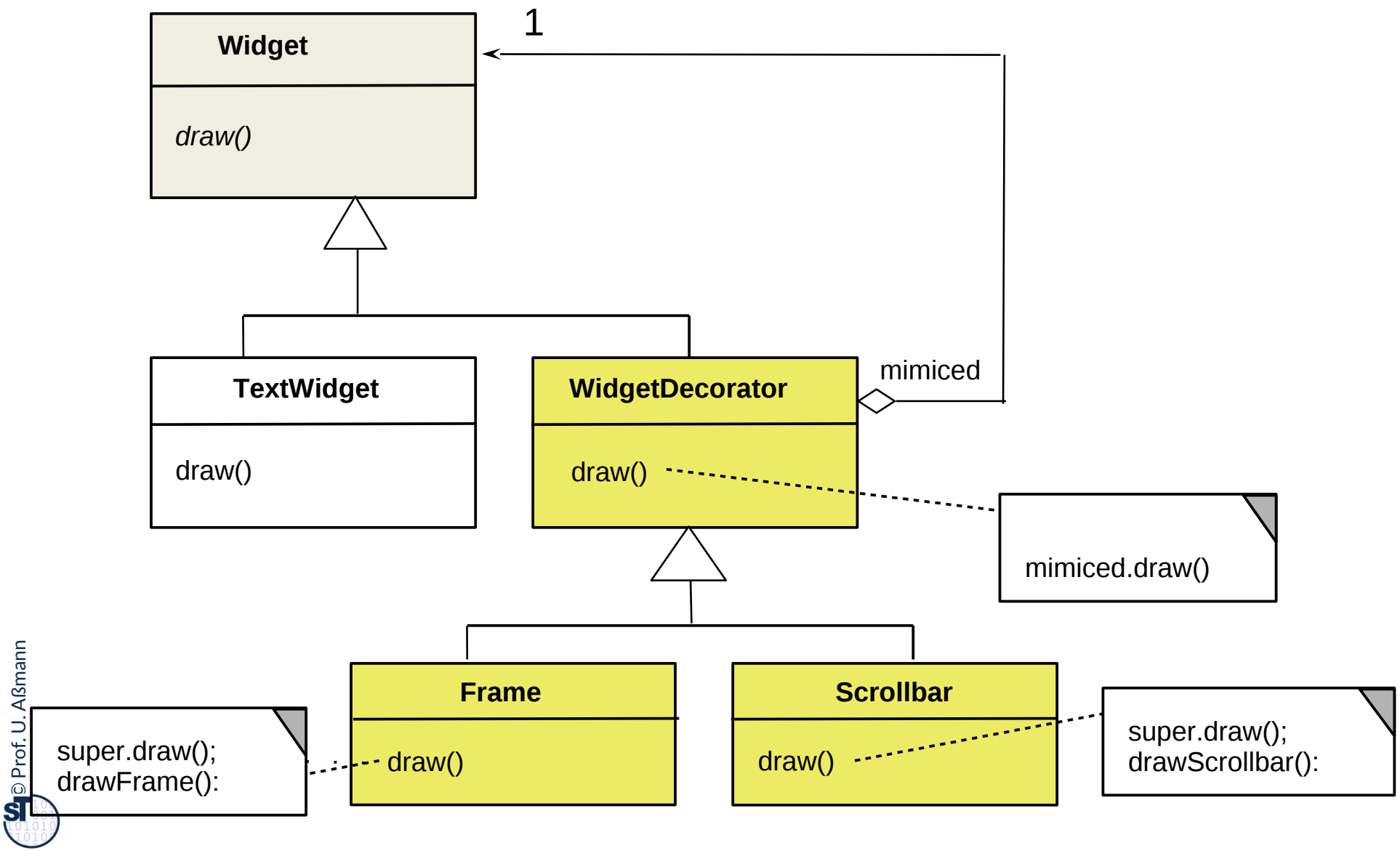


Decorator – Structure Diagram

- It is a restricted Composite with a 1-aggregation to the superclass
  - 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

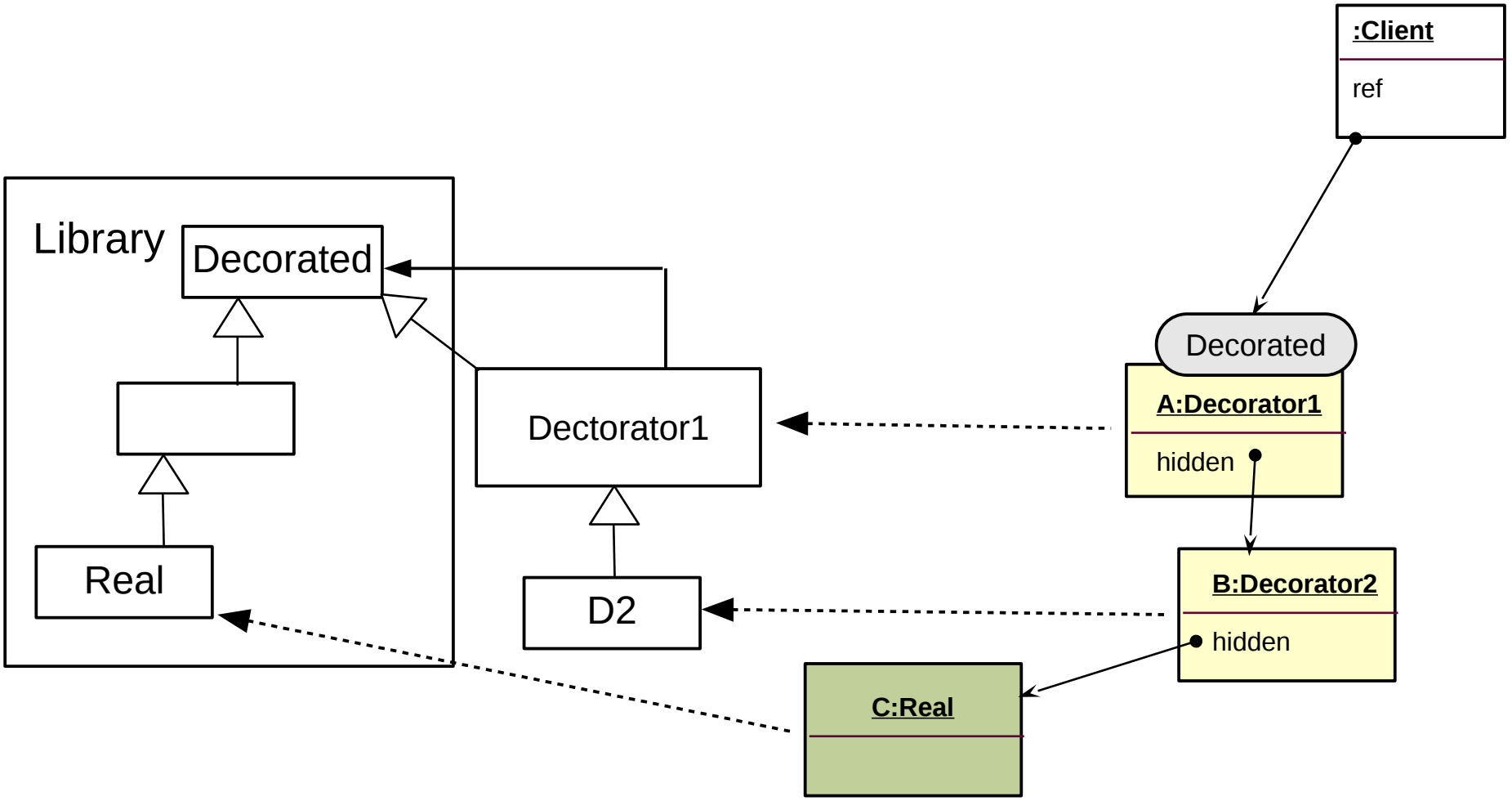


Ex.: Decorator for Widgets



Purpose Decorator

- For dynamically extensible objects (i.e., decoratable objects)
  - Addition to the decorator chain or removal possible
- For complex objects

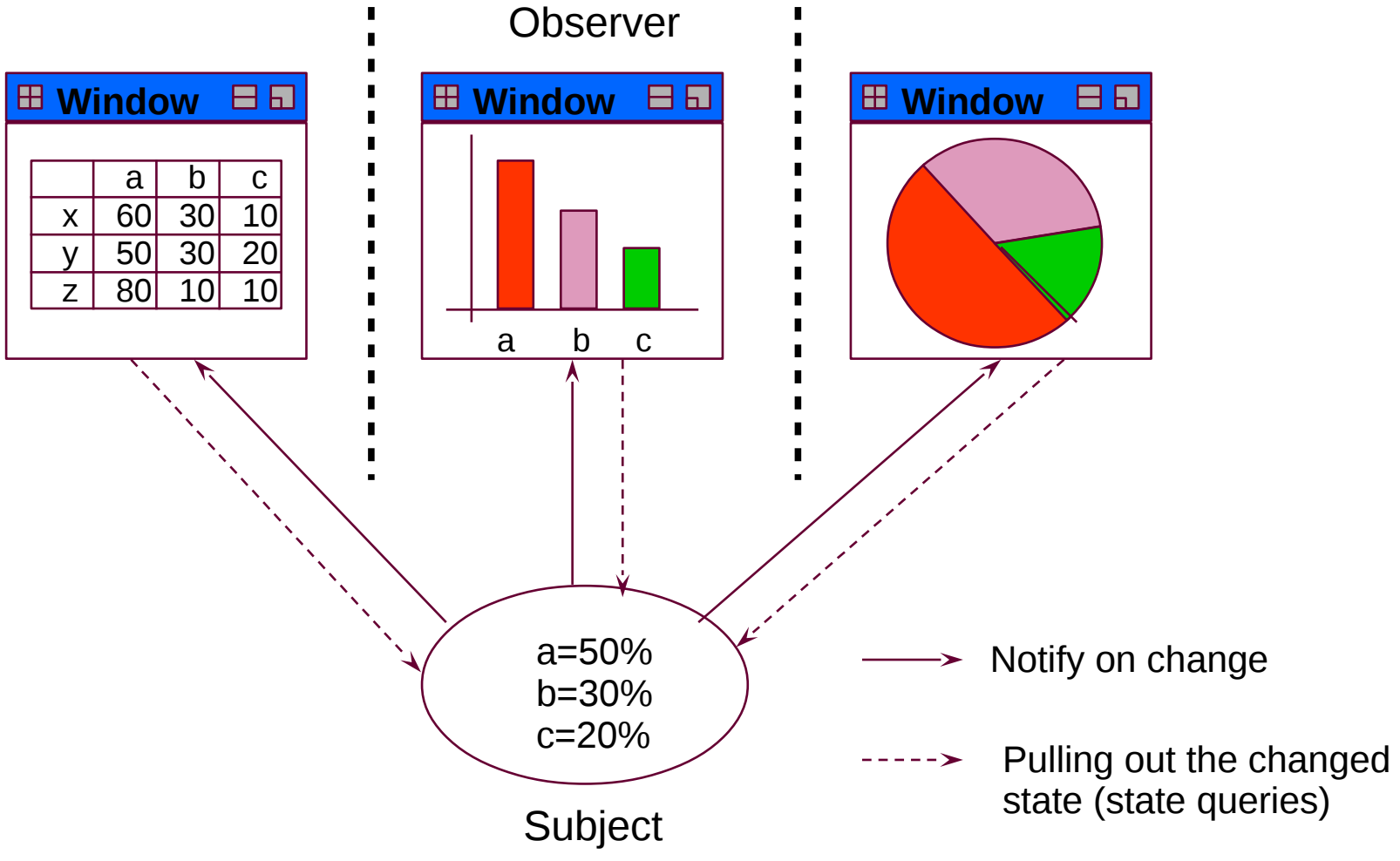


24.2.3 Different Kinds of Publish/Subscribe Patterns – (Event Bridge)

- Publish/Subscribe patterns are for dynamic, event-based communication in synchronous or asynchronous scenarios
- Subscribe functions build up dynamic communication nets
- Callback
- Observer
- EventBus

Publish/Subscribe Patterns

- Distinguish: Subscription of Observers to Subjects // Notification of event // Source of event (subject) // Data to be transfered // Relation of Subject and Observer
- Therefore, Observer exists in several variants (push, pull, CallBack, EventBus, ChannelBus)



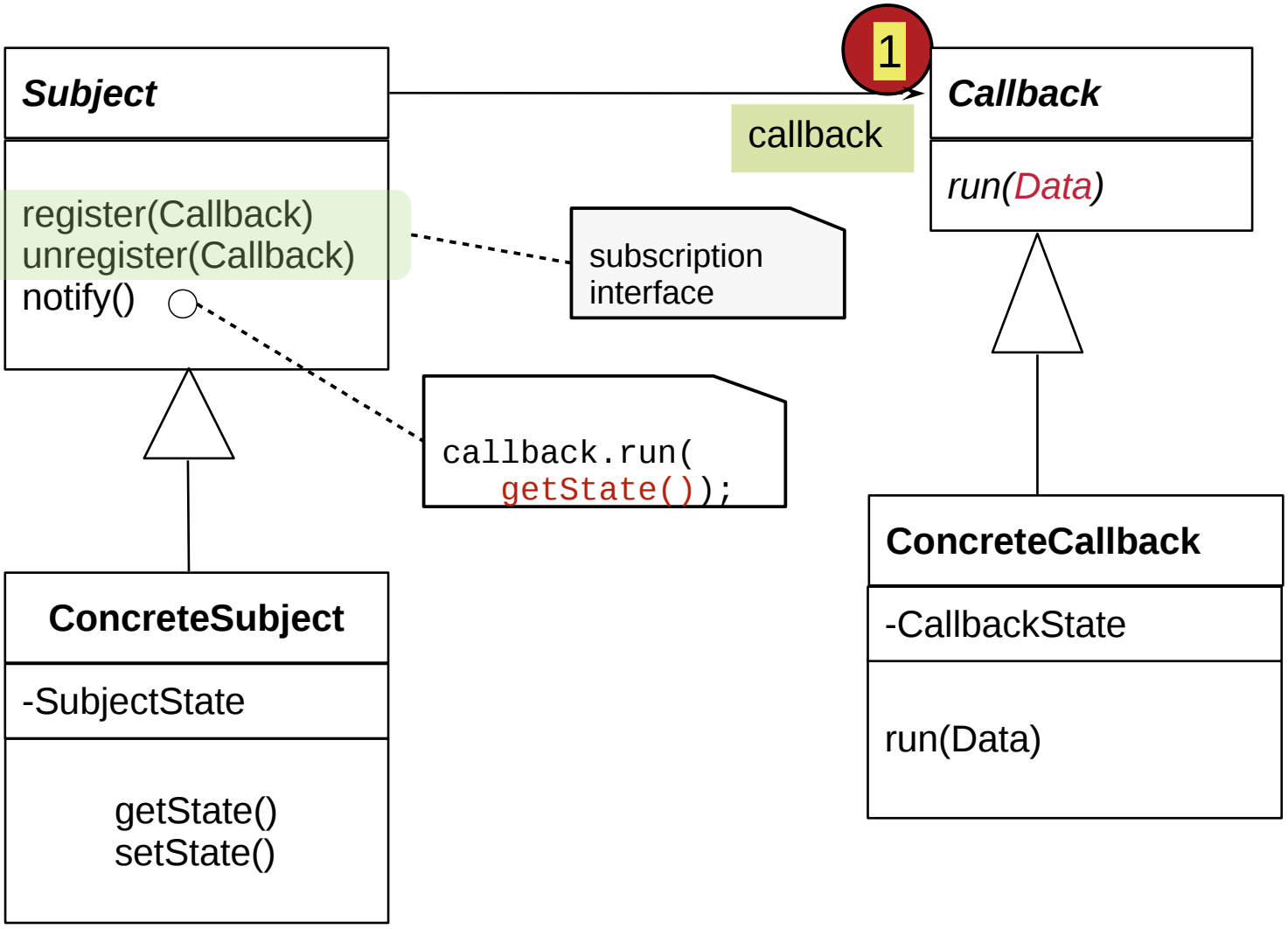
Overview

Push		Data is flowing with the call to “update”
	Callback	1 observer
	Observer	n observer
Pull		Data is pulled on demand
	Callback	1 observer
	Observer	n observer

- A **callback** is a variant of the observer pattern with **one** observer

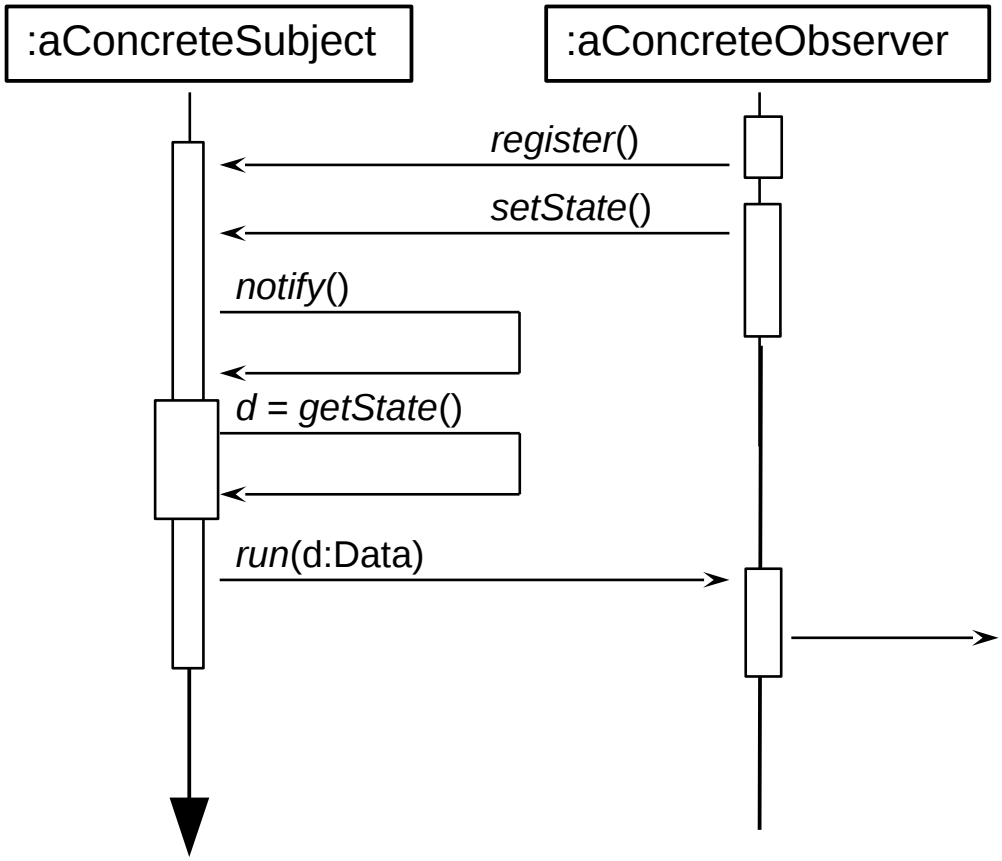
24.2.3.1 Publish/Subscribe with 1 Observer: Callback

- **Callbacks** have only one observer. It is not known statically, but registered dynamically, at run time
- A (**push-)Callback** pushes its data with the call to `run`



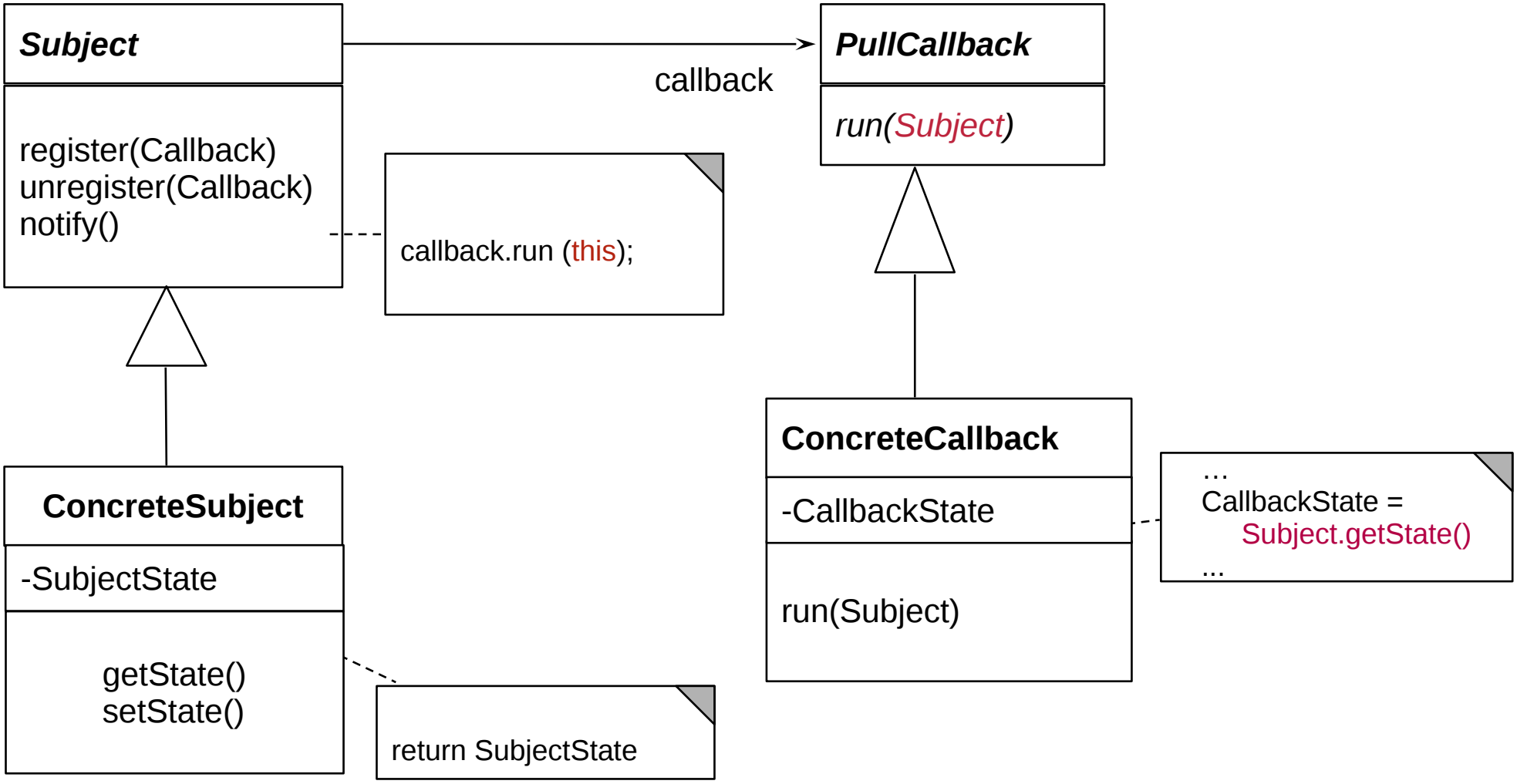
Sequence Diagram push-Callback

- run() directly transfers Data to Observer (push)



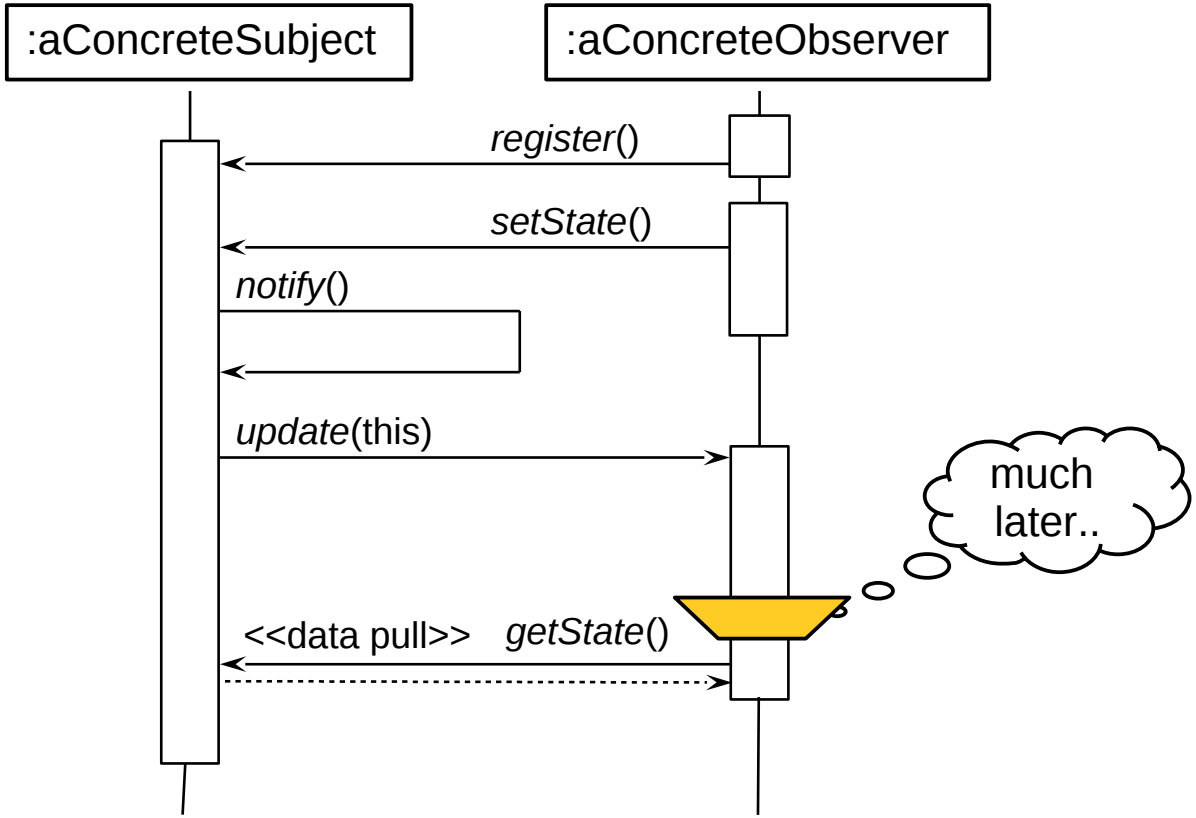
24.2.3.2 Structure pull-Callback

- A **pull-Callback** must push the Subject to later pull the data
- Responsibility for pull lies with the Callback; Subject is passed as argument



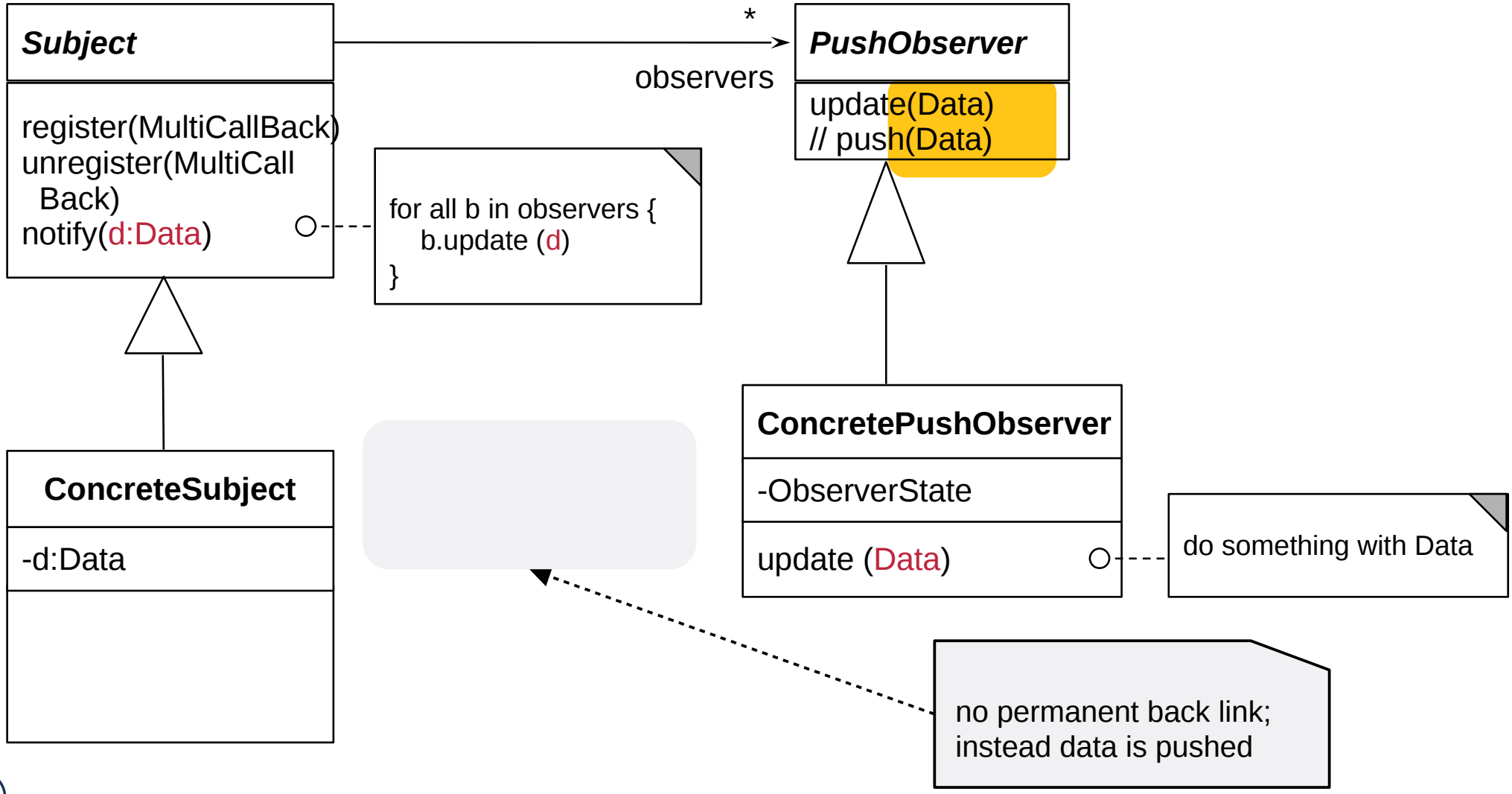
Sequence Diagram pull-Callback

- Update() does not transfer data, only an event (anonymous communication possible)
  - Observer pulls data out itself with getState()
  - Lazy processing (on-demand processing)



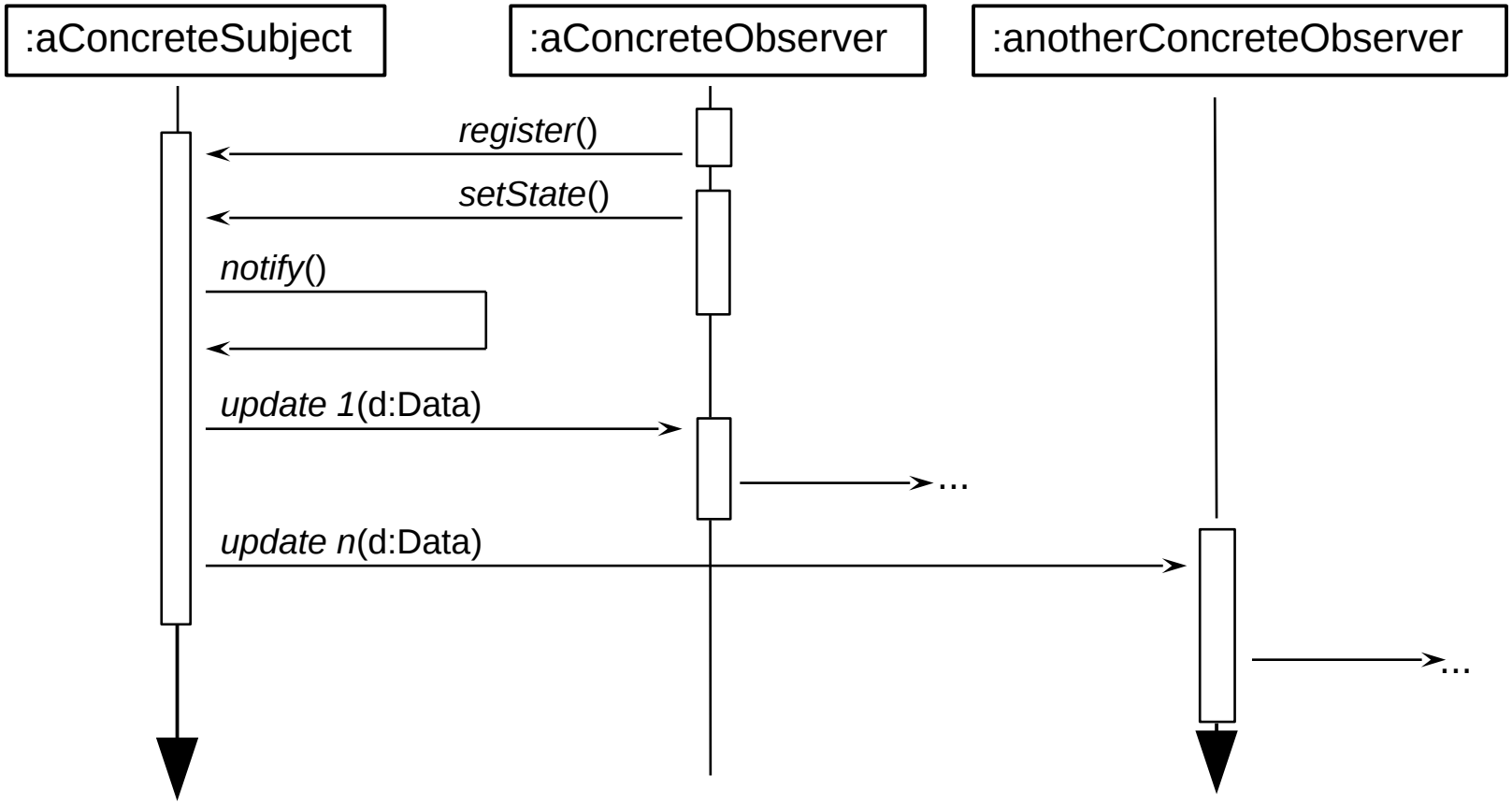
24.2.3.3 Structure push-Observer

- Subject pushes data with `update(Data)`
- Pushing resembles *Sink*, if data is pushed iteratively



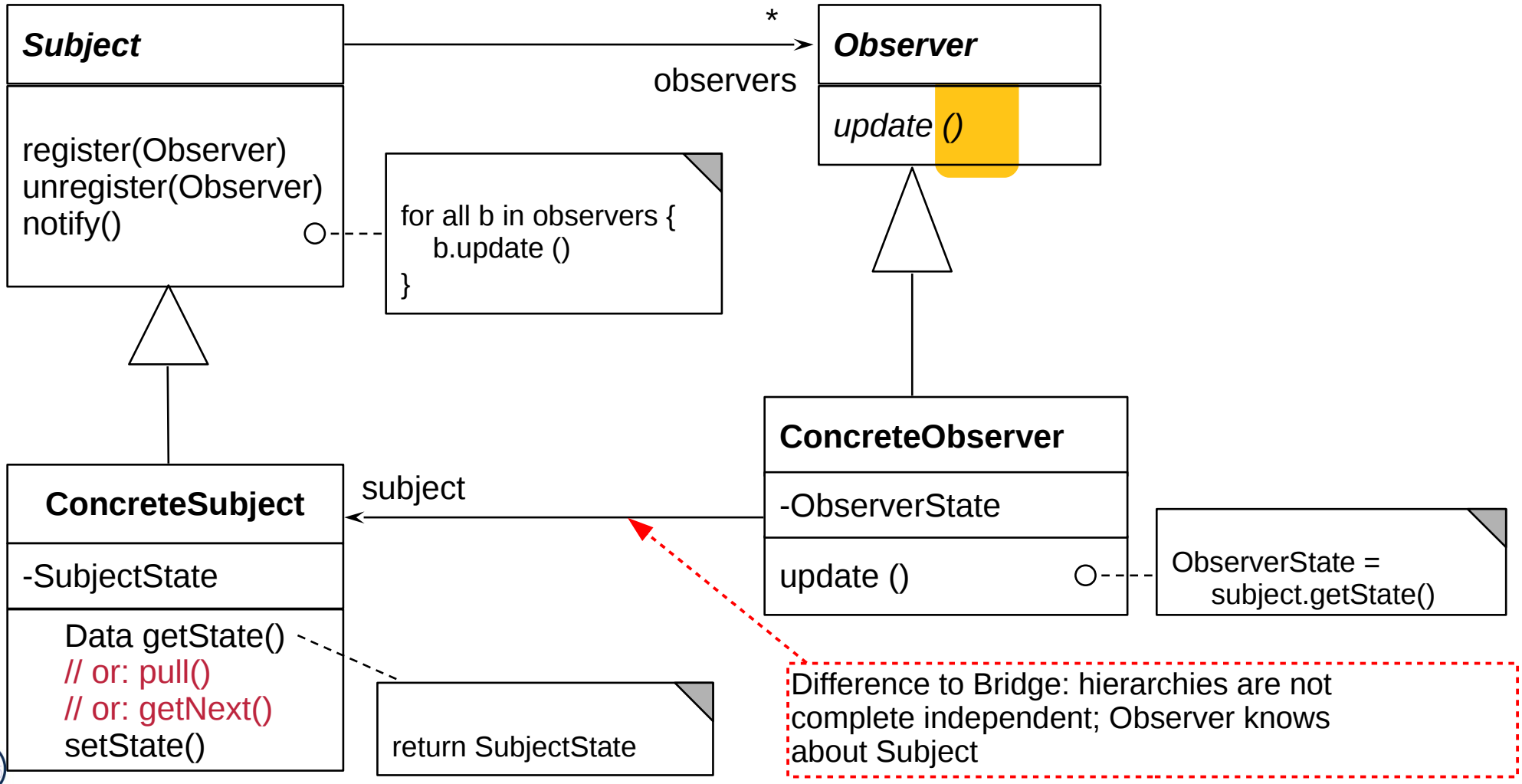
Sequence Diagram push-Observer

- Update() transfers Data to Observer (push)



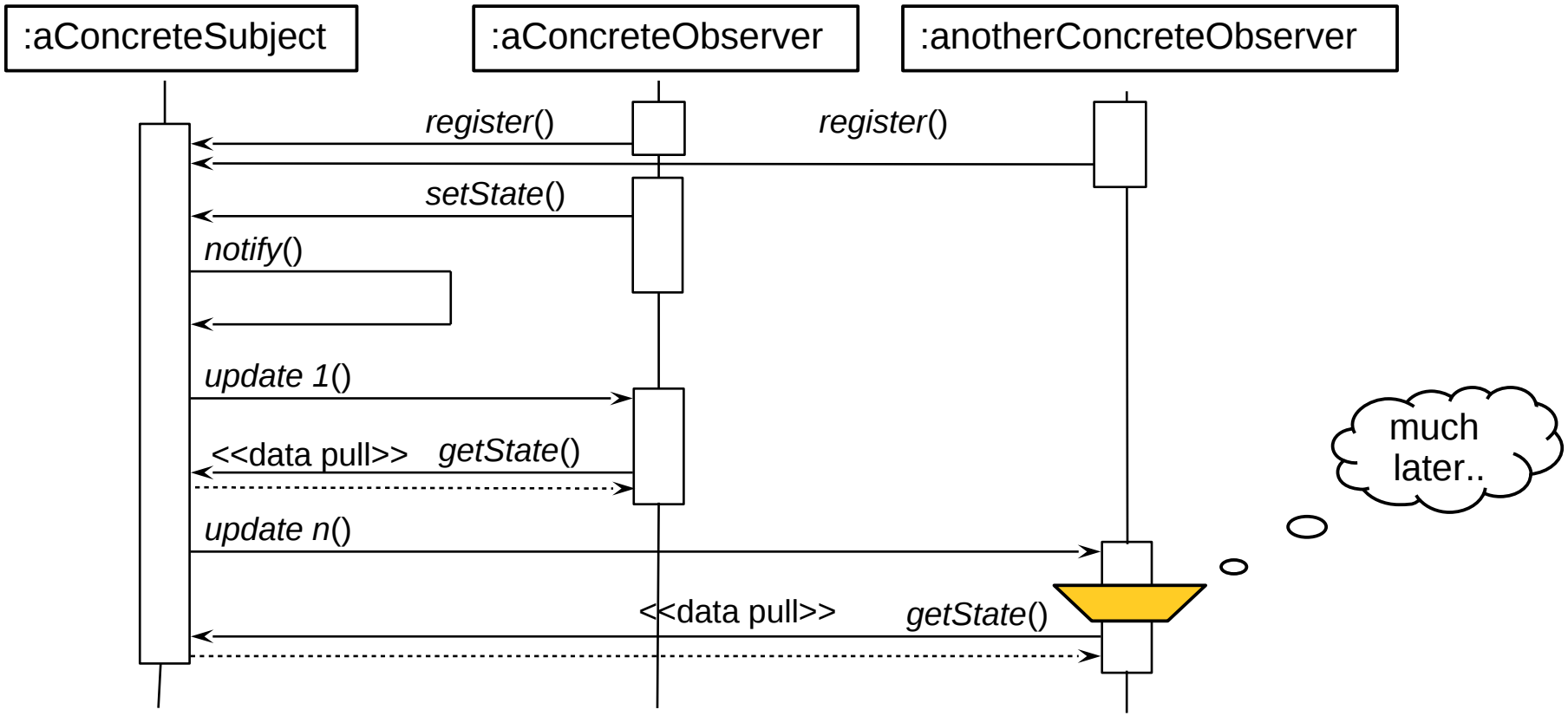
24.2.3.4 Pull-Observer (The Gamma Variant, Rpt.)

- The pull-Observer does not push anything, but pulls data later out with getState() or getNext() (same as in Iterator)
- Pulling resembles *Iterator (Stream)*, if data is pulled repeatedly



Sequence Diagram pull-Observer

- Update() does not transfer data, only an event (anonymous communication possible)
  - Observer pulls data out itself with getState()
  - Lazy processing (on-demand processing) with large data
- pull-Observer uses Iterator, if data is pulled iteratively



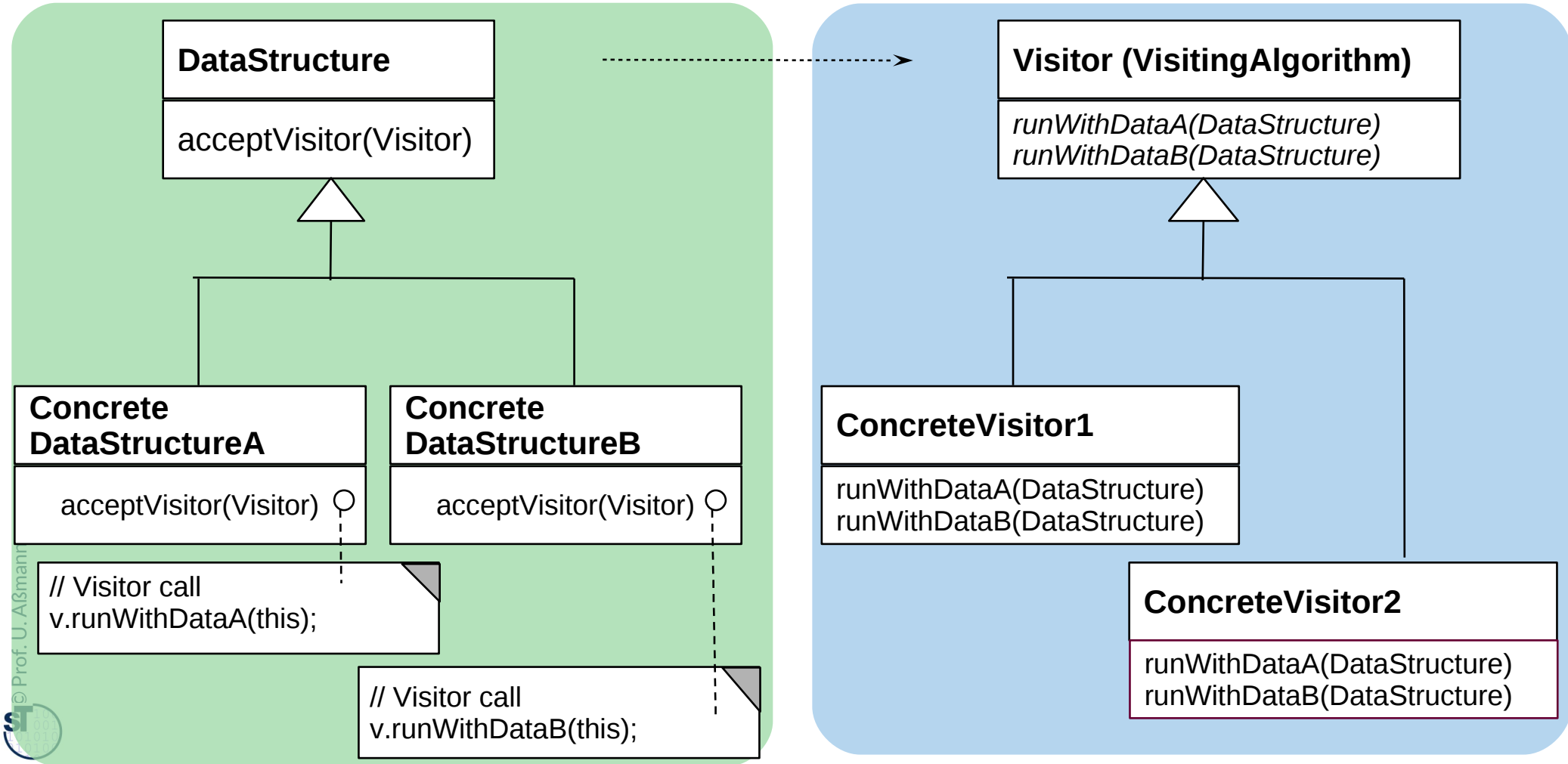
24.2.4. Visitor

Visitor provides an extensible family of algorithms on a data structure

Powerful pattern for modeling Materials and their Commands

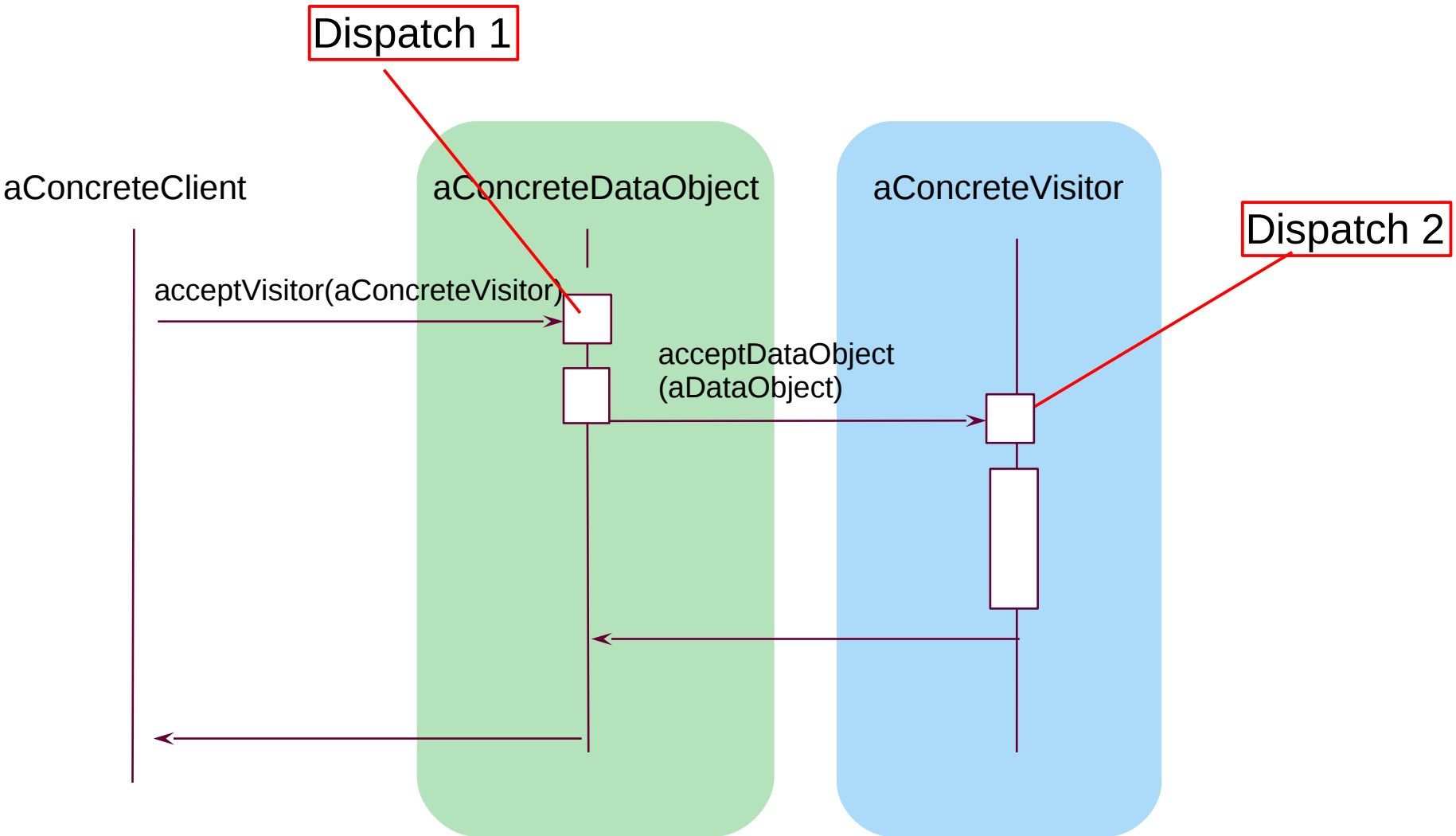
Visitor (VisitingAlgorithm)

- Implementation of *complex object* with a 2-dimensional structure
  - First dispatch on dimension 1 (data structure), then on dimension 2 (algorithm)
  - The Visitor has a lot of Callback methods (Command methods)
- Beauty: visiting algorithms can be added without touching the DataStructure

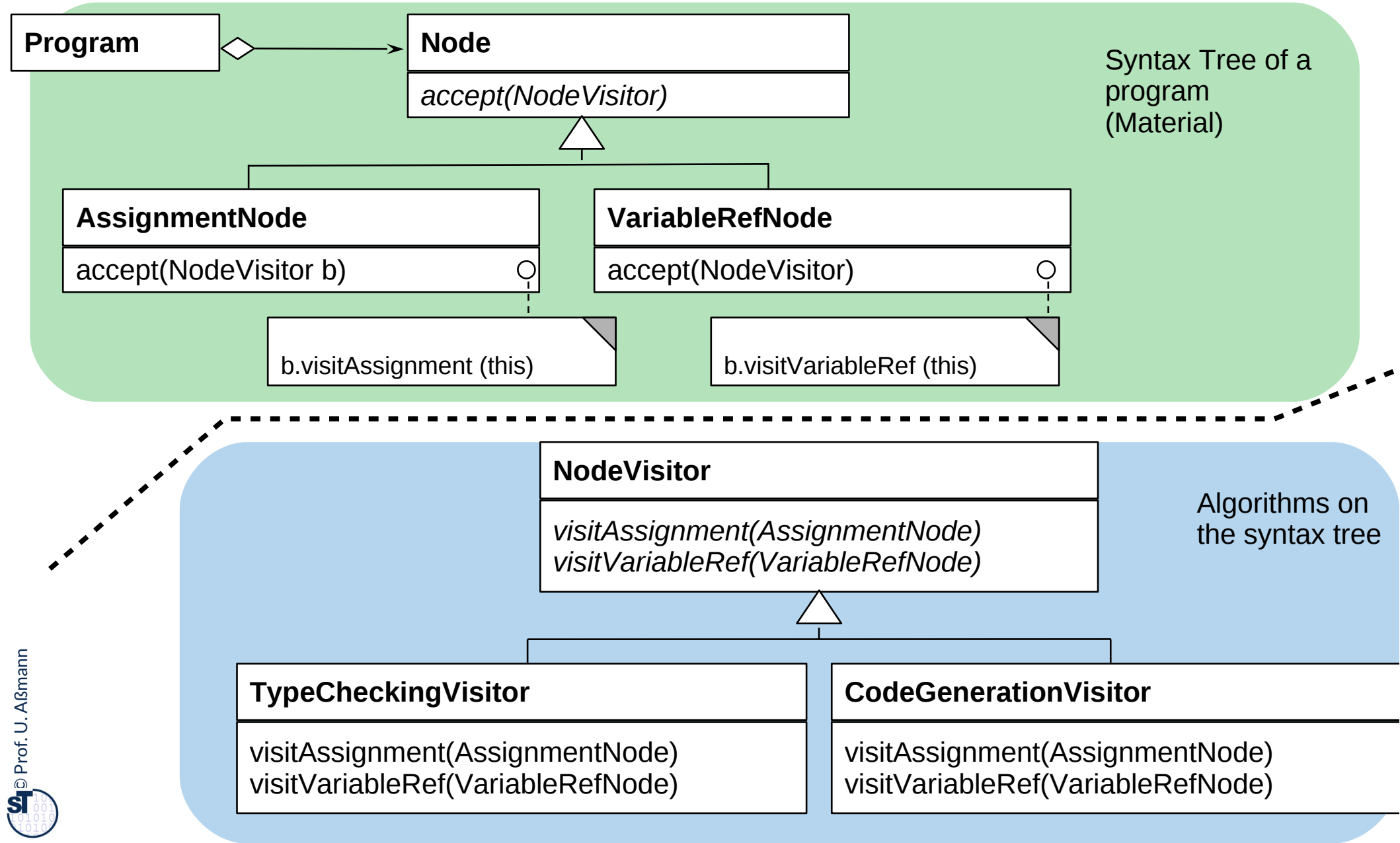


Sequence Diagram Visitor

- First dispatch on data, then on visiting algorithm



Intermediate Data of a Compiler: Working on Syntax Trees of Programs with Visitors

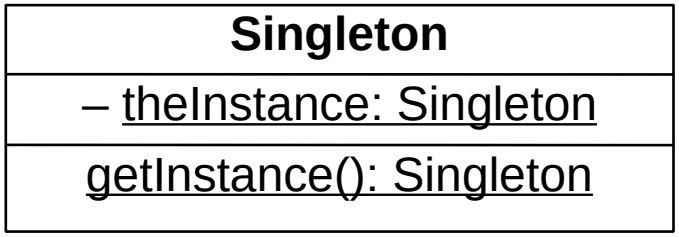


24.3) Patterns for Glue - Bridging Architectural Mismatch

Glue Pattern	# Run-time objects	Key feature
Singleton	1	Only one object per class
Adapter	2	Adapting interfaces and protocols that do not fit
Facade	1+*	Hiding a subsystem
Class Adapter	1	Integrating the adapter into the adapteel
Proxy (Appendix)	2	1-decorator

24.3.1 Singleton (dt.: Einzelinstanz)

- Problem: Store the global state of an application
  - Ensure that only *one* object exists of a class



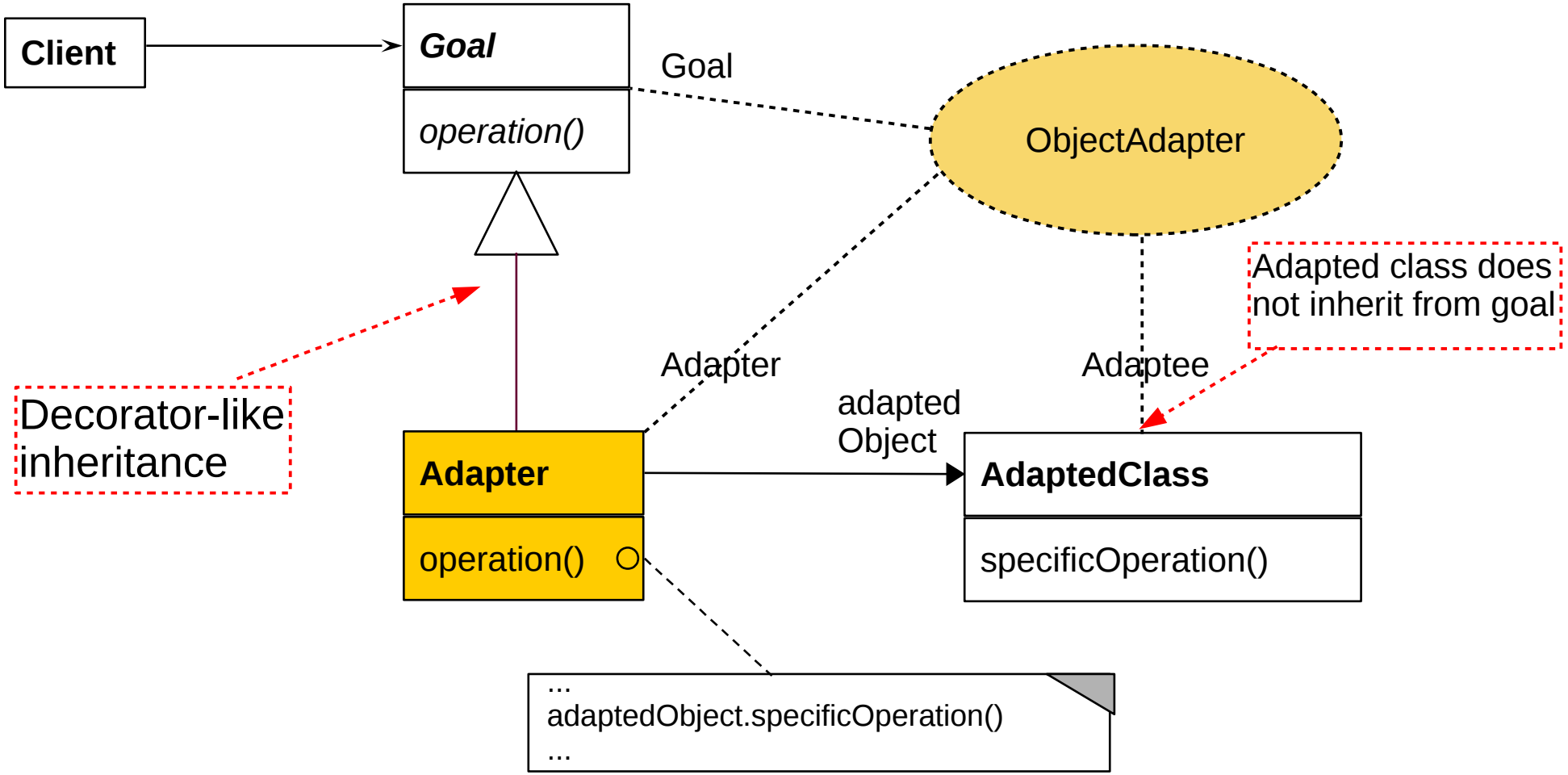
The usual constructor is invisible

```
class Singleton {

  private static Singleton theInstance;

  private Singleton () {}

  public static Singleton getInstance() {
    if (theInstance == null)
      theInstance = new Singleton();
    return theInstance;
  }
}
```

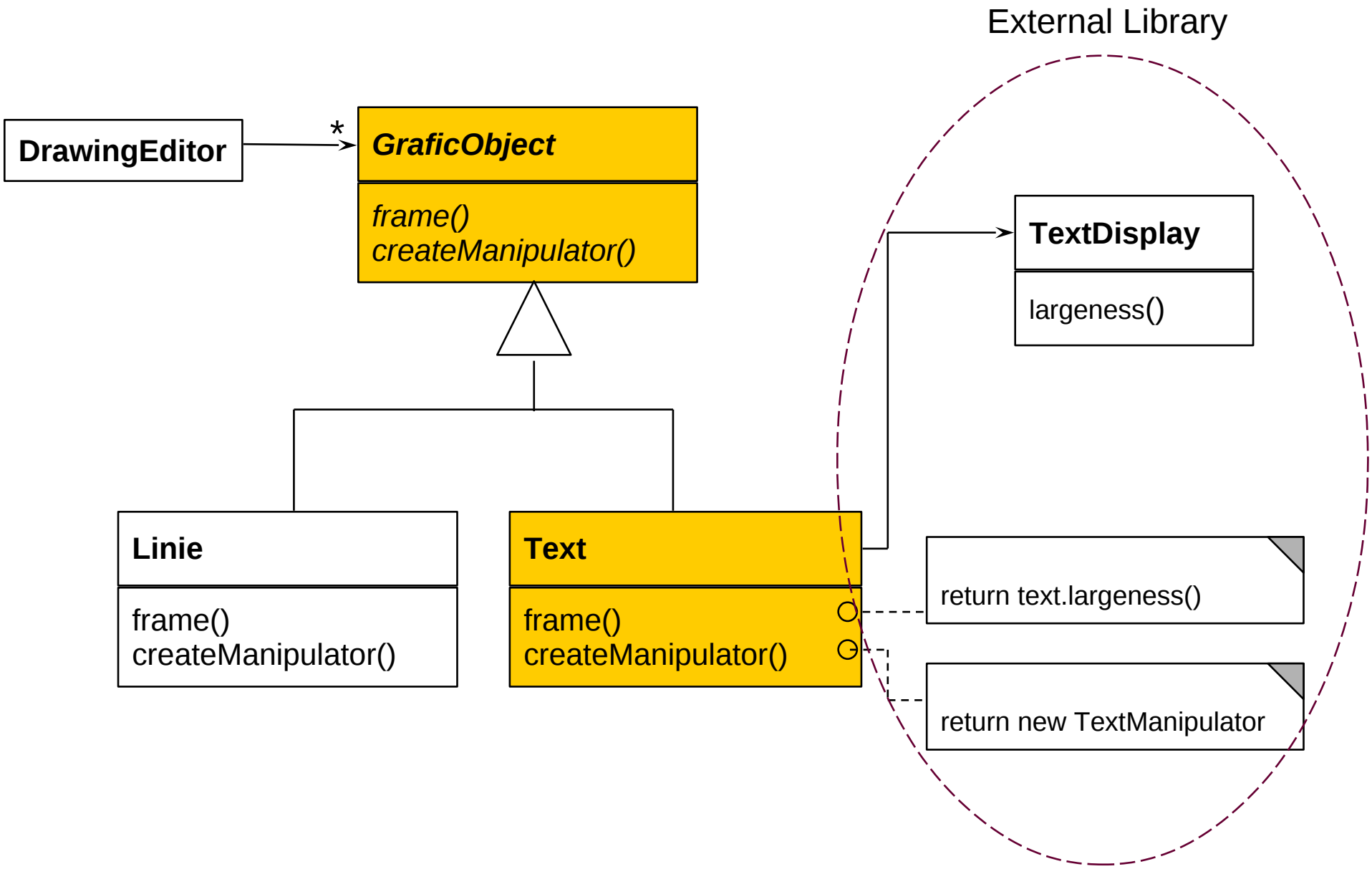
24.3.2 Adapter

Object Adapter

- An **object adapter** is a kind of a proxy mapping one interface, protocol, or data format to another

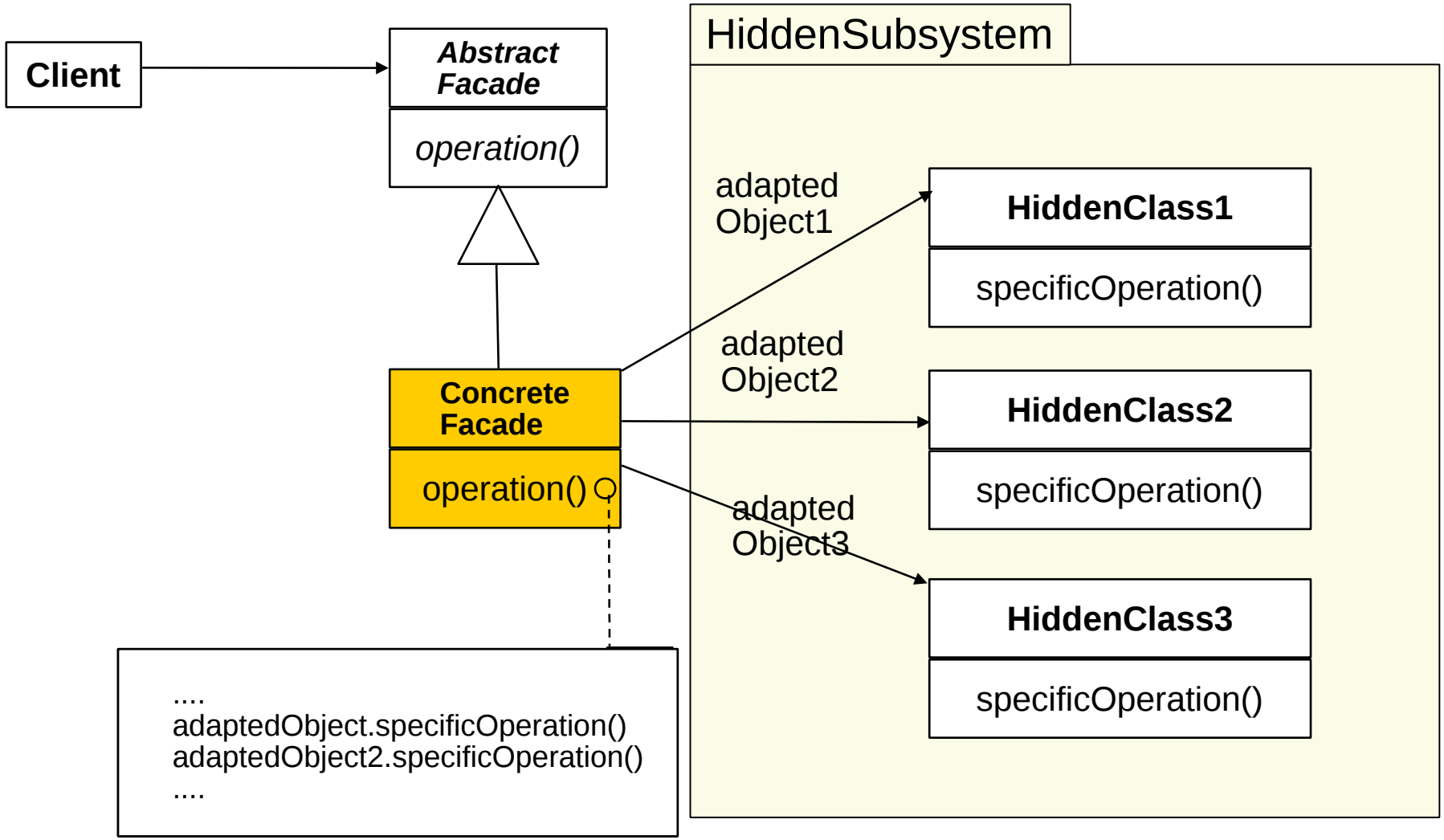


Example: Use of an External Class Library For Texts



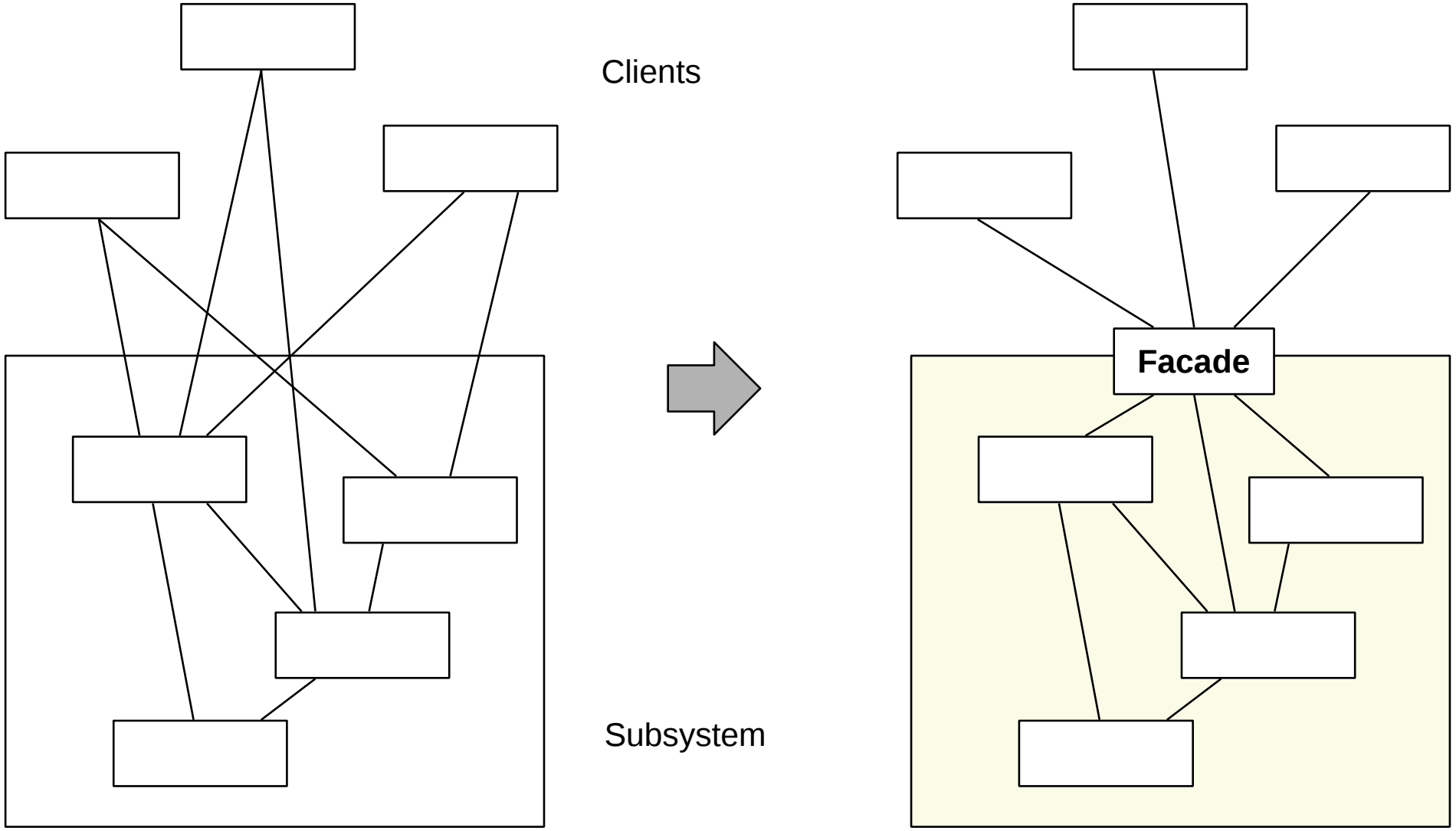
24.3.3 Facade Hides a Subsystem

- A **facade** is a specific object adapter hiding a complete set of objects (subsystem)
  - The facade has to map its own interface to the interfaces of the hidden objects



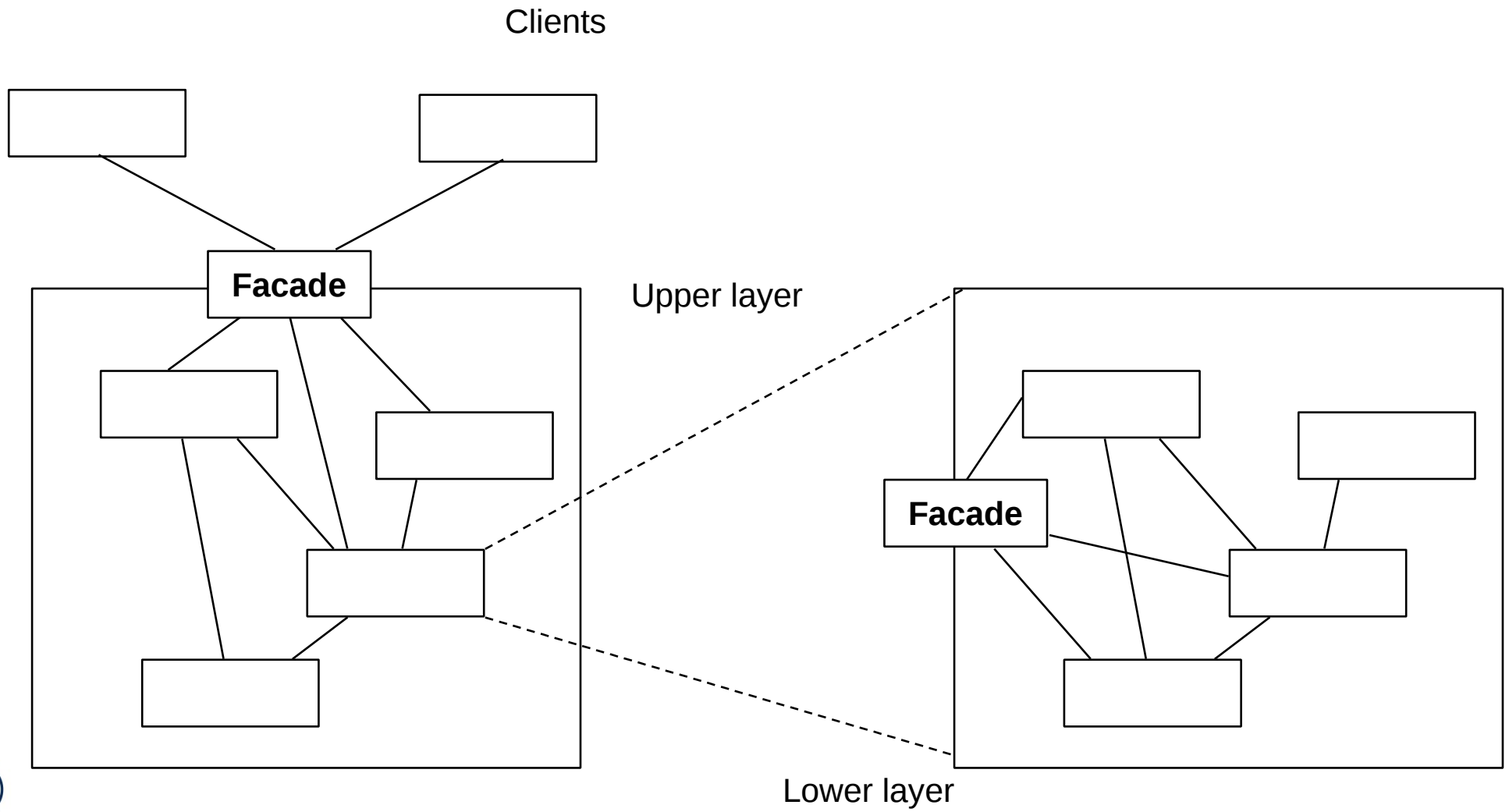
Refactoring a Legacy System Towards a Facade

- After a while, components are too much intermingled
- Facades serve for clear layered structure



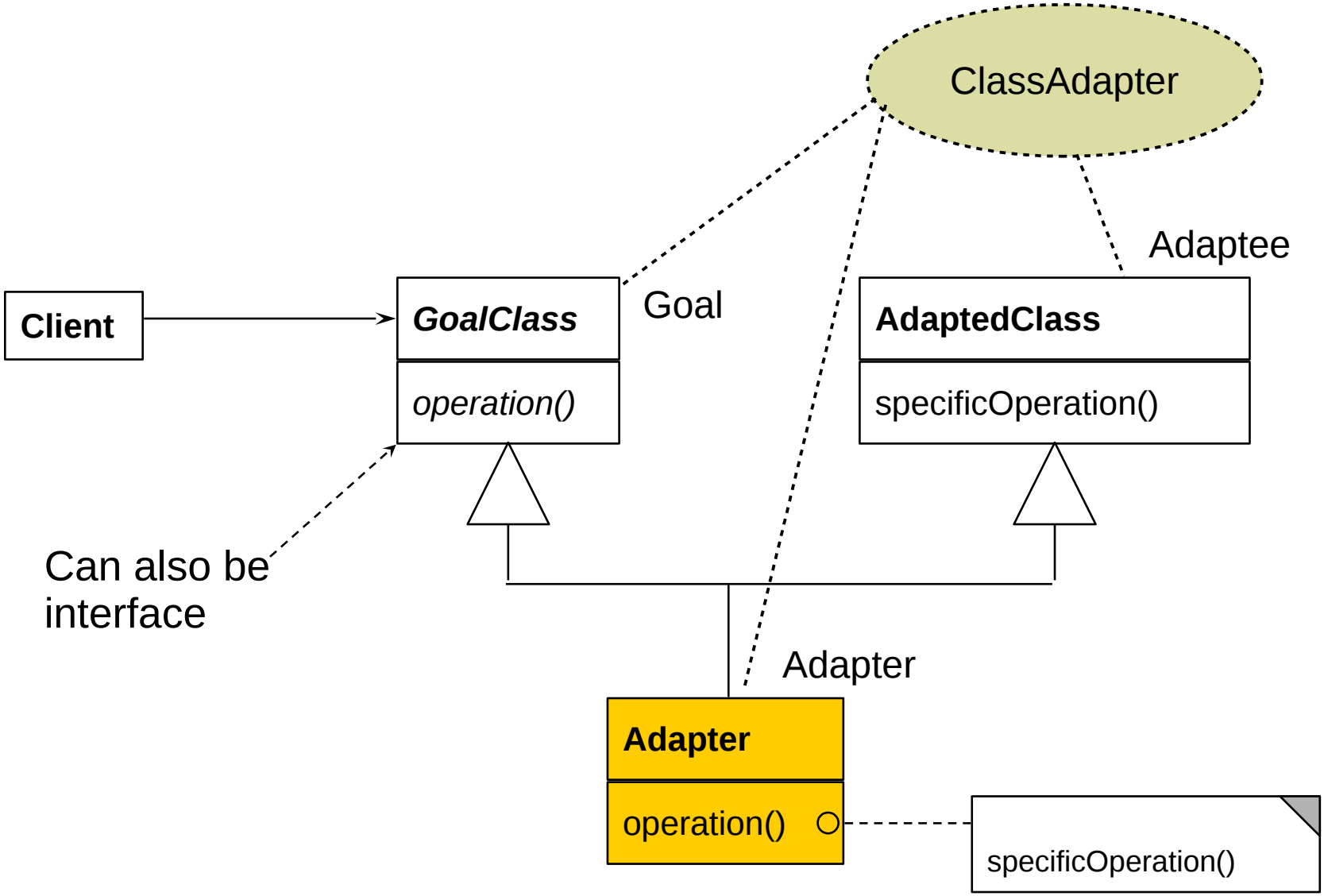
The Layer Pattern

- If classes of the subsystem are again facades, **layers** result
  - Layers need nested facades



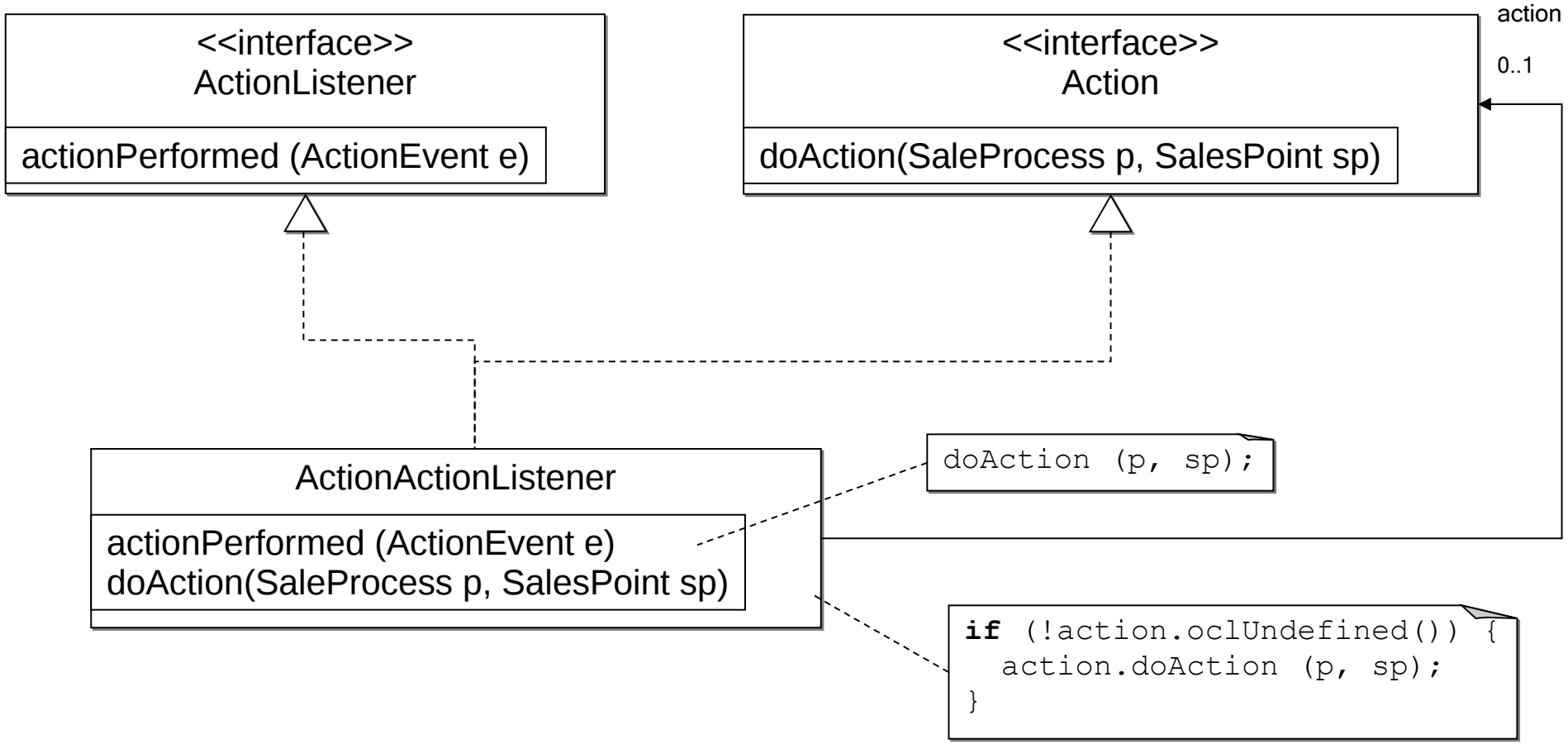
24.3.4 Class Adapter

- Instead of delegation, class adapters use multiple inheritance



Adapter for Observer in SalesPoint Framework

- In the SalesPoint framework (project course), a ClassAdapter is used to embed an Action class in an Listener of Observer Pattern



24.4 Other Patterns

What is discussed elsewhere...

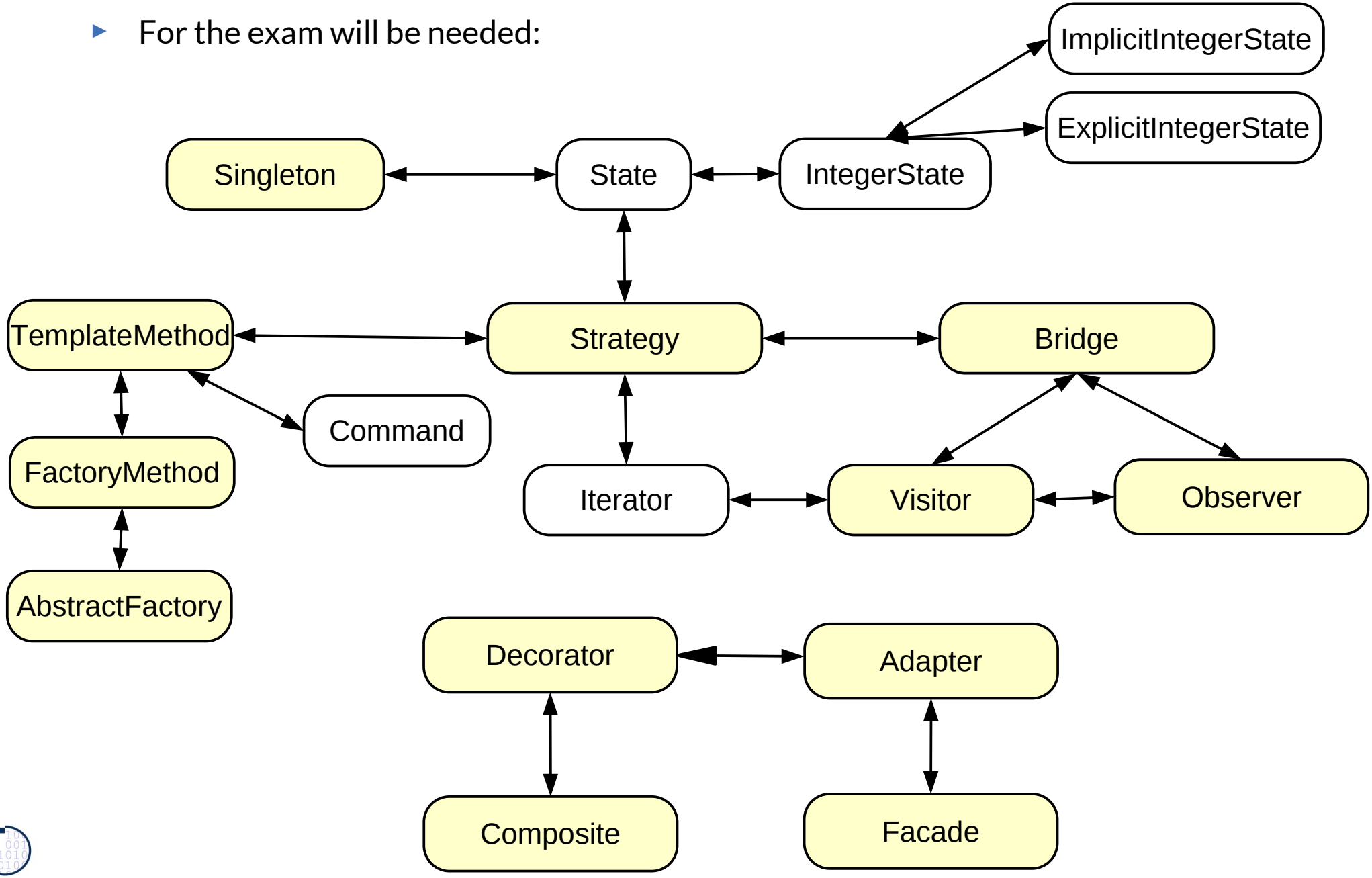
- Iterator, Sink, and Channel
- Composite
- TemplateMethod, FactoryMethod
- Command

Part III:

- Chapter “Analysis”:
  - State (Zustand), IntegerState, Explicit/ImplicitIntegerState
- Chapter “Architecture”:
  - Facade (Fassade)
  - Layers (Schichten)
  - 4-tier architecture (4-Schichtenarchitektur, BCED)
  - 4-tier abstract machines (4-Schichtenarchitektur mit abstrakten Maschinen)

Relations between Design Patterns

- For the exam will be needed:



Other Important GOF Patterns

Variability Patterns

- Visitor: Separate a data structure inheritance hierarchy from an algorithm hierarchy, to be able to vary both of them independently
- AbstractFactory: Allocation of objects in consistent families, for frameworks which maintain lots of objects
- Builder: Allocation of objects in families, adhering to a construction protocol
- Command: Represent an action as an object so that it can be undone, stored, redone

Extensibility Patterns

- Proxy: Representant of an object
- ChainOfResponsibility: A chain of workers that process a message

Others

- Memento: Maintain a state of an application as an object
- Flyweight: Factor out common attributes into heavy weight objects and flyweight objects

24.5 Design Patterns in a Larger Library

Design Pattern in the AWT

- AWT/Swing is part of the Java class library
  - Uniform window library for many platforms (portable)
- Employed patterns
  - Pull-Observer (for widget super class java.awt.Window)
  - Compositum (widgets are hierarchic)
  - Strategy: The generic composita must be coupled with different layout algorithms
  - Singleton: Global state of the library
  - Bridge: Widgets such as Button abstract from look and provide behavior
    - Drawing is done by a GUI-dependent drawing engine (pattern bridge)
  - Abstract Factory: Allocation of widgets in a platform independent way

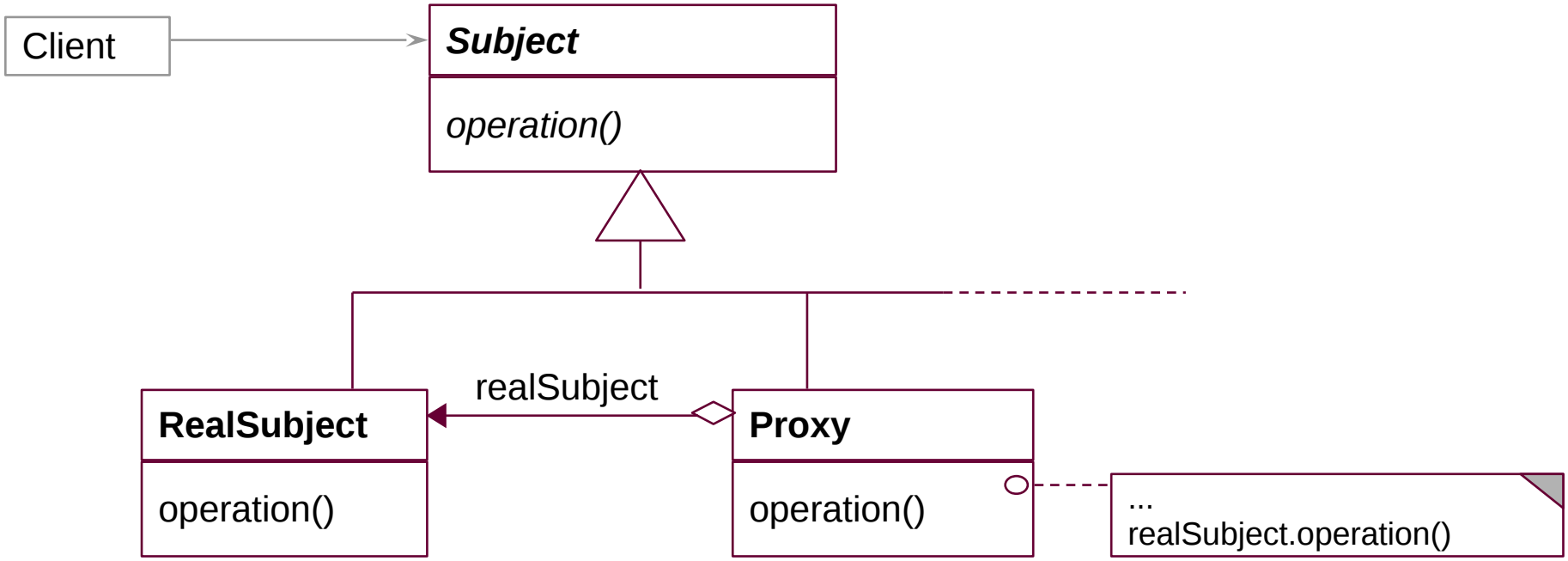
What Have We Learned?

- Design Patterns grasp good, well-known solutions for standard problems
- Variability patterns allow for variation of applications
  - They rely on the template/hook principle
- Extensibility patterns for extension
  - They rely on recursion
  - An aggregation to the superclass
  - This allows for constructing runtime nets: lists, sets, and graphs
  - And hence, for dynamic extension
- Architectural Glue patterns map non-fitting classes and objects to each other

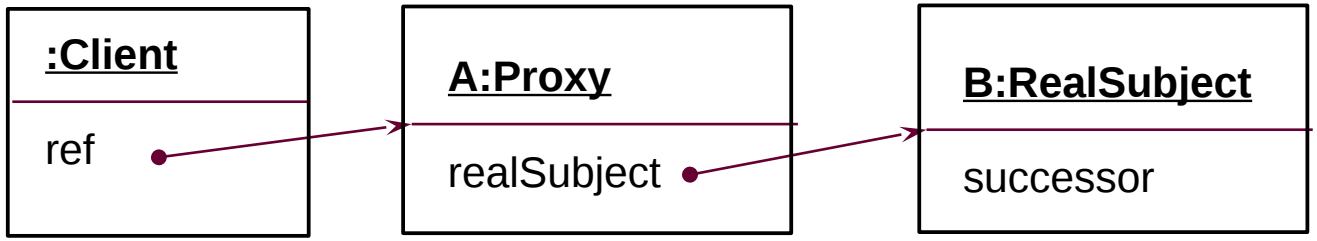
24.A.1 Proxy

Proxy

- Hide the access to a real subject by a representant



Object Structure:



Proxy

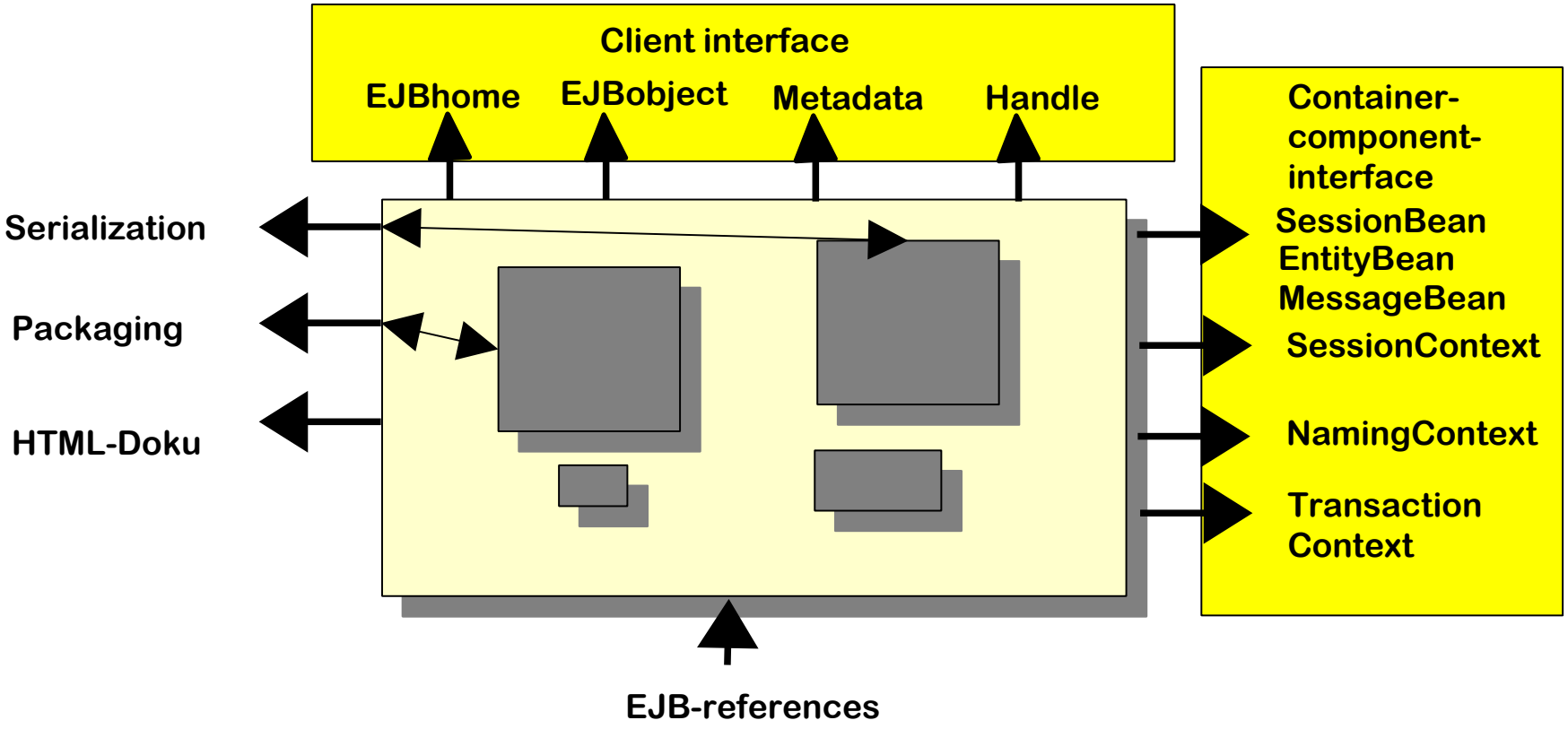
- The proxy object is a representant of an object
  - The Proxy is similar to Decorator, but it is not derived from ObjectRecursion
  - It has a direct pointer to the sister class, *not* to the superclass
  - It may collect all references to the represented object (shadows it). Then, it is a facade object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

Proxy Variants

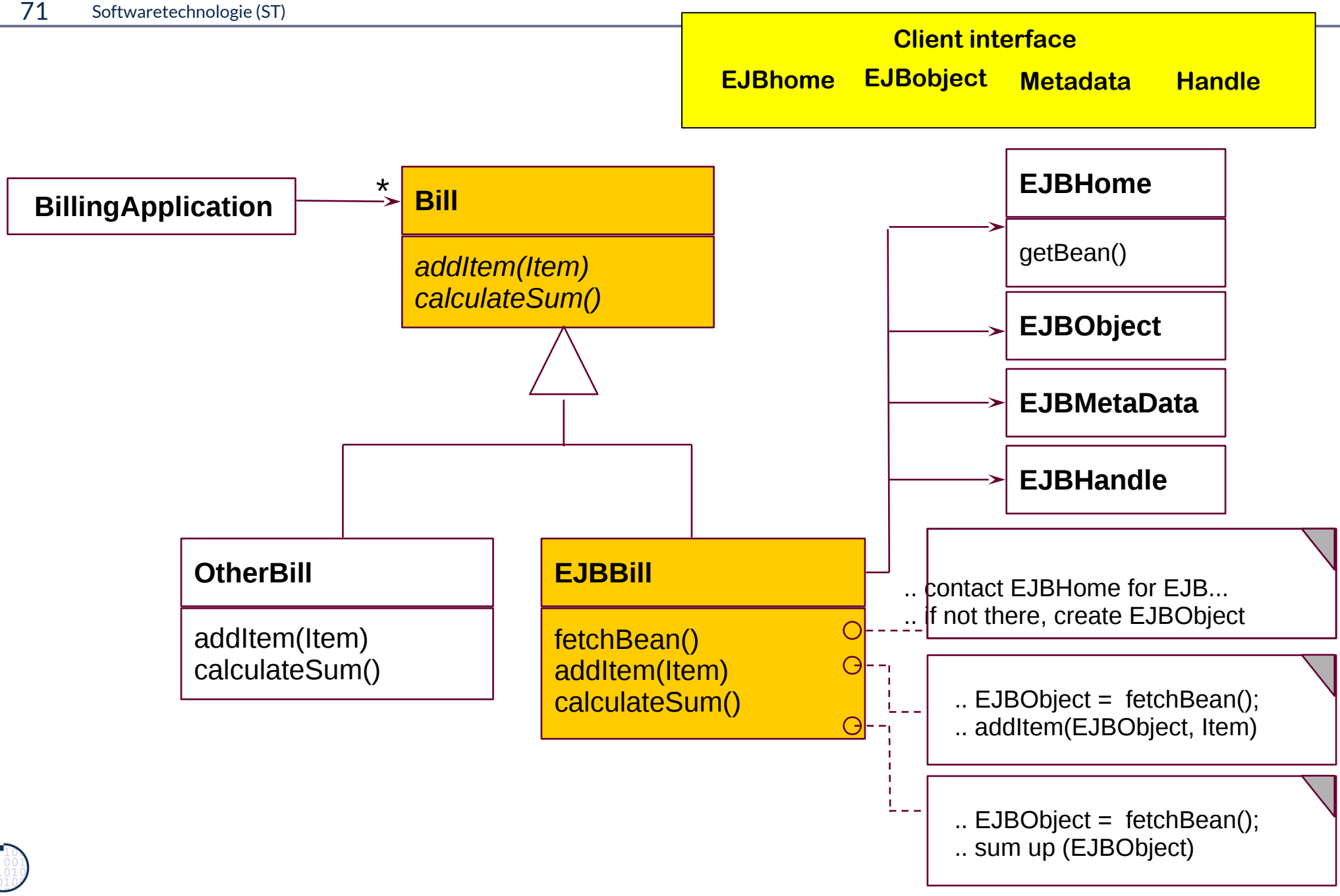
- **Filter proxy** (smart reference):
  - executes additional actions, when the object is accessed
- **Protocol proxy**:
  - Counts references (reference-counting garbage collection
  - Or implements a synchronization protocol (e.g., reader/writer protocols)
- **Indirection proxy** (facade proxy):
  - 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
  - Caching of remote objects for on-demand loading
- **Protection proxy**
  - Firewall proxy

Adapters and Facades for COTS

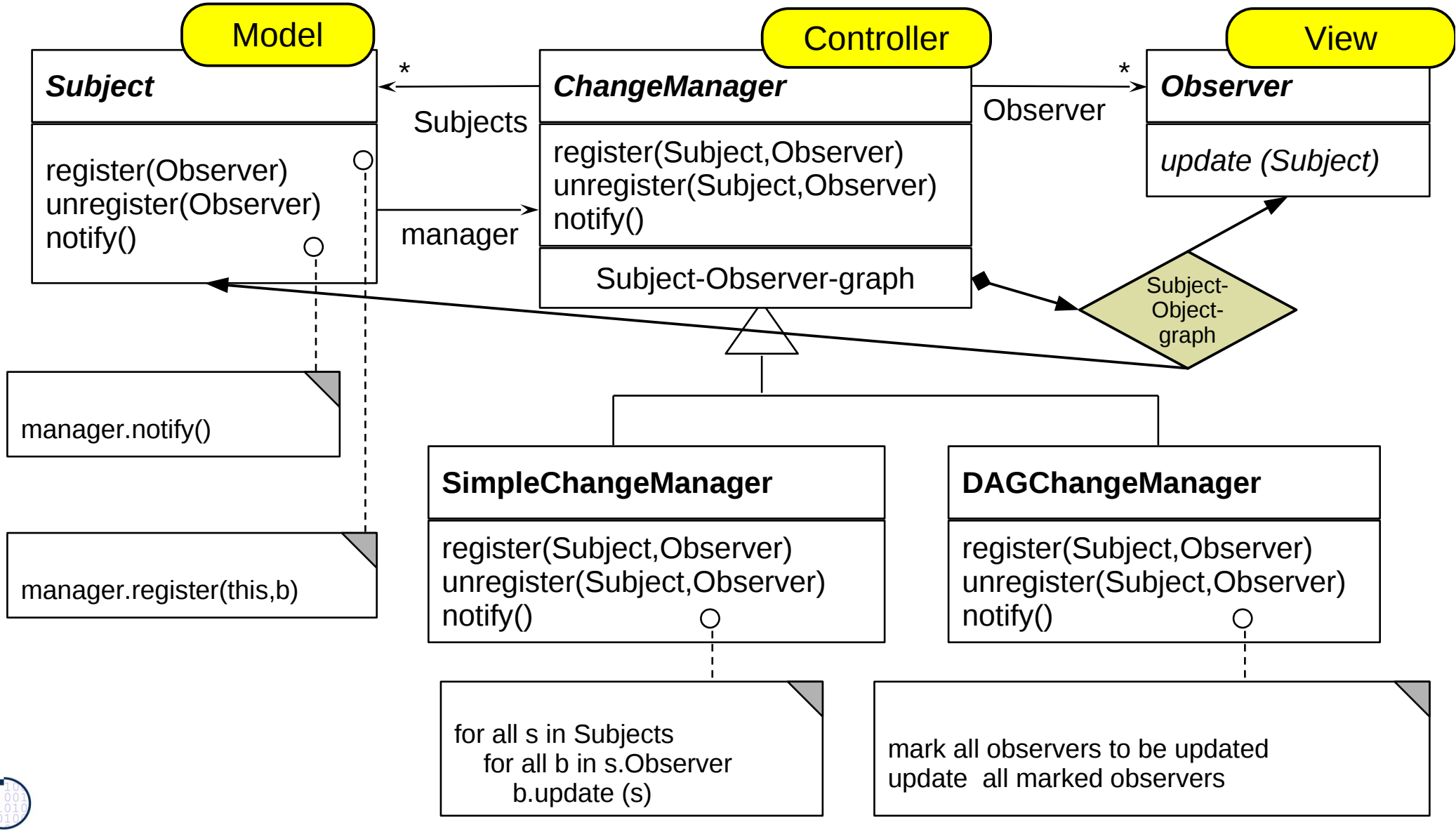
- Adapters and Facades are often used to adapt components-off-the-shelf (COTS) to applications
- For instance, an EJB-adapter allows for reuse of an Enterprise Java Bean in an application



EJB Adapter

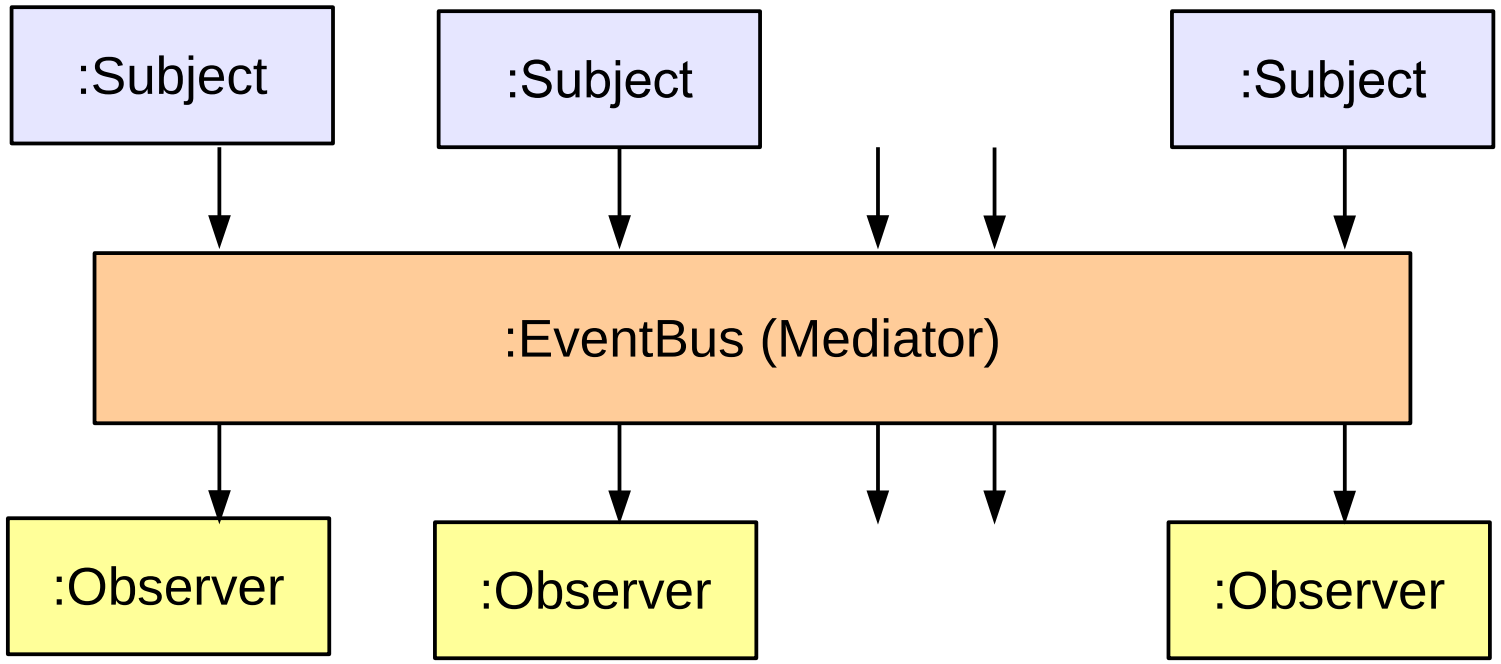


24.A.2 Observer with ChangeManager (EventBus)



Observer with ChangeManager is also Called Event-Bus

- Basis of many interactive application frameworks (Xwindows, Java AWT, Java InfoBus, ...)
- Loose coupling in communication
  - Observers decide what happens
- Dynamic extension of communication
  - Anonymous communication
  - Multi-cast and broadcast communication



Why is the Frauenkirche Beautiful?

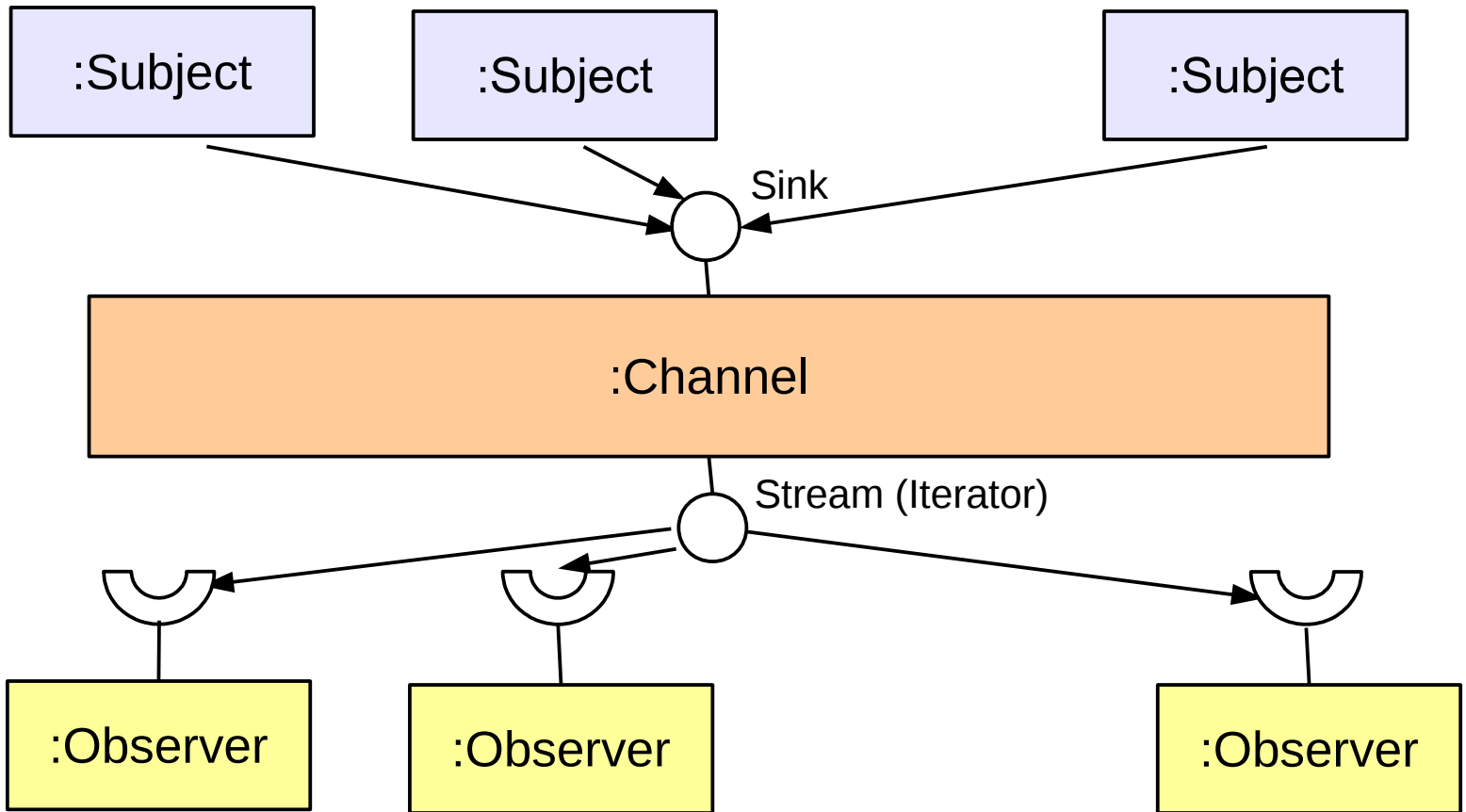
- ..because she contains a lot of patterns from the baroque pattern language...

The End

- Design patterns and frameworks, WS, contains more material.
- © Uwe Aßmann, Heinrich Hussmann, Walter F. Tichy, Universität Karlsruhe, Germany, used by permission

24.2.3.7 A Variant of EventBus is the Channel

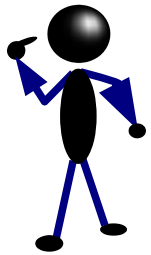
- push-Subjects and pull-Observers can be connected by Channel, to emphasize the continuous pushing and pulling
- Then Subjects write the Sink of the Channel and Observers pull the Stream of the Channel
  - Channel is a buffer

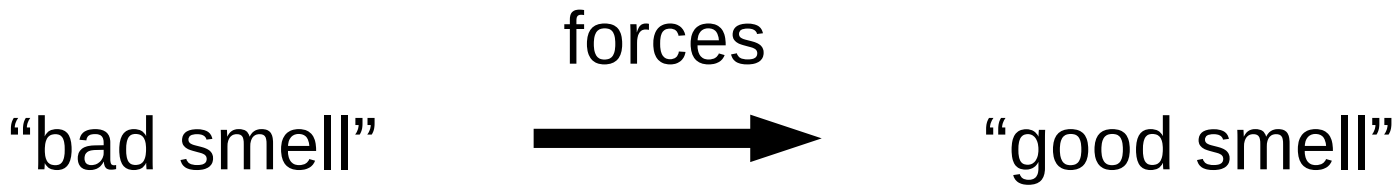


Appendix

What Does a Design Pattern Contain?

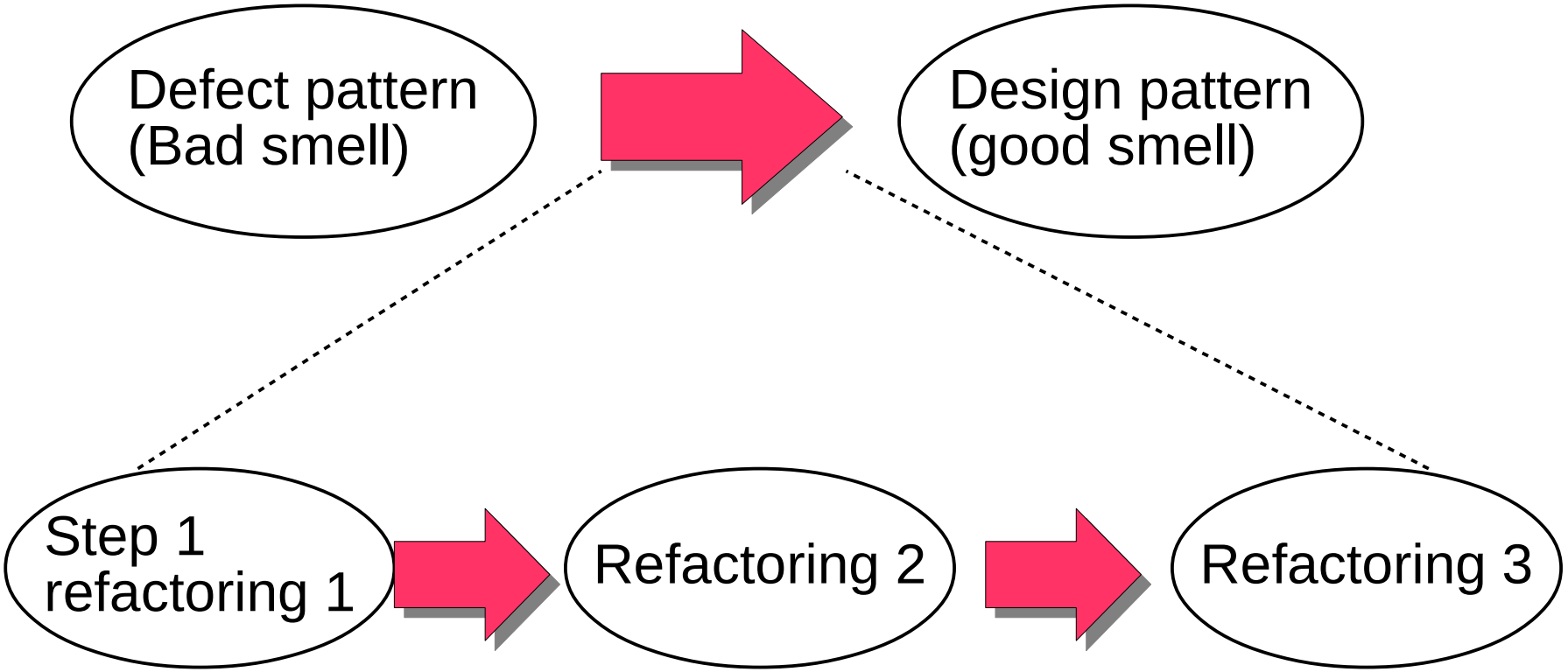
- A part with a “bad smell”
  - A structure with a bad smell
  - A query that proved a bad smell
  - A graph parse that recognized a bad smell
- A part with a “good smell” (standard solution)
  - A structure with a good smell
  - A query that proves a good smell
  - A graph parse that proves a good smell
- A part with “forces”
  - The context, rationale, and pragmatics
  - The needs and constraints





Refactorings Transform Antipatterns (Defect Patterns, Bad Smells) Into Design Patterns

- Software can contain bad structure
- A DP can be a goal of a *refactoring*, transforming a bad smell into a good smell

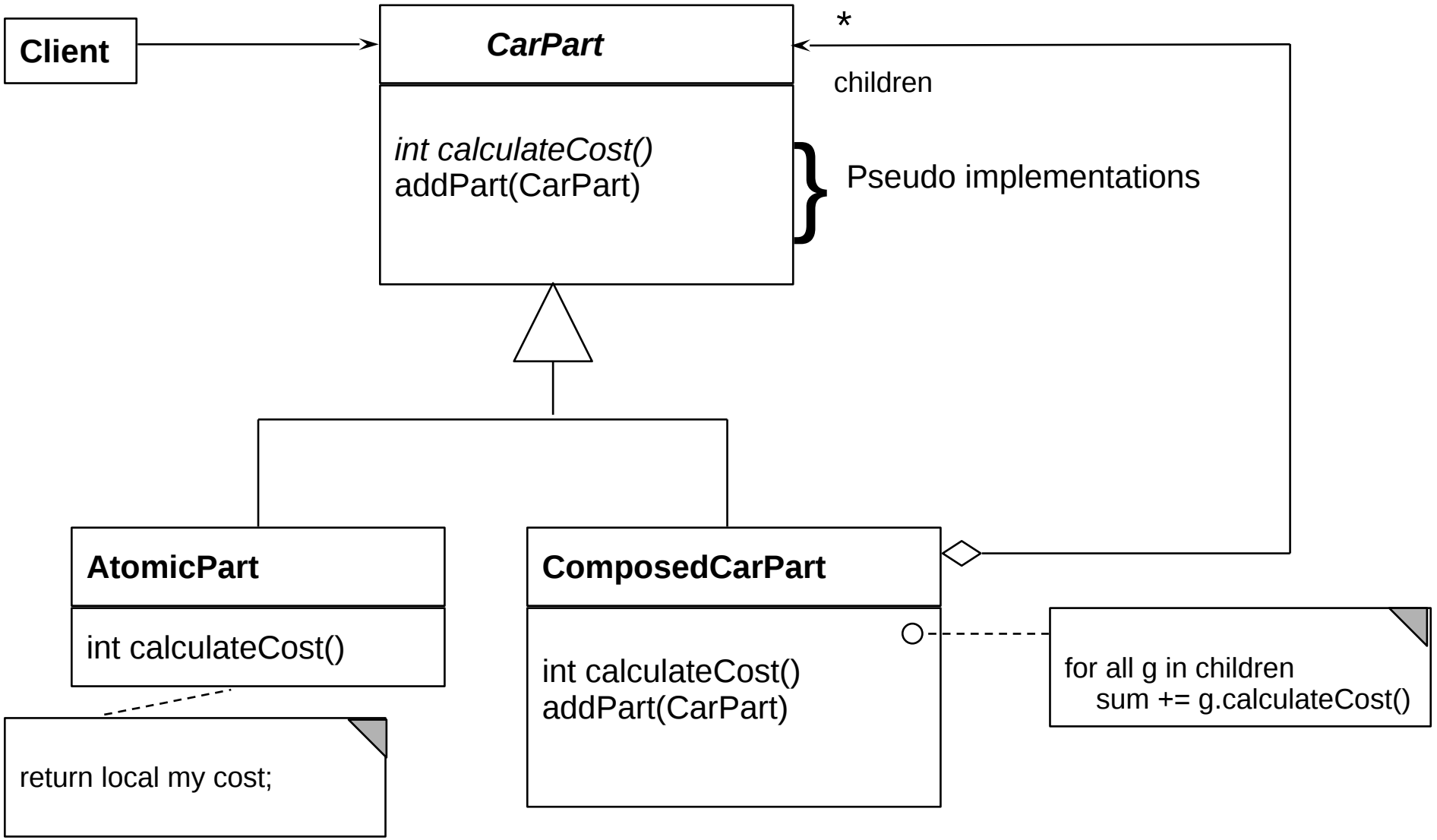


Structure for Design Pattern Description (GOF Form)

- Name (incl. Synonyms) (also known as)
- Motivation (purpose)
  - also “bad smells” to be avoided
- Employment
- Solution (the “good smell”)
  - Structure (Classes, abstract classes, relations): UML class or object diagram
  - Participants: textual details of classes
  - Interactions: interaction diagrams (MSC, statecharts, collaboration diagrams)
  - Consequences: advantages and disadvantages (pragmatics)
  - Implementation: variants of the design pattern
  - Code examples
- Known Uses
- Related Patterns

A.2 Example for Composite: PieceLists in Cars

- Big technical objects can have thousands of parts



Piece Lists of Complex Technical Objects


```
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;
  }
```

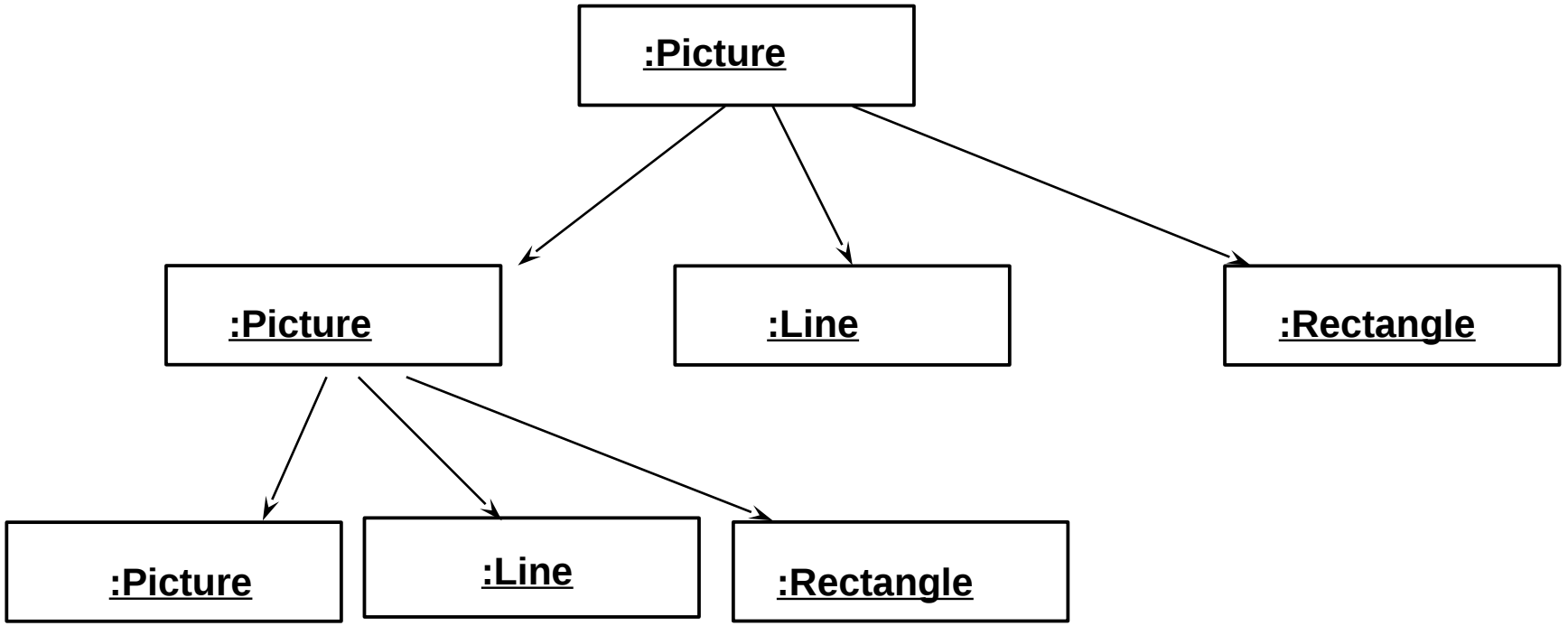
```
class AtomicCarPart extends CarPart {
   int calculateCost() { return  myCost; }
  void addPart(CarPart c) {
      /// impossible, dont do anything
  }
}
class Screw extends AtomicCarPart {
    int myCost = 10;
}
class SteeringWheel extends AtomicCarPart {
  int myCost = 200;
}
```

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

Iterator algorithms (map)
Folding algorithm (folding a tree with a scalar function)

Composite for Part/Whole Hierarchies (Structured Piece Lists)

- Part/Whole hierarchies, e.g., nested graphic objects (widgets)
- Dynamic Extensibility of Composite
  - Due to the n-recursion, new children can always be added dynamically into a composite node
  - Whenever you have to program an extensible part of a framework, consider Composite



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

Different Forms of Patterns

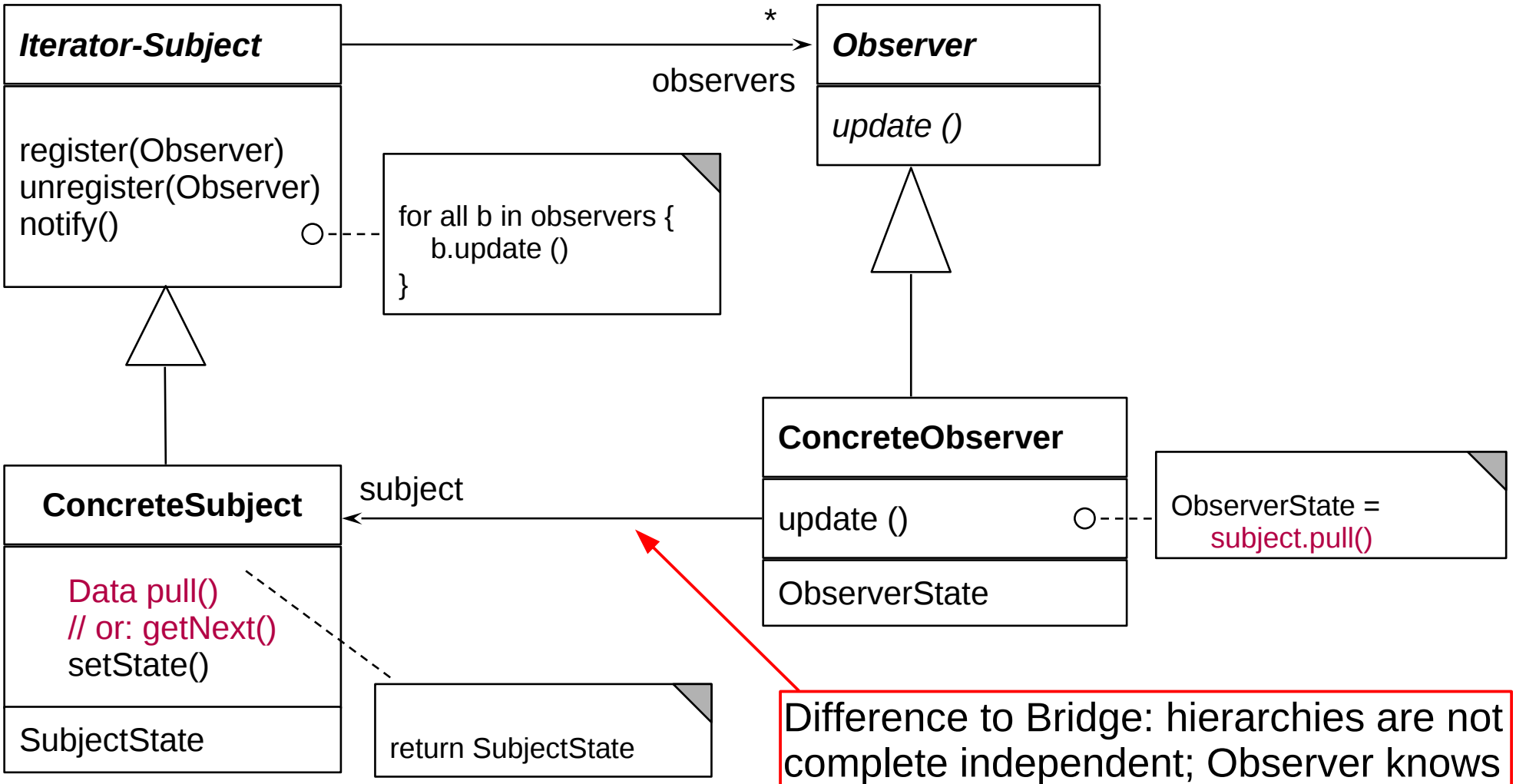
- **Conceptual Patterns** of good system structures
  - Desktop pattern, Wastebasket pattern, Tool and Material pattern, ...
- Specific **Design Patterns** for good design structures
  - **Product Line Patterns** will be discussed here
  - **Architectural styles** describe course-grain styles for applications
  - **Antipatterns ("bad smells")** are defective patterns (**Structural smells, Qualty smells)**
- **Implementation Patterns** (programming patterns, idioms, workarounds) replace missing language constructs
- **Process Patterns** describe good structures in development processes
- **Reengineering Patterns** describe good practices in reengineering
- **Organizational Patterns** describe good patterns in company structuring

A **pattern** is the abstraction from a concrete form which keeps recurring in specific non-arbitrary contexts

[Riehle/Zülinghoven, Understanding and Using Patterns in Software Development]

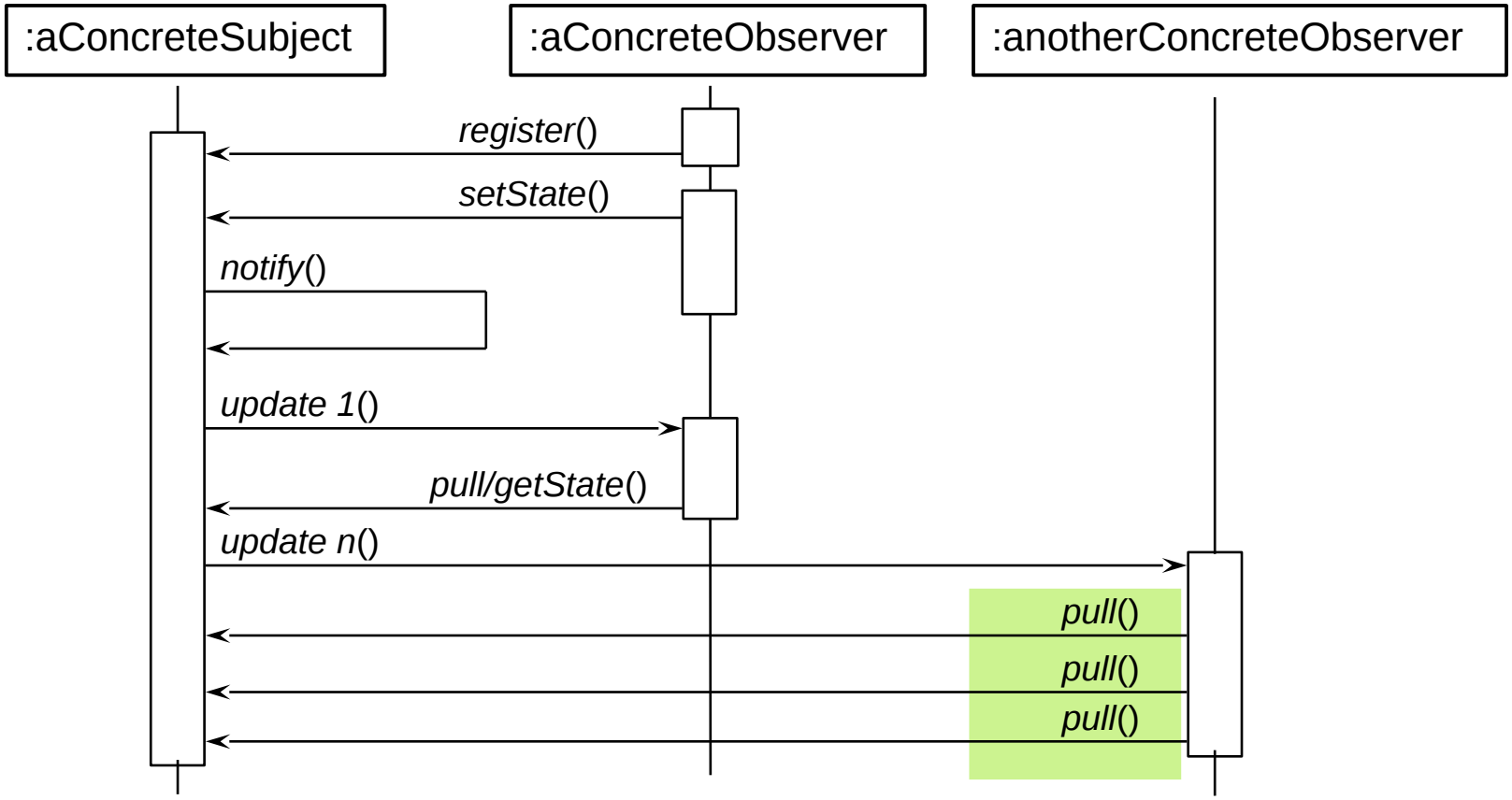
24.A.3 Pull-Stream

- Pulling resembles *Iterator (Stream)*, if data is pulled repeatedly



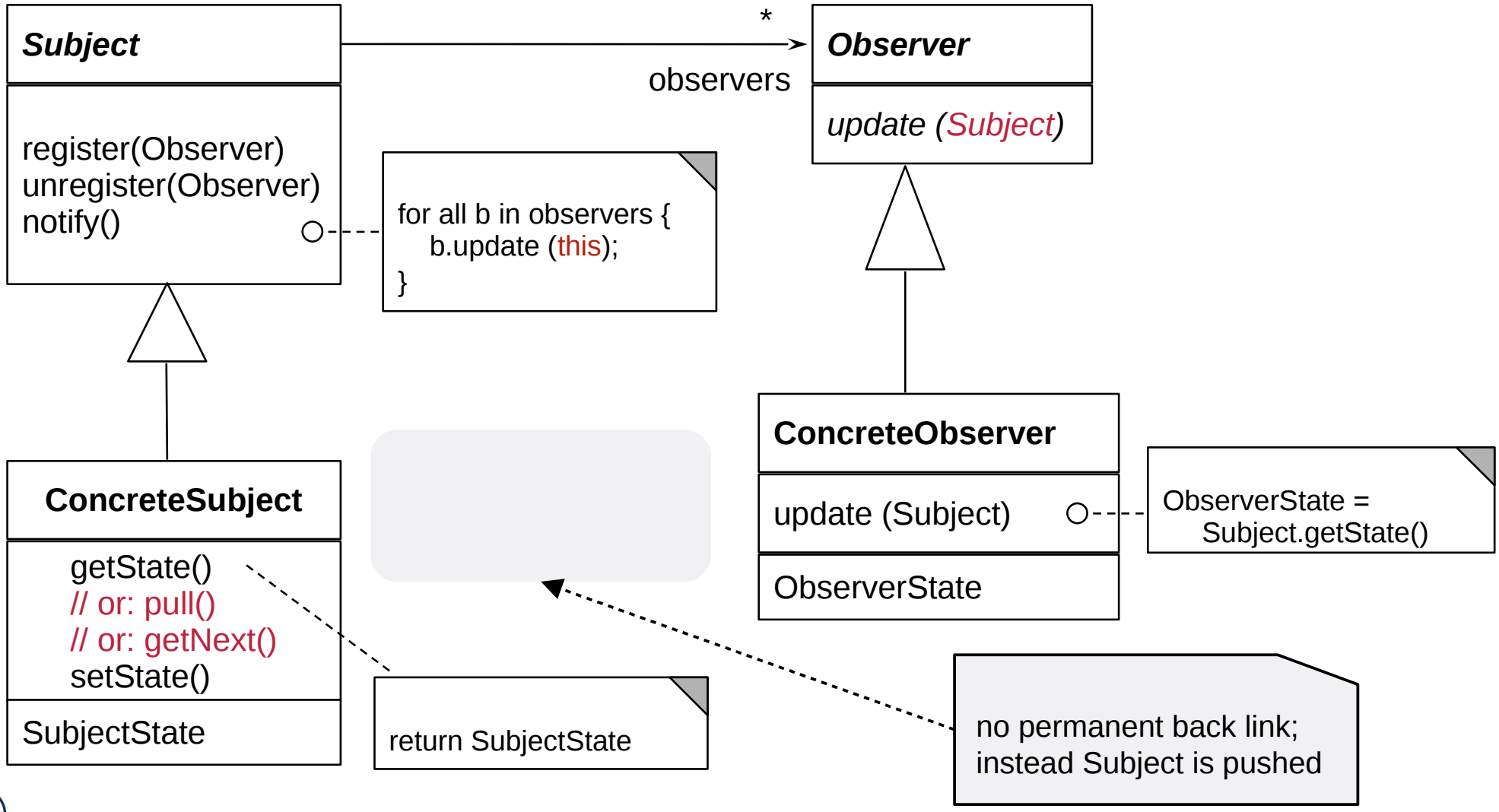
Sequence Diagram pull-Observer

- Update() does not transfer data, only an event (anonymous communication possible)
  - Observer pulls data out itself with getState()
  - Lazy processing (on-demand processing)
- pull-Observer uses Iterator, if data is pulled iteratively



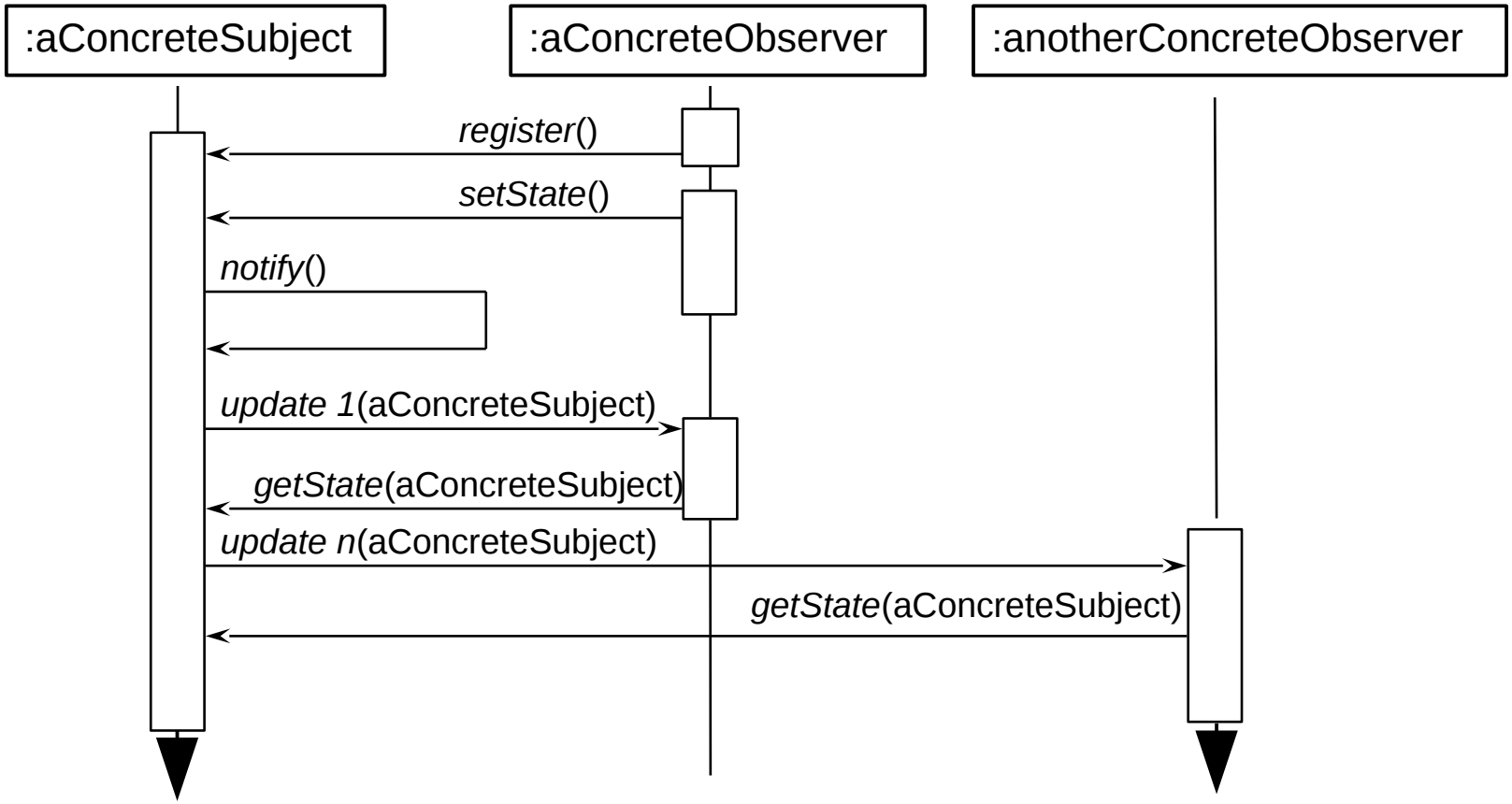
24.A.2.3 Structure Subject-Pushing pull-Observer

- A **Subject-pushing Observer** is a even simpler variant of the pull-Observer, which gets the subject as argument of `update()`



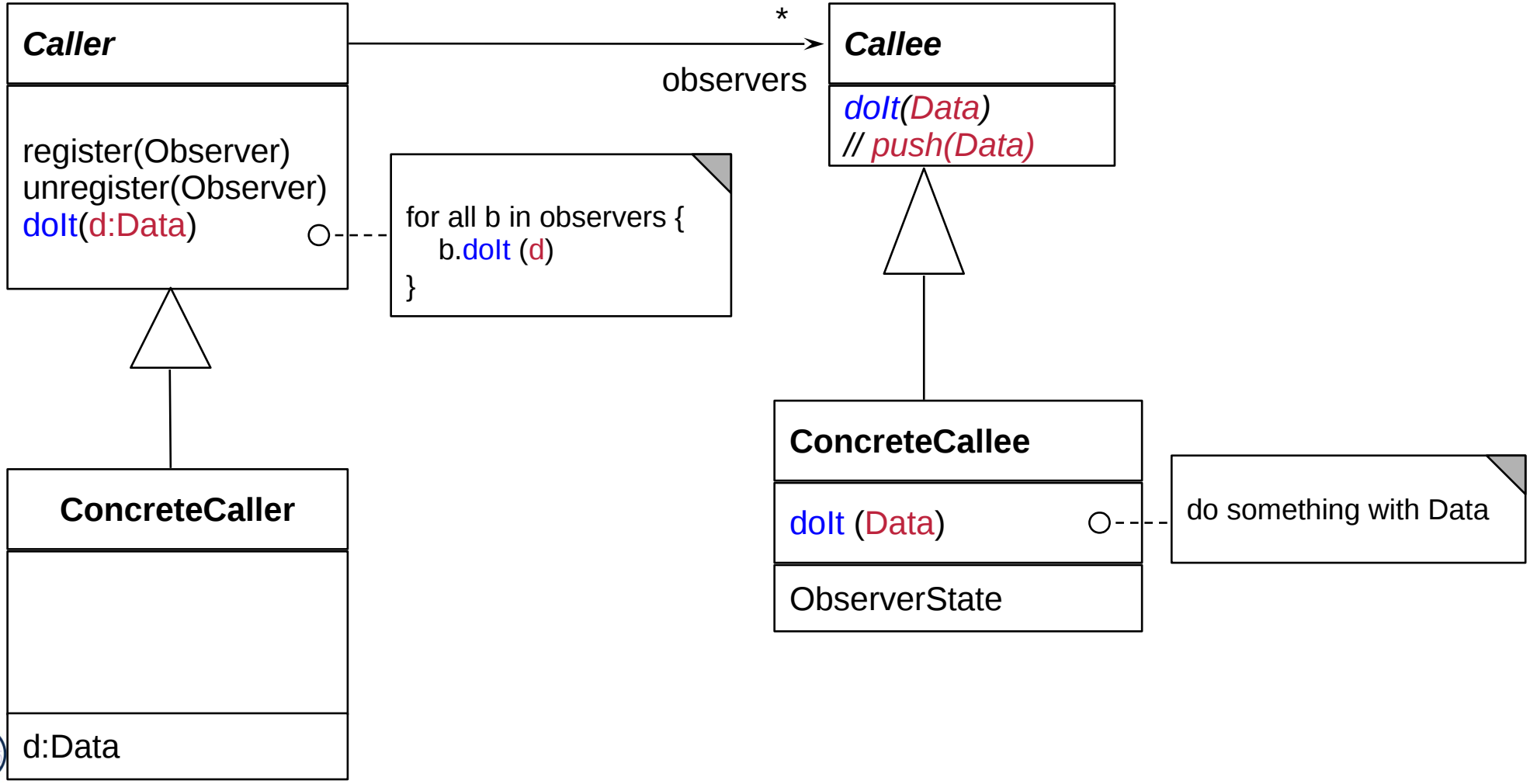
Sequence Diagram Subject-push-Observer

- Update() transfer Subject to Observer
  - Observer pulls data out of given Subject itself with getState(subject)



Structure Multi-Call

- If the methods in the Subject and the Observer are called the same, we speak of a **multi-call (extensible call)**
- At first, this looks like a normal call, but it can be extended from outside by registering new Callees

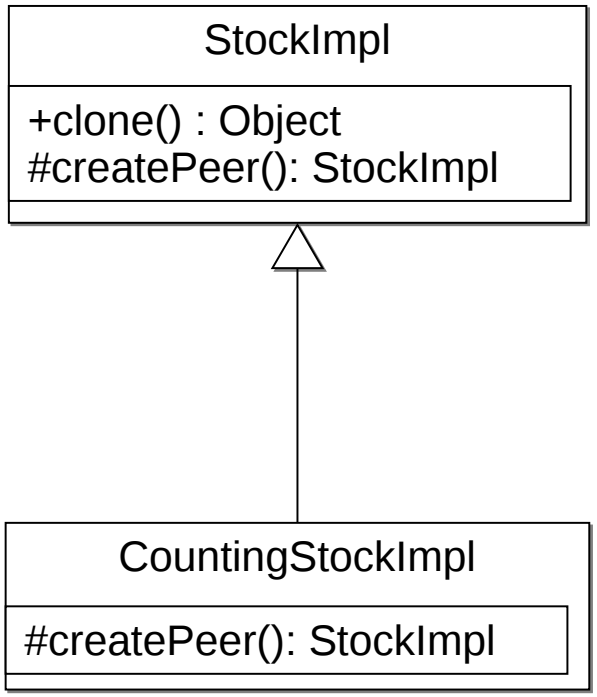


T&H on the Level of Classes

- Methods can be reified, i.e., represented as objects
  - In the TemplateMethod, the hook method can be split out of the class and put into a separate object
- We hand out additional roles for some classes
  - The template role
  - The hook role
- Resulting patterns:
  - Strategy (Template Class)
  - Bridge (Dimensional Class Hierarchies) for variability with parallel class hierarchies

Factory Method im SalesPoint-Rahmenwerk

- Anwender von SalesPoint verfeinern die StockImpl-Klasse, die ein Produkt des Warenhauses im Lager repräsentiert
  - z.B. mit einem CountingStockImpl, der weiß, wieviele Produkte noch da sind



Einsatz in Komponentenarchitekturen

- In Rahmenwerk-Architekturen wird die Fabrikmethode eingesetzt, um von oberen Schichten (Anwendungsschichten) aus die Rahmenwerkschicht zu konfigurieren: