# 24. Entwurfsmuster für Produktfamilien (Product Line Patterns)

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21-1.1, 6/5/21

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

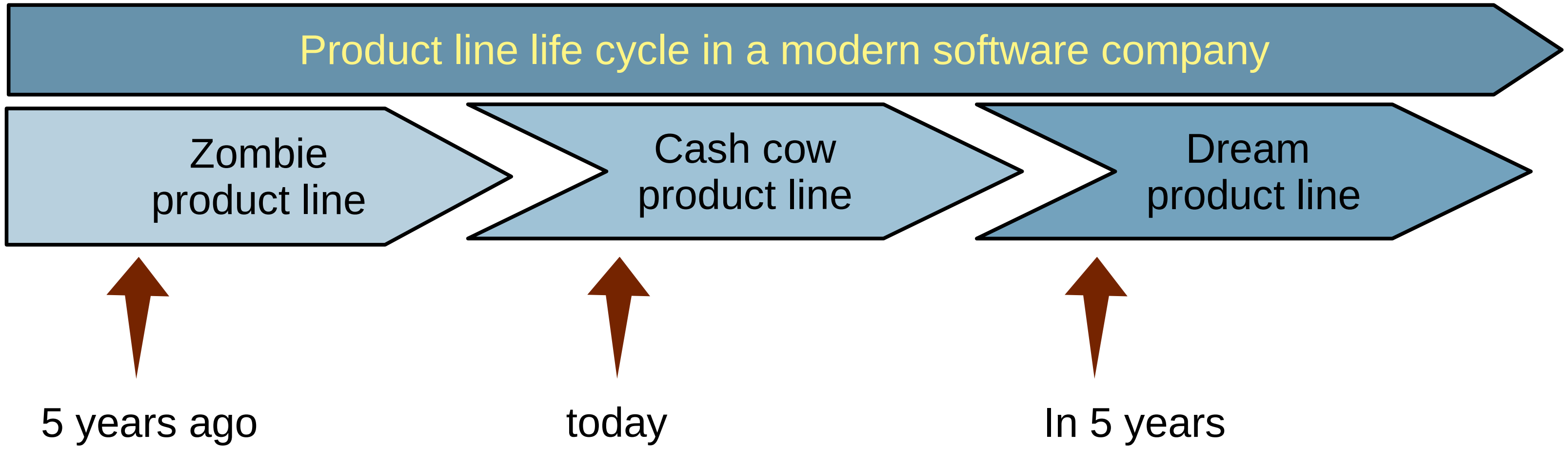
Achtung: Dieser Foliensatz ist teilweise in Englisch gefasst, weil das Thema in der Englisch-sprachigen Kurs “Design Patterns and Frameworks” (WS) wiederkehrt.
Mit der Bitte um Verständnis.

# 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.
- James W. Cooper. Java™ Design Patterns: A Tutorial. Addison Wesley, 2000, ISBN: 0-201-48539-7
  - http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.183.2228&rep=rep1&type=pdf
  - http://www.informit.com/store/java-design-patterns-a-tutorial-9780201485394 Section Download
  - Download books at http://www.freebookcentre.net/SpecialCat/Free-Design-Patterns-Books-Download.html
- https://refactoring.guru/design-patterns/java

# Standard Problems to Be Solved By *Product Line Patterns*

- Def.: A ***software product line (SPL)*** is a systematically engineered family of software products.
- **Product Line Patterns** are used to construct SPL, containing specific design knowledge about:
- **Variability: Exchanging parts easily**
  - Variation, variability, complex parameterization
  - Static and dynamic
  - For product lines, framework-based development
- **Extensibility: Add new features**
  - Software must change
- **Glue: Adapt to overcome architectural mismatches**
  - Coupling software that was not built for each other

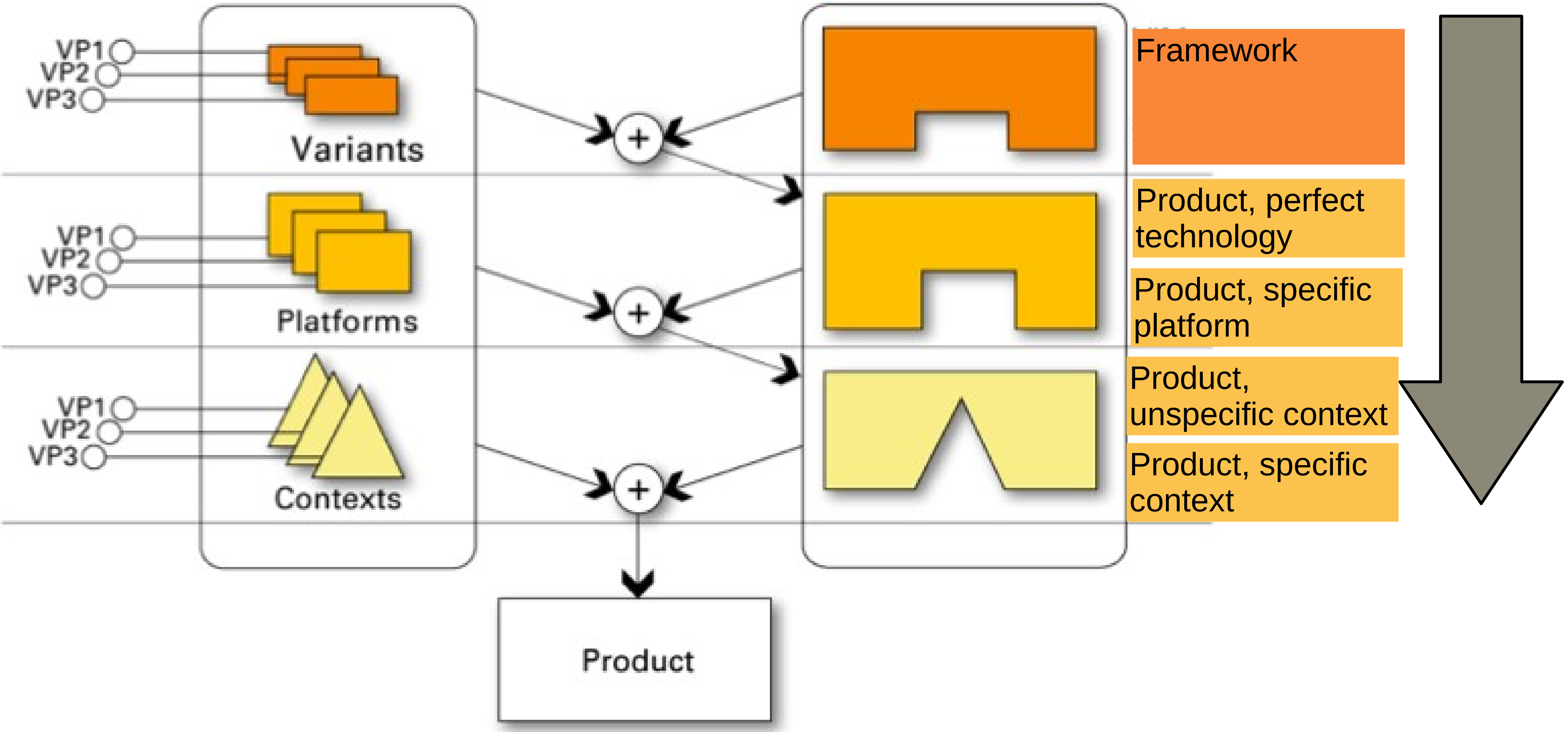


# 24.1) Patterns for Variability

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

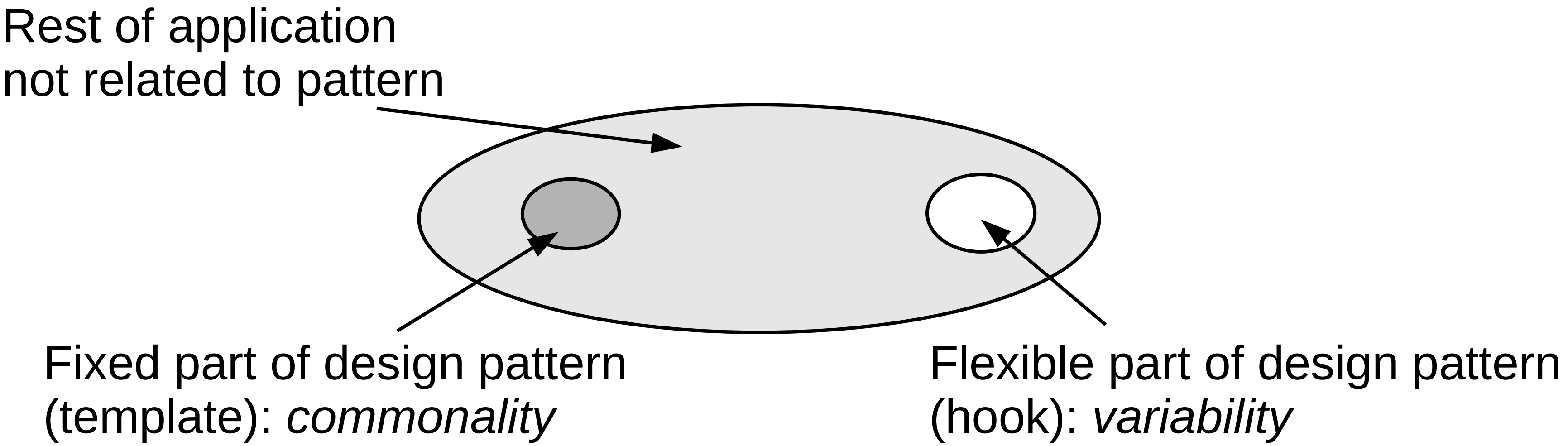
# Why Do We Need Variability?

- **Functional** features, packages (payed vs free use), etc can be varied
- **Platforms** (Hardware, operating system, database, GUI package, etc.) should be varied
- **Dynamic contexts** (personalization, time and location) may vary


VP1
VP2
VP3
Variants
VP1
VP2
VP3
Platforms
VP1
VP2
VP3
Contexts
+
+
+
Product
Framework
Product, perfect technology
Product, specific platform
Product, unspecific context
Product, specific context

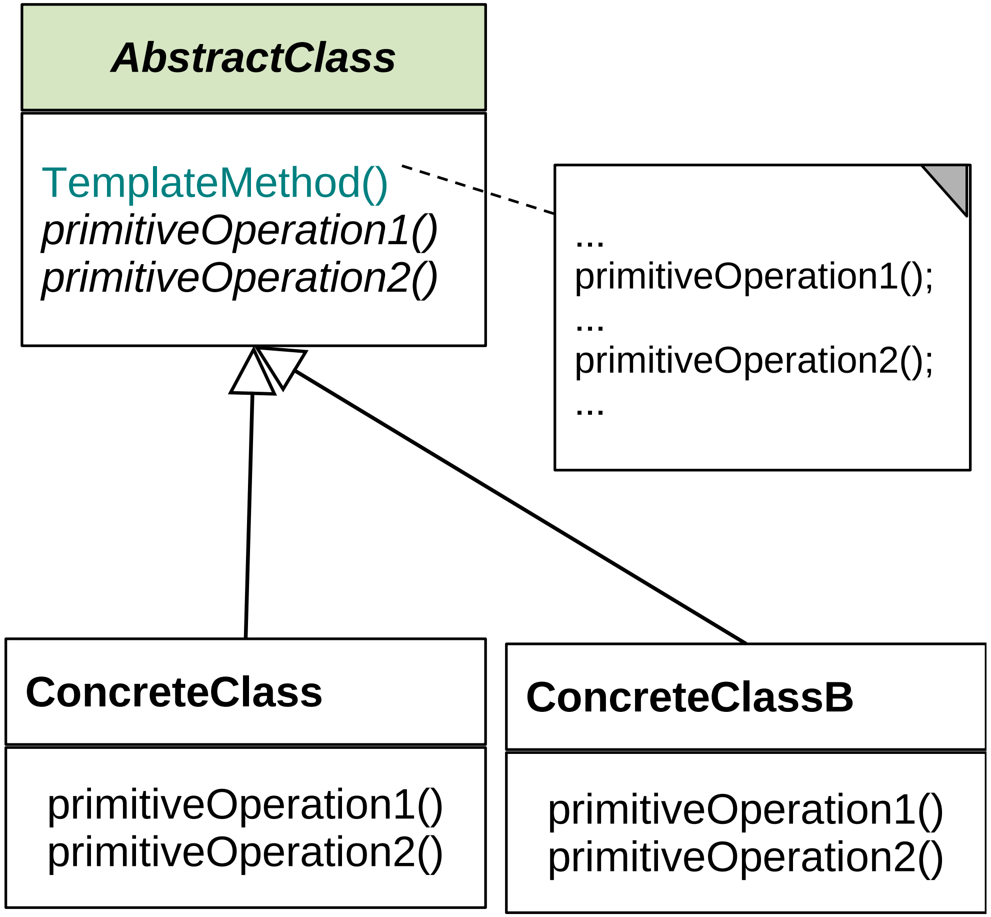
# Commonalities and Variabilities

- A ***variability design pattern*** describes
  - Code *common* to several applications
    - Commonalities lead to *frameworks* of *product lines*
  - Code *different or variable* from application to application
    - Variabilities lead 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)


Rest of application
not related to pattern
Fixed part of design pattern
(template): *commonality*
Flexible part of design pattern
(hook): *variability*

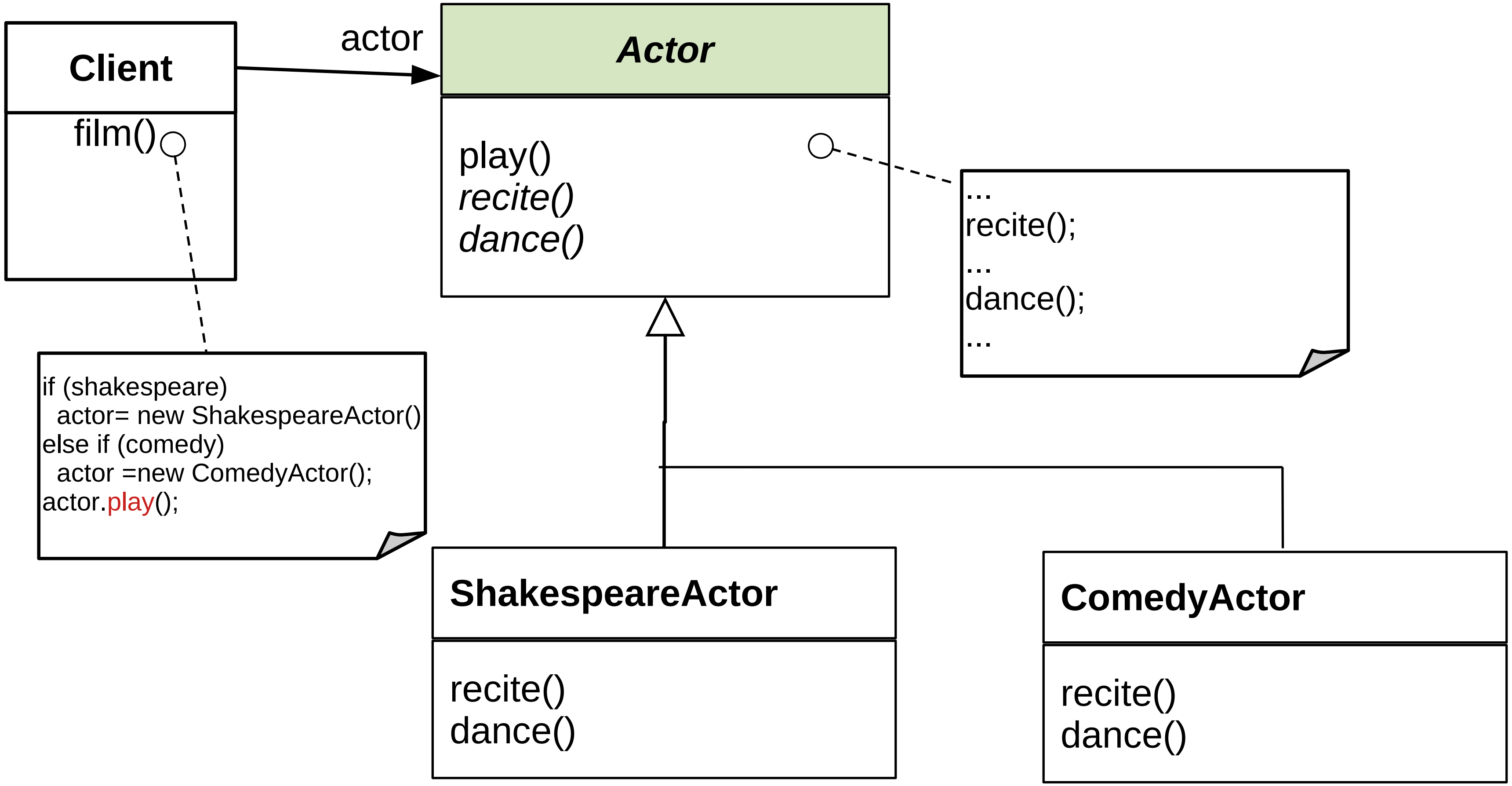
# TemplateMethod Pattern is a Variability Design Pattern (Rpt.)

- 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

- Polymorphy in a common template method `play()`
- Binding an Actor's hook to be a ShakespeareActor *or* a Comedy Actor
- The behavior visible to a client will
  - be common in play()
  - but differ in two aspects, reciting and dancing

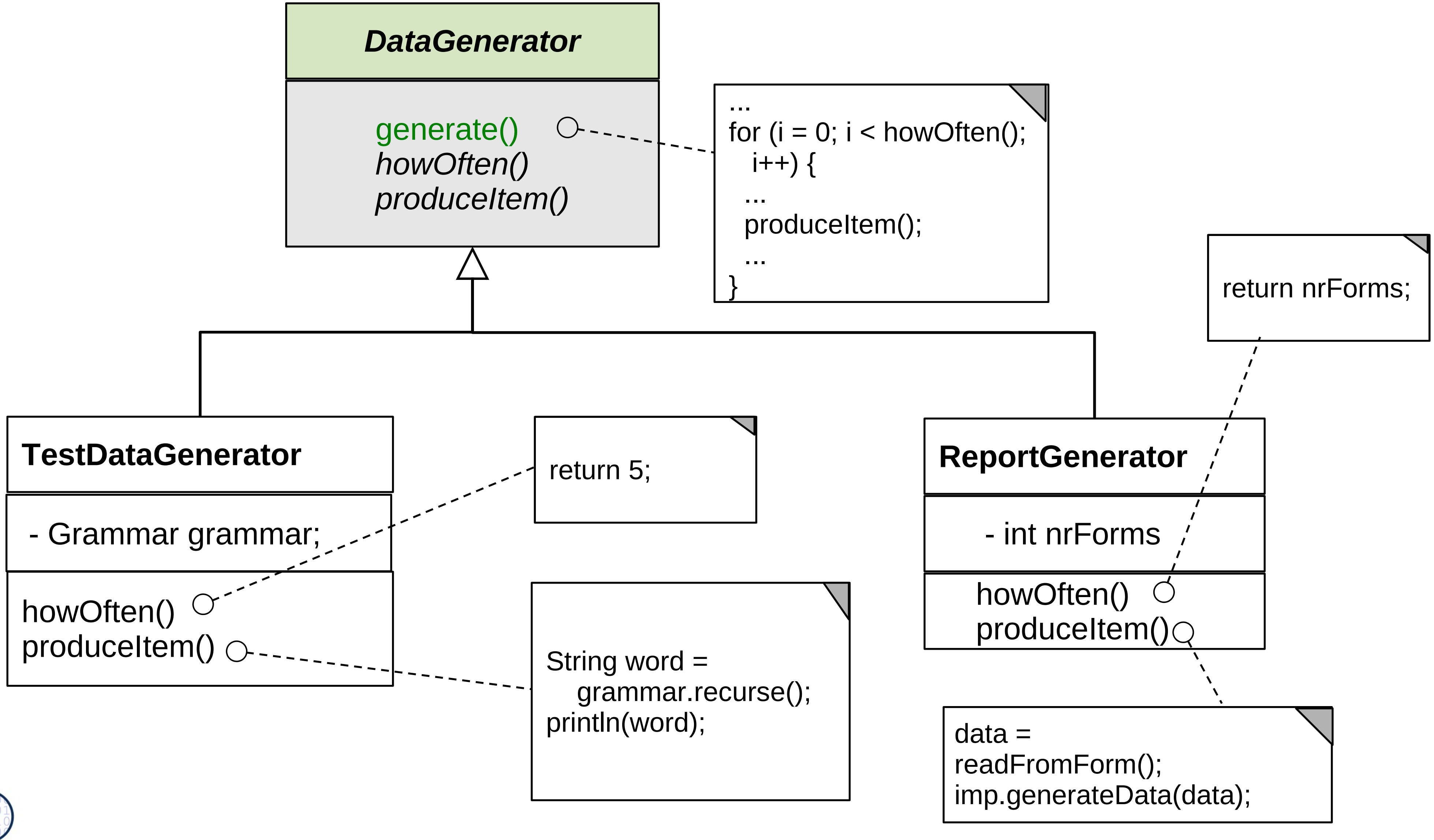


```
if (shakespeare)
  actor= new ShakespeareActor()
else if (comedy)
  actor =new ComedyActor();
actor.play();
```

```
...
recite();
...
dance();
...
```

# Running Example: A Data Generator

- Parameterizing a data generator by frequency and kind of production



```
...
for (i = 0; i < howOften();
   i++) {
  ...
  produceItem();
  ...
}
```

```
return nrForms;
```

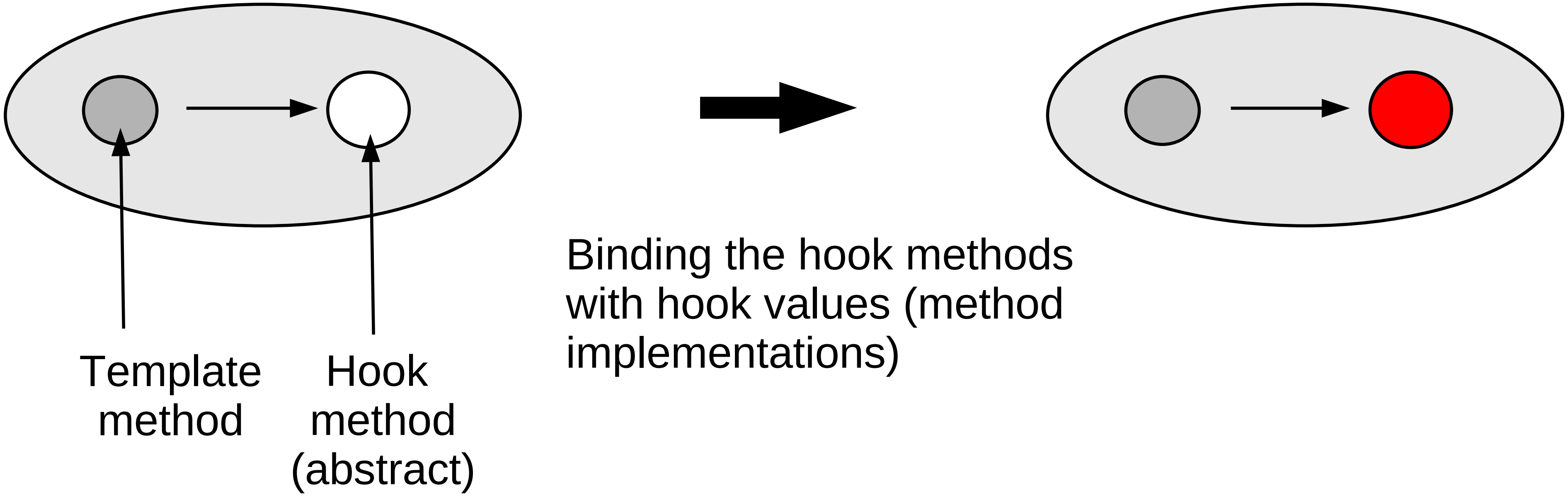
```
return 5;
```

```
String word =
    grammar.recurse();
println(word);
```

```
data =
readFromForm();
imp.generateData(data);
```

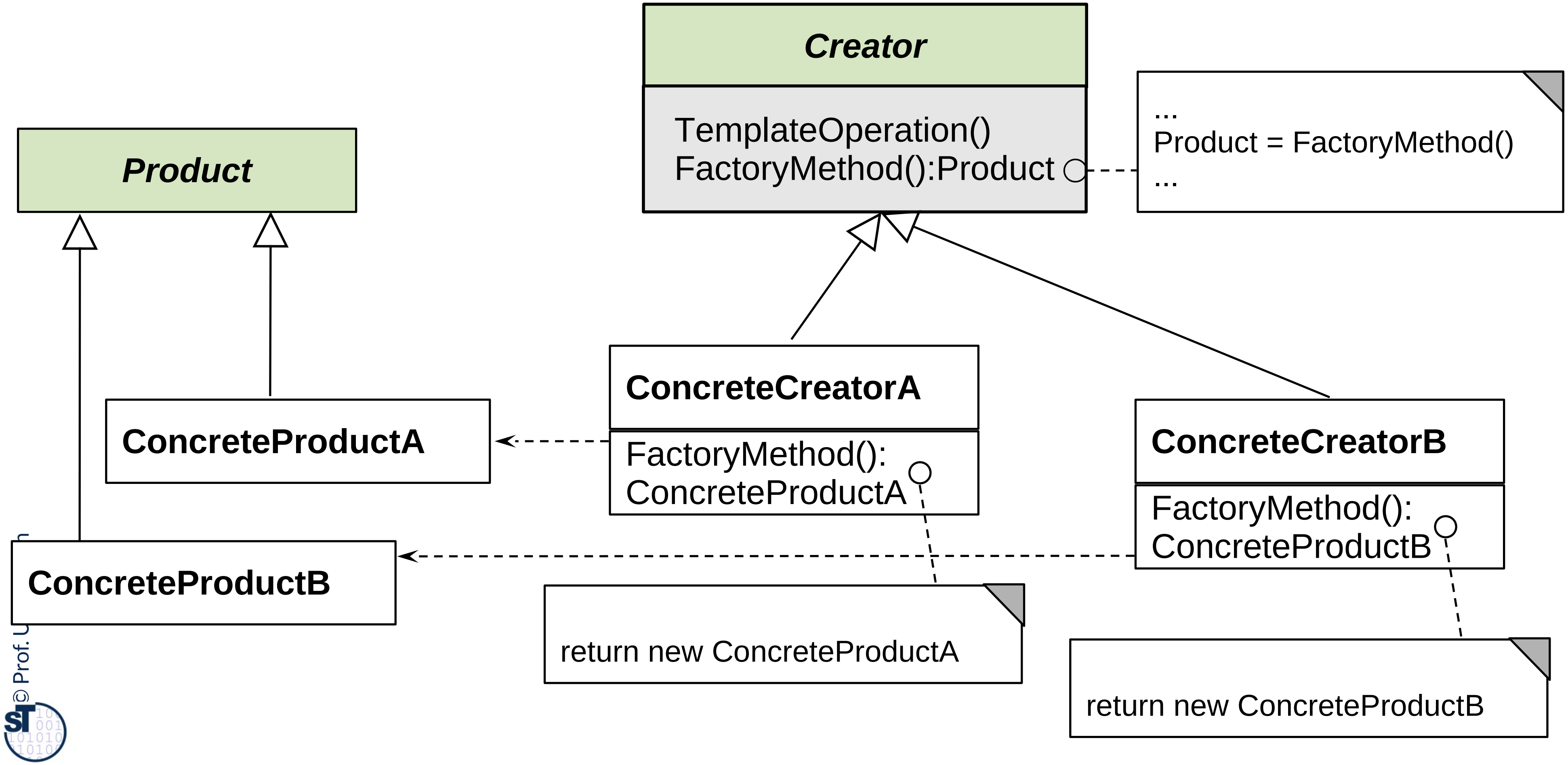
# Variability with TemplateMethod

- **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


Template method
Hook method (abstract)
Binding the hook methods with hook values (method implementations)

# 24.1.2 FactoryMethod

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

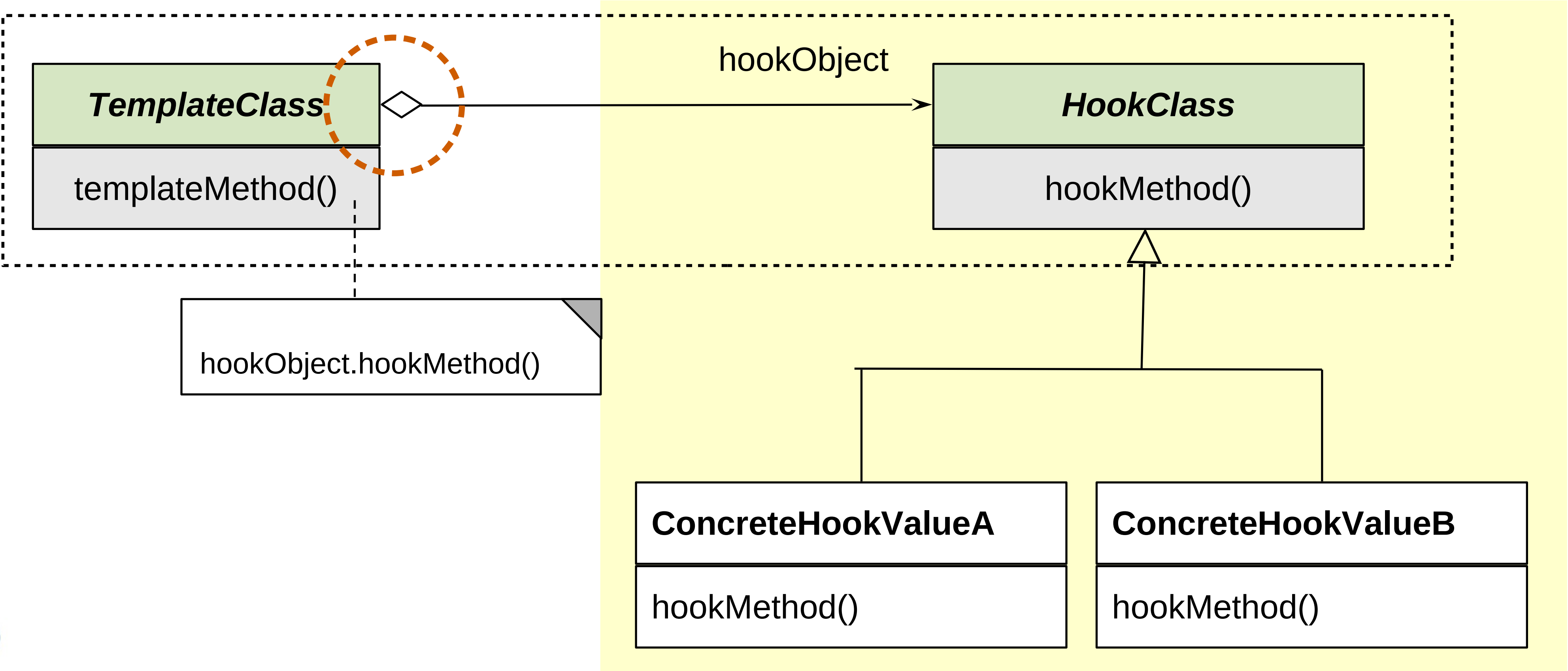


# 24.1.3 Strategy (Template Class)

- The STRATEGY pattern is a TEMPLATE CLASS pattern with the same structure, but a more specific intent

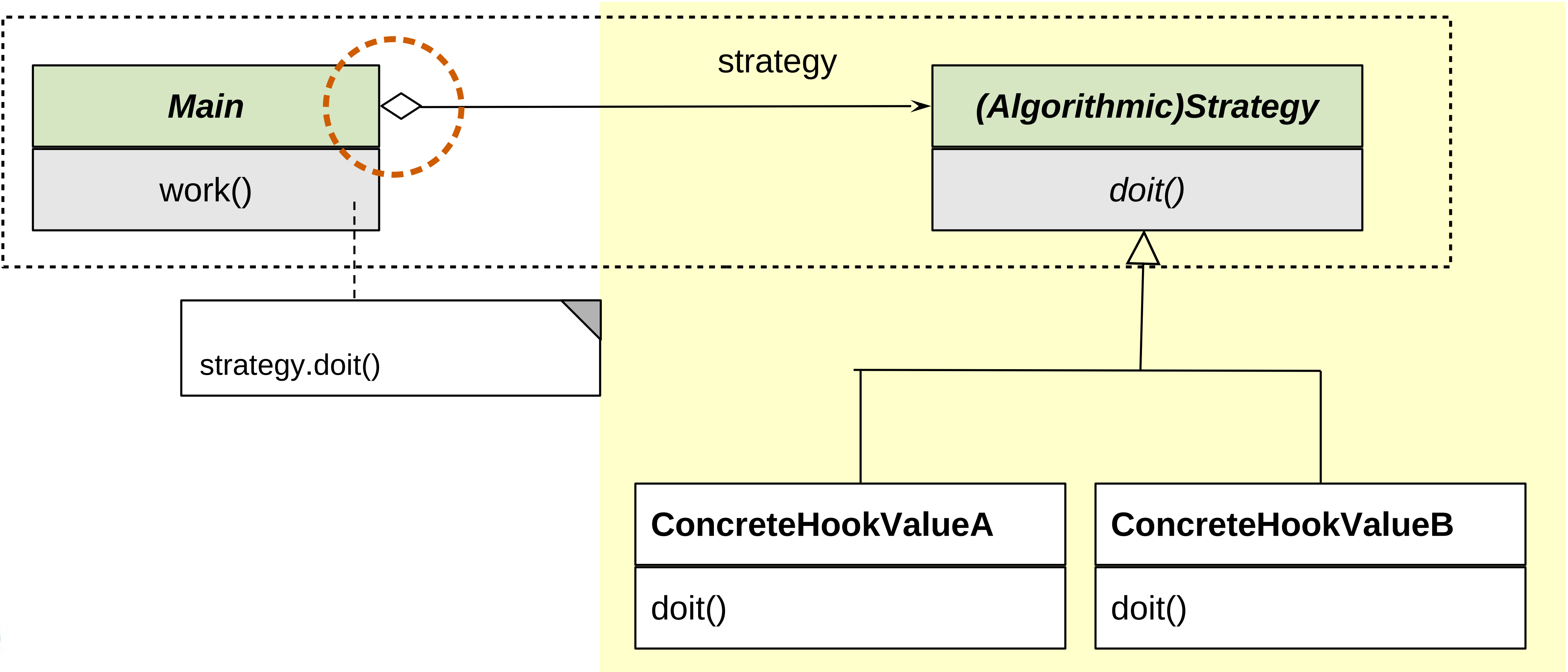
# Template Class

- 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
  - May exchange several methods (a set of methods) at the same time
- This pattern is basis of Bridge, Builder, Command, Iterator, Observer, Visitor.



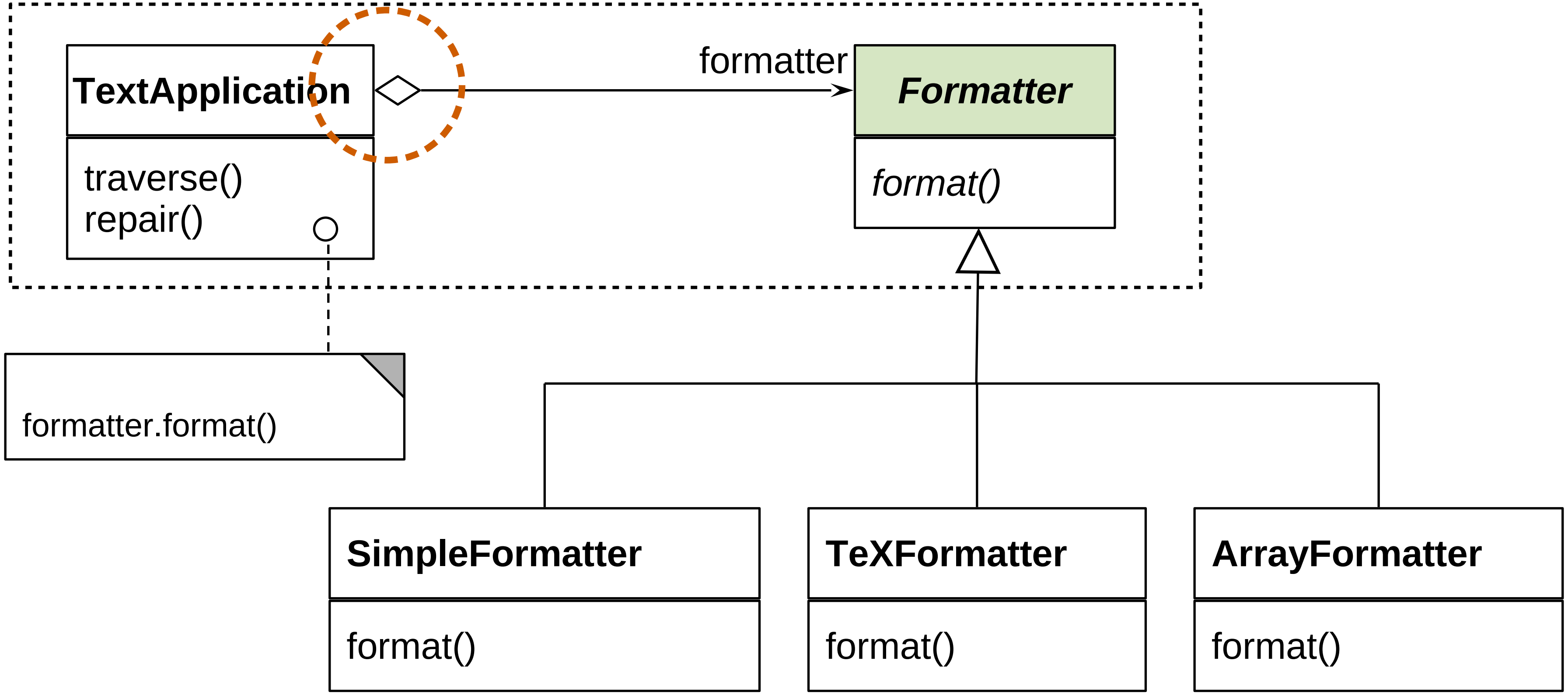
# Strategy (Specific Template Class with Algorithm Mixin)

- Similar to TemplateClass, but different intention
  - Consistent exchange of **several parts of an algorithm within a main object**, not only one method
- This pattern is basis of Bridge, Builder, Command, Iterator, Observer, Visitor.



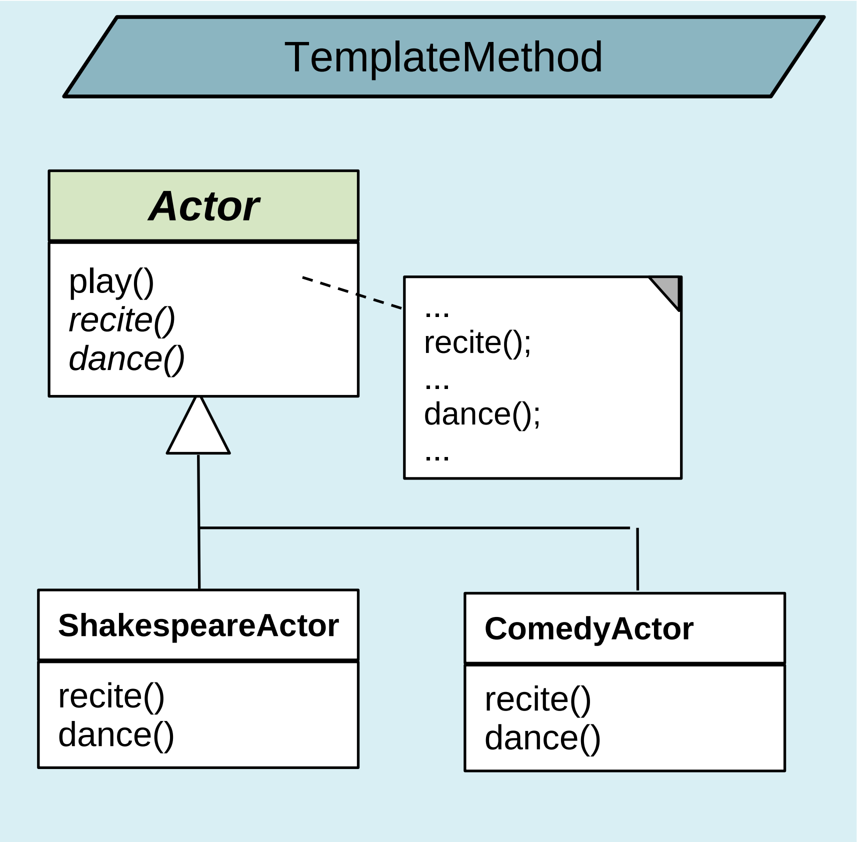
# Example for (algorithmic) Strategy

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

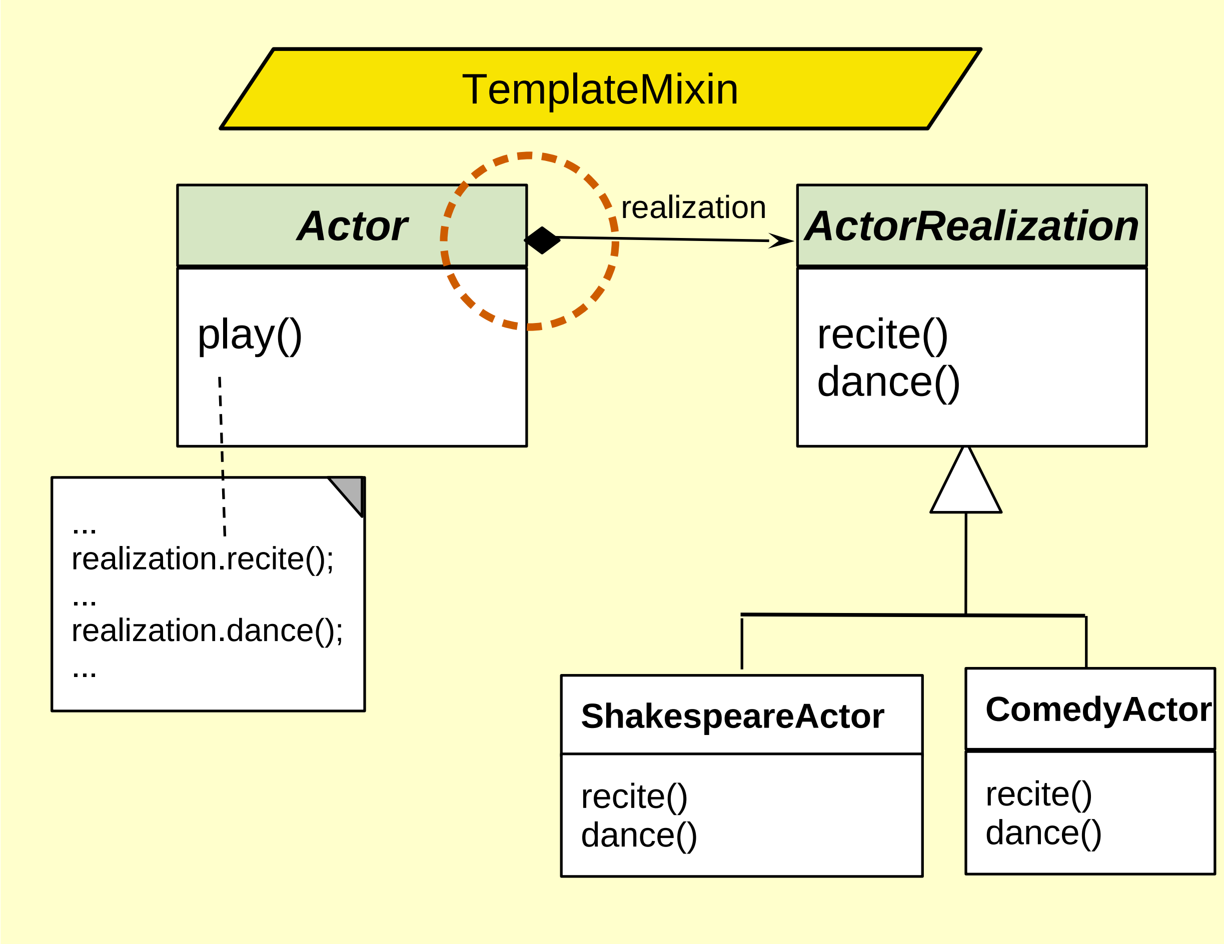


# Variants of TemplateClass: Strategy, TemplateMethod, TemplateMixin

- TemplateMethod creates *one* run-time object
- TemplateClass creates *two physical objects belonging to one logical object*
- TemplateMixin is a TemplateClass *with Mixin and Composition*
- Strategy is a TemplateClass with algorithmic Hook object



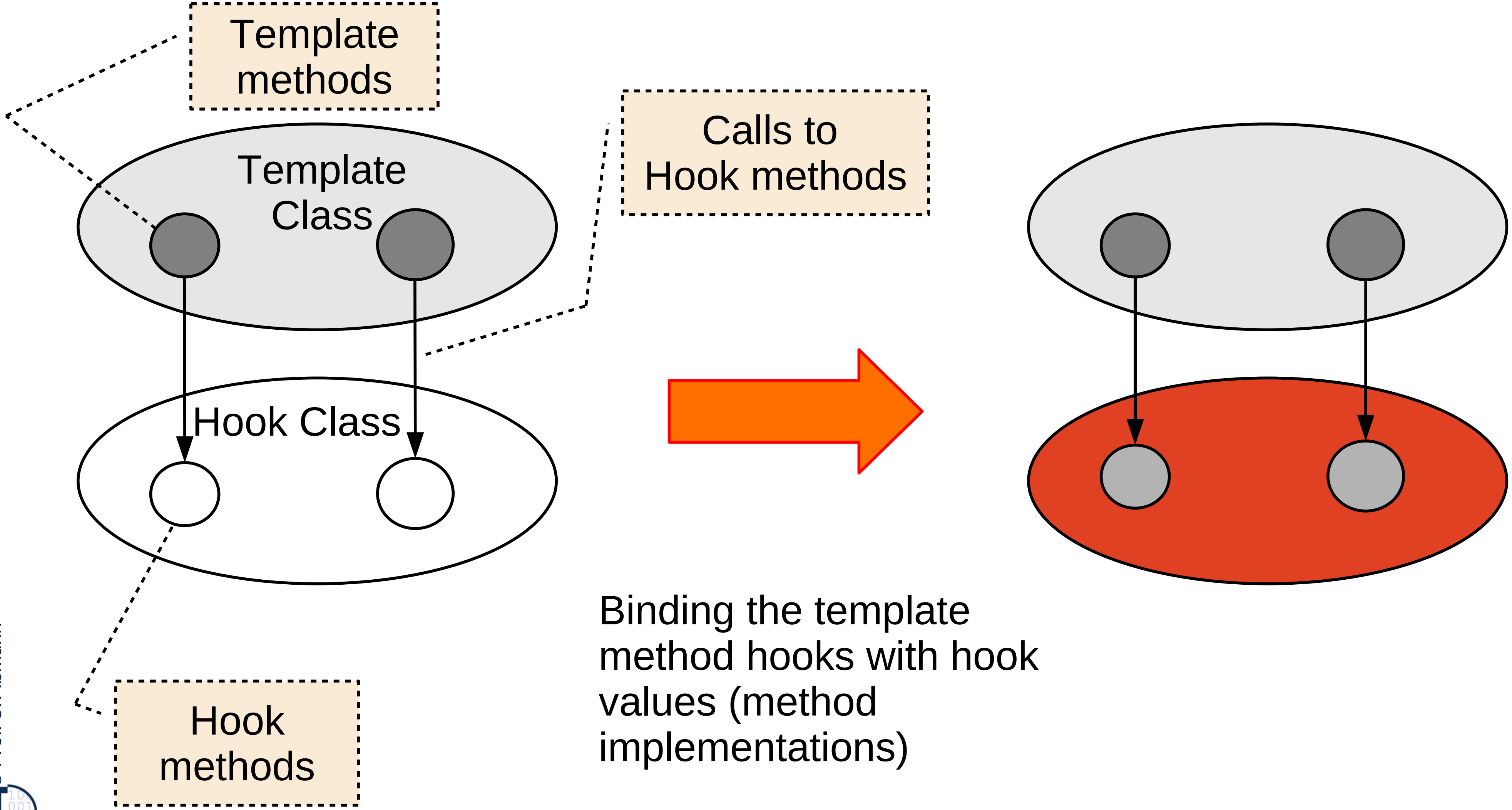
```
...
recite();
...
dance();
...
```



```
...
realization.recite();
...
realization.dance();
...
```

# 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

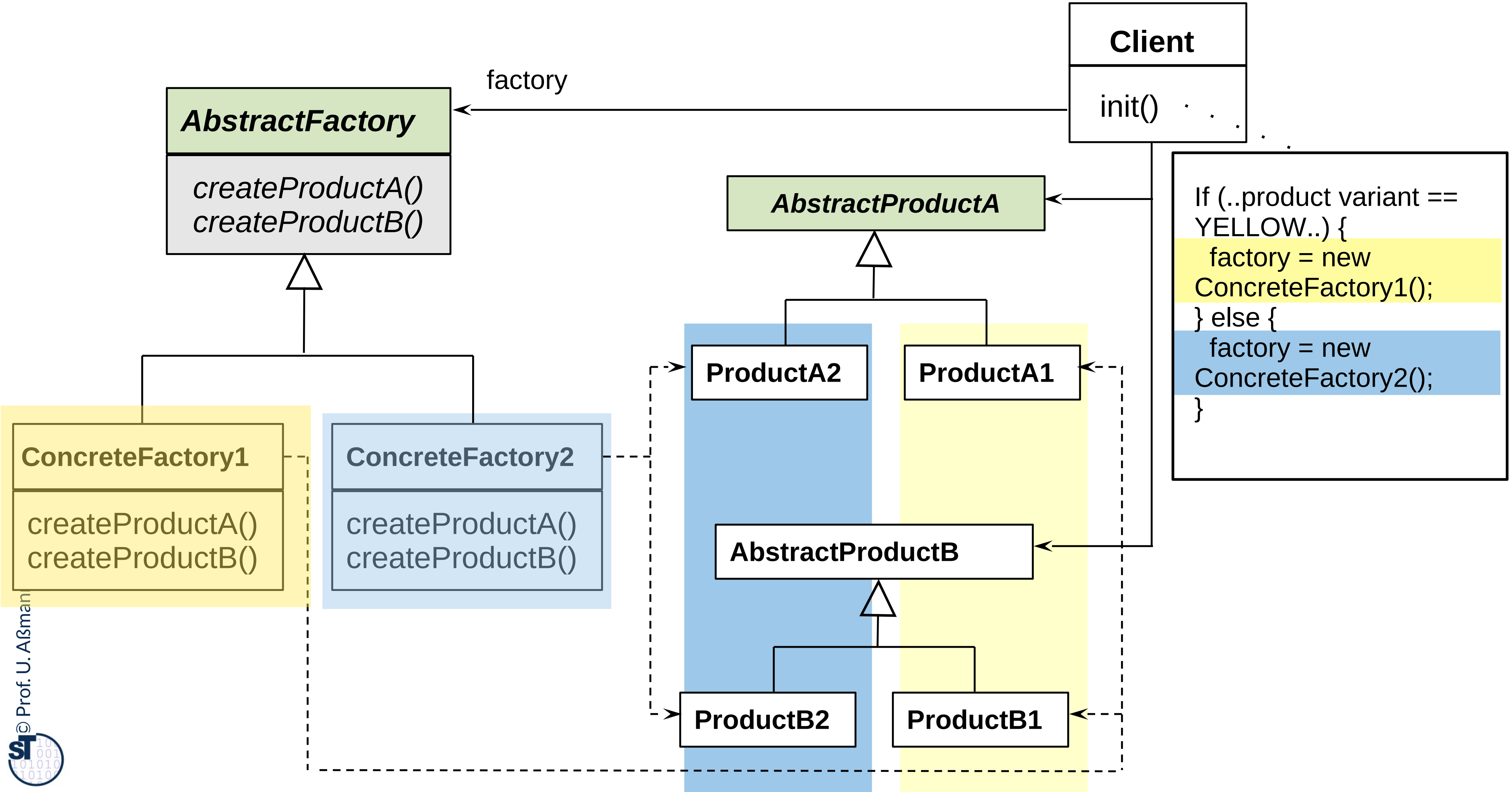


Binding the template method hooks with hook values (method implementations)

# 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



Client

init()

factory

*AbstractFactory*

*createProductA()*
*createProductB()*

ConcreteFactory1

createProductA()
createProductB()

ConcreteFactory2

createProductA()
createProductB()

*AbstractProductA*

ProductA2

ProductA1

AbstractProductB

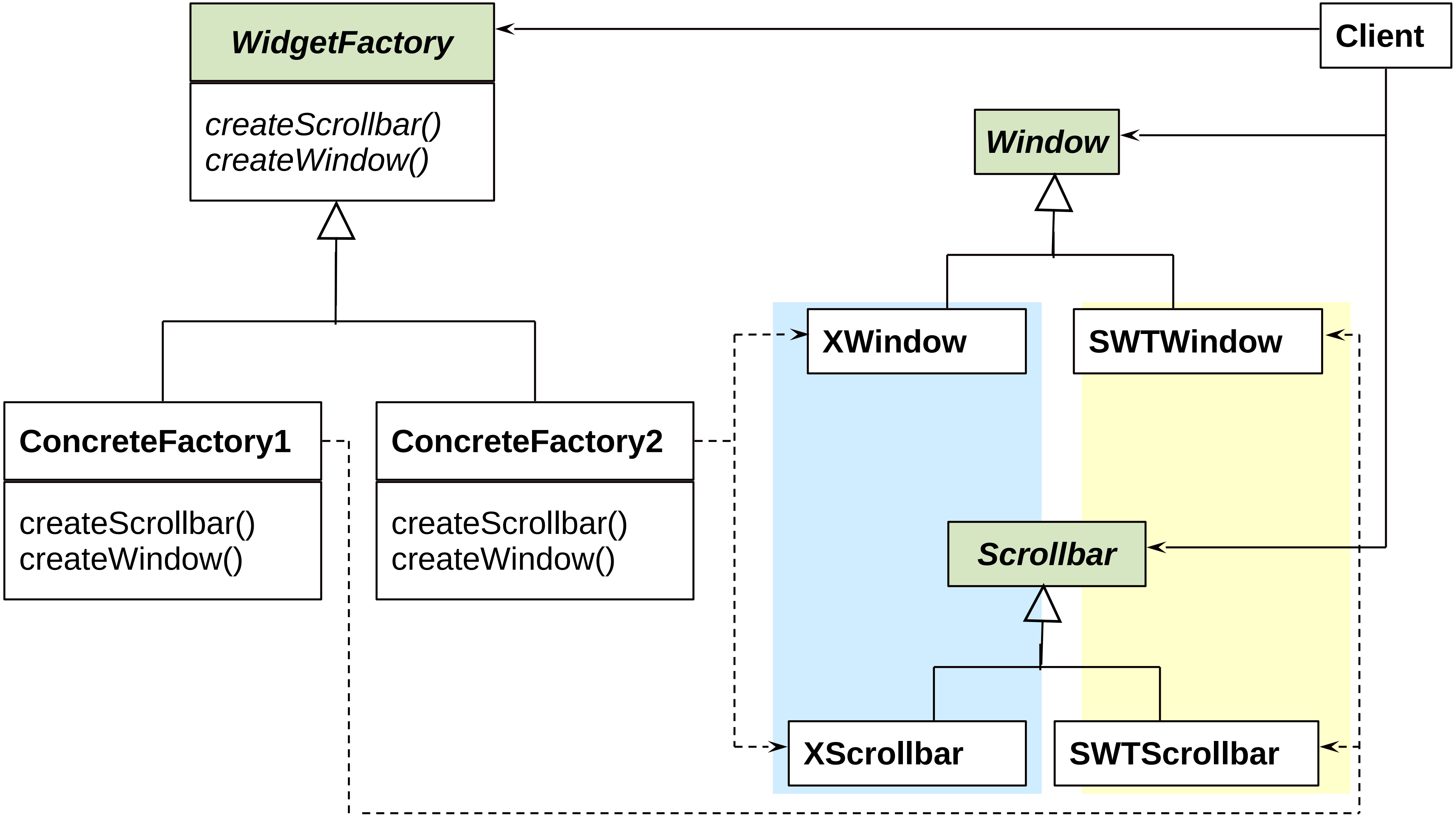
ProductB2

ProductB1

```
If (..product variant ==
YELLOW..) {
  factory = new
ConcreteFactory1();
} else {
  factory = new
ConcreteFactory2();
}
```

# Example for  Factory Class

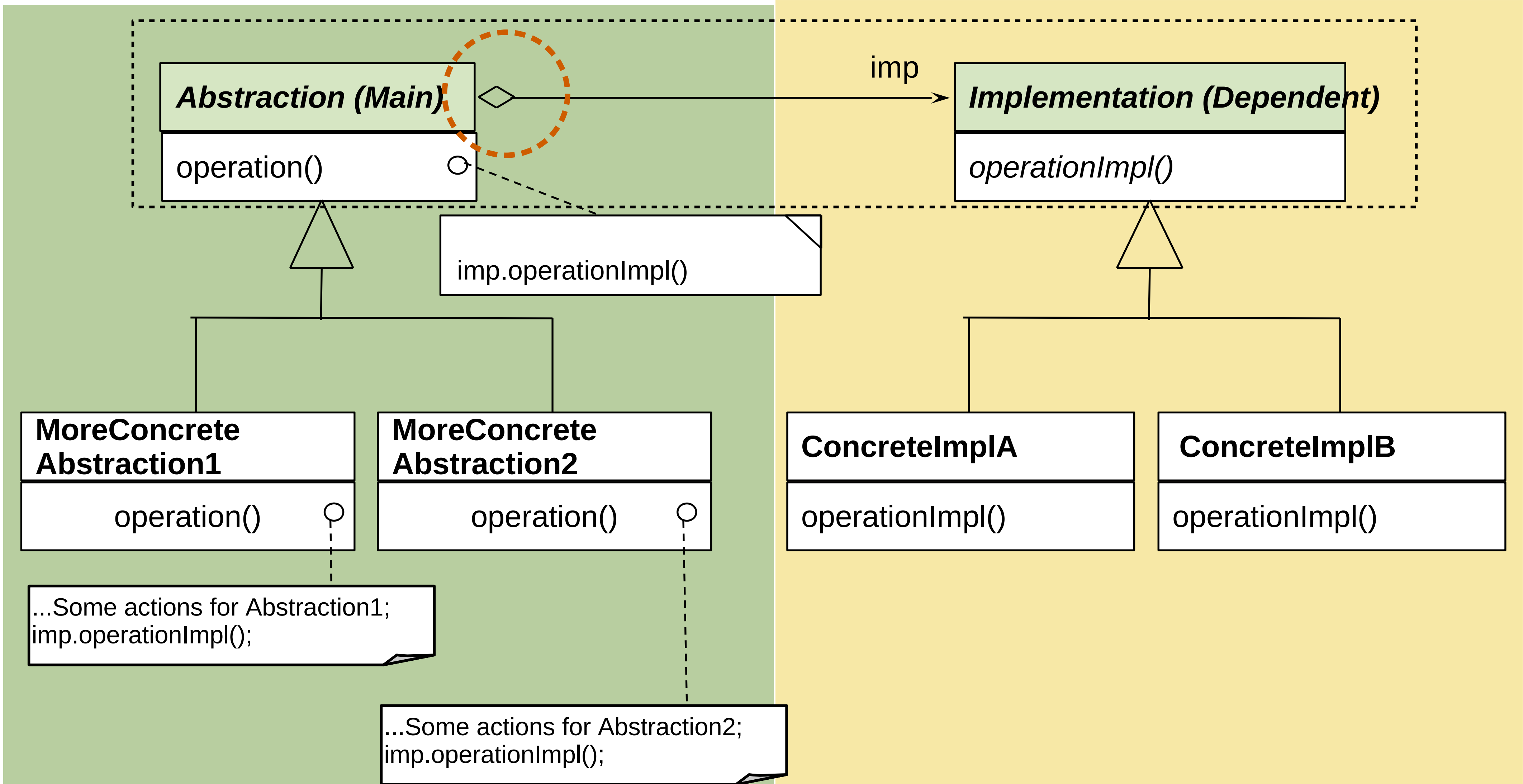
- Consistently varying a family of widgets



# 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*



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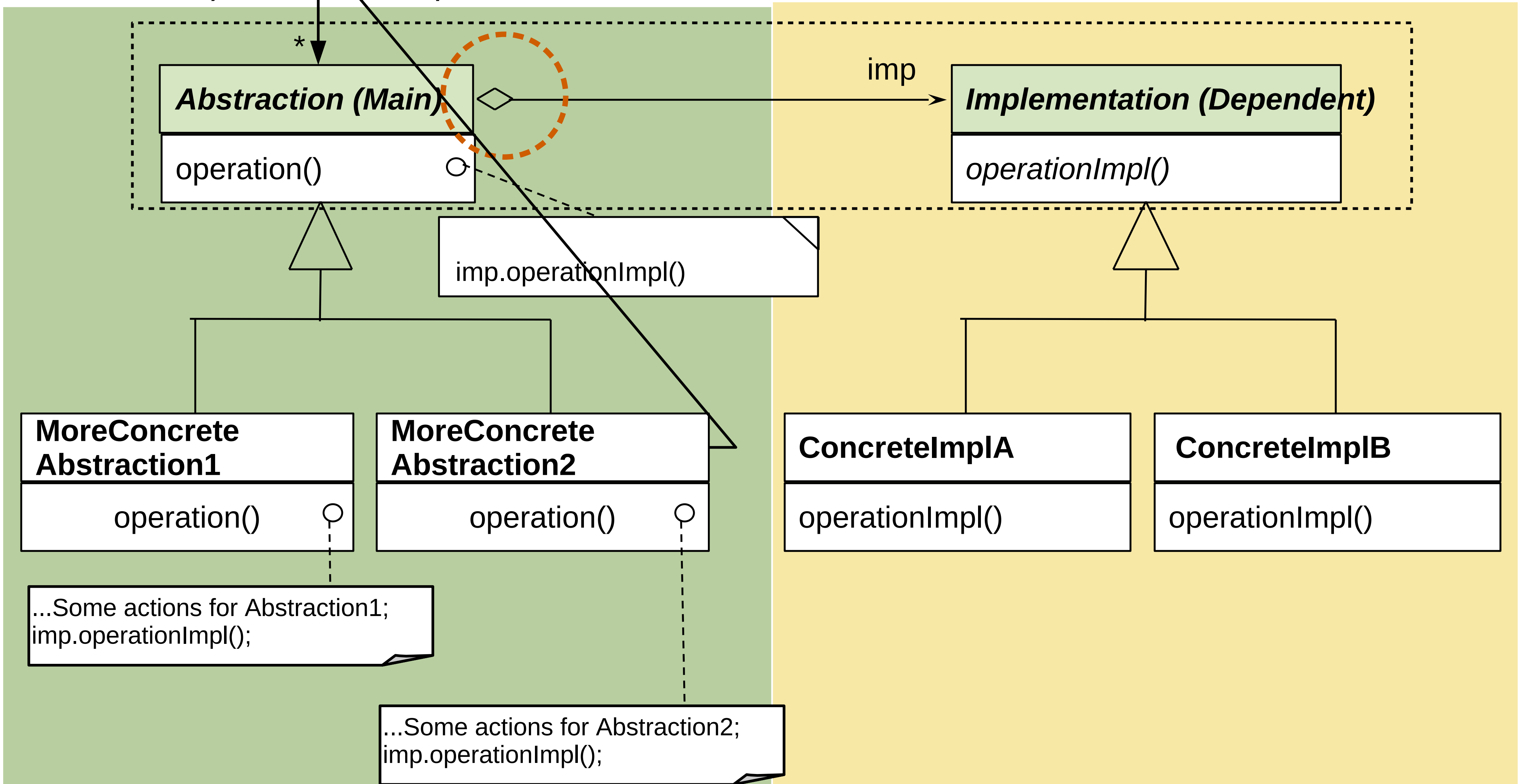
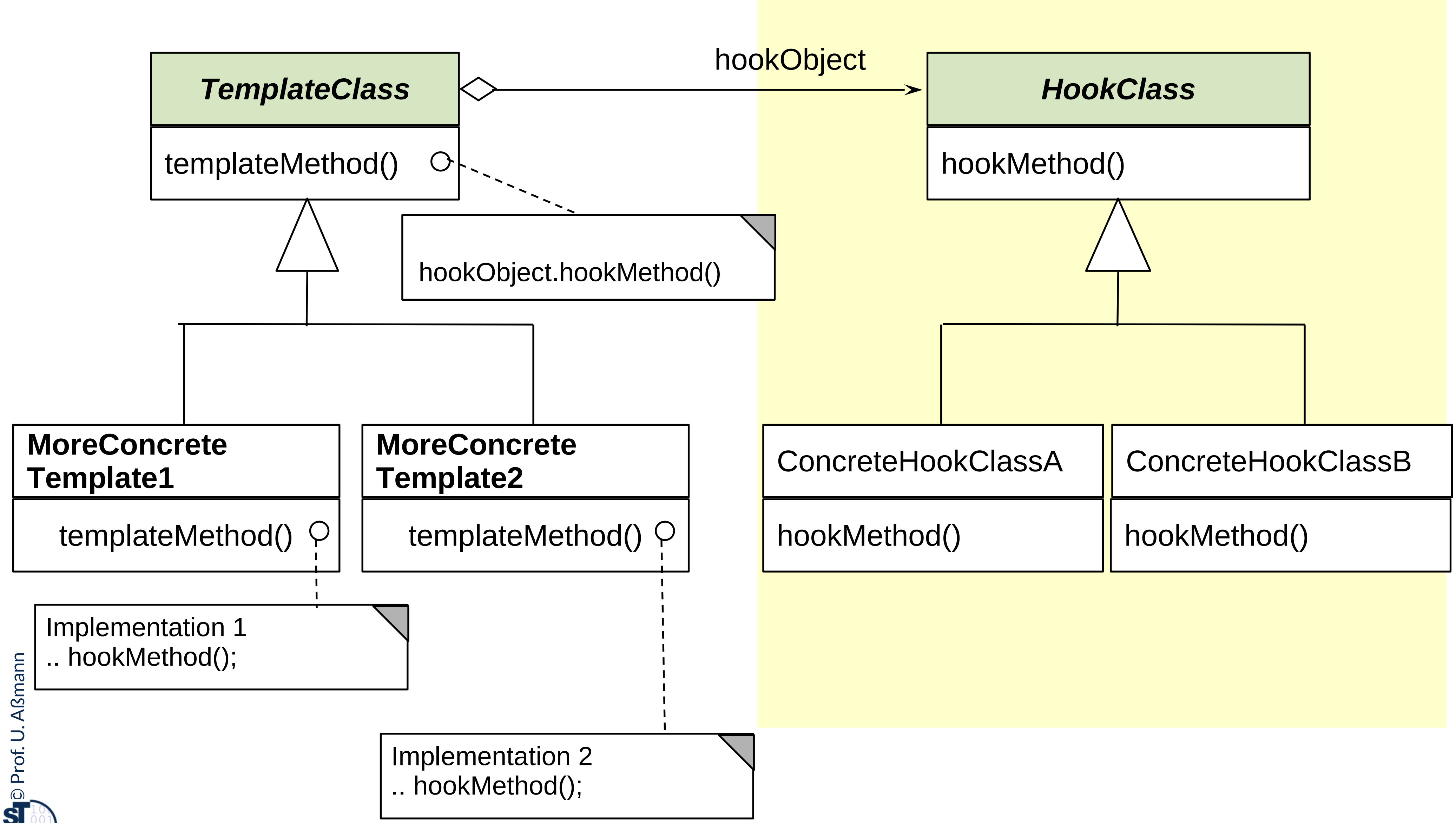


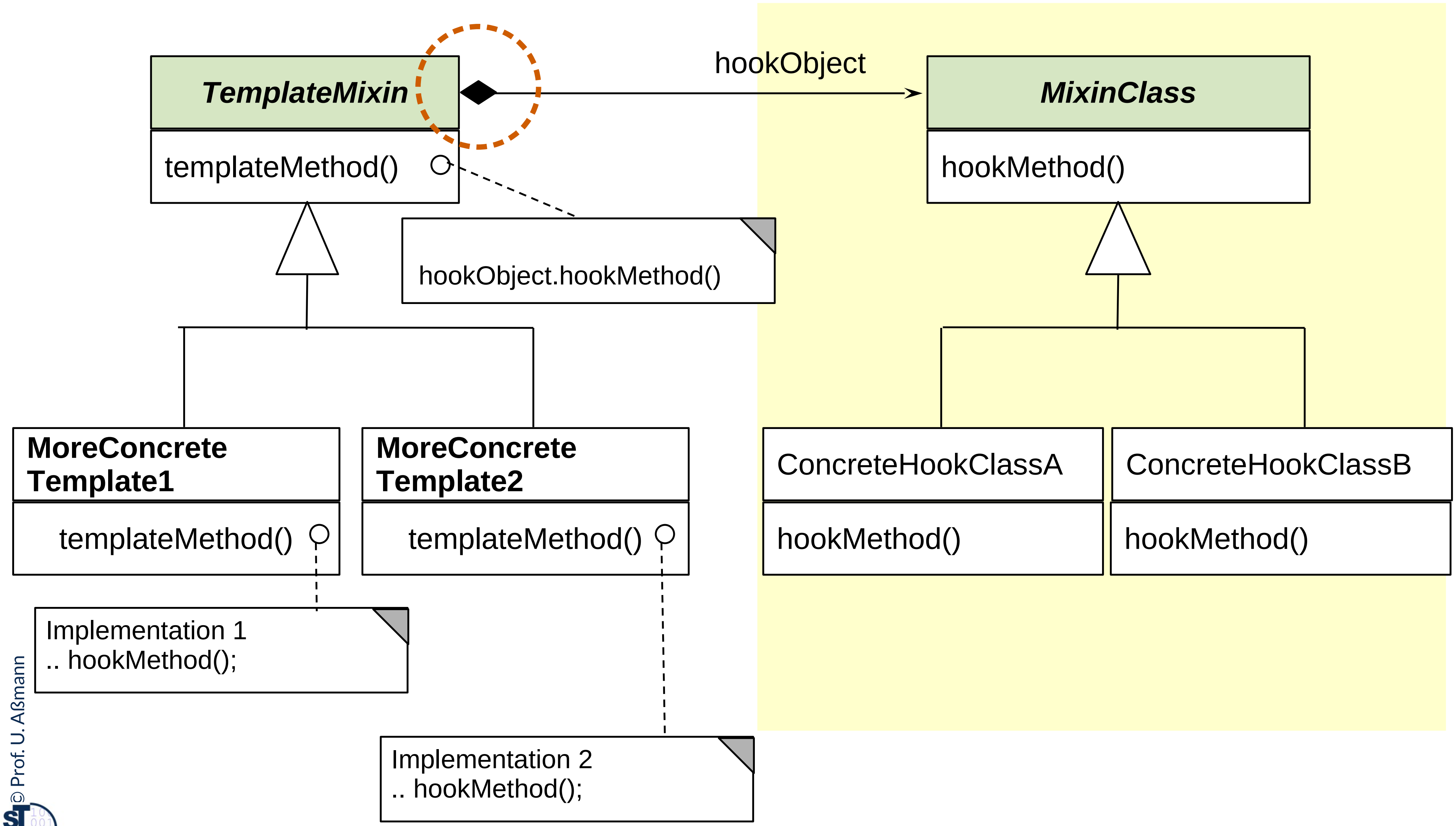
# Bridge as DimensionalClassHierarchies

- DimensionalClassHierarchies is an extension of TemplateClass

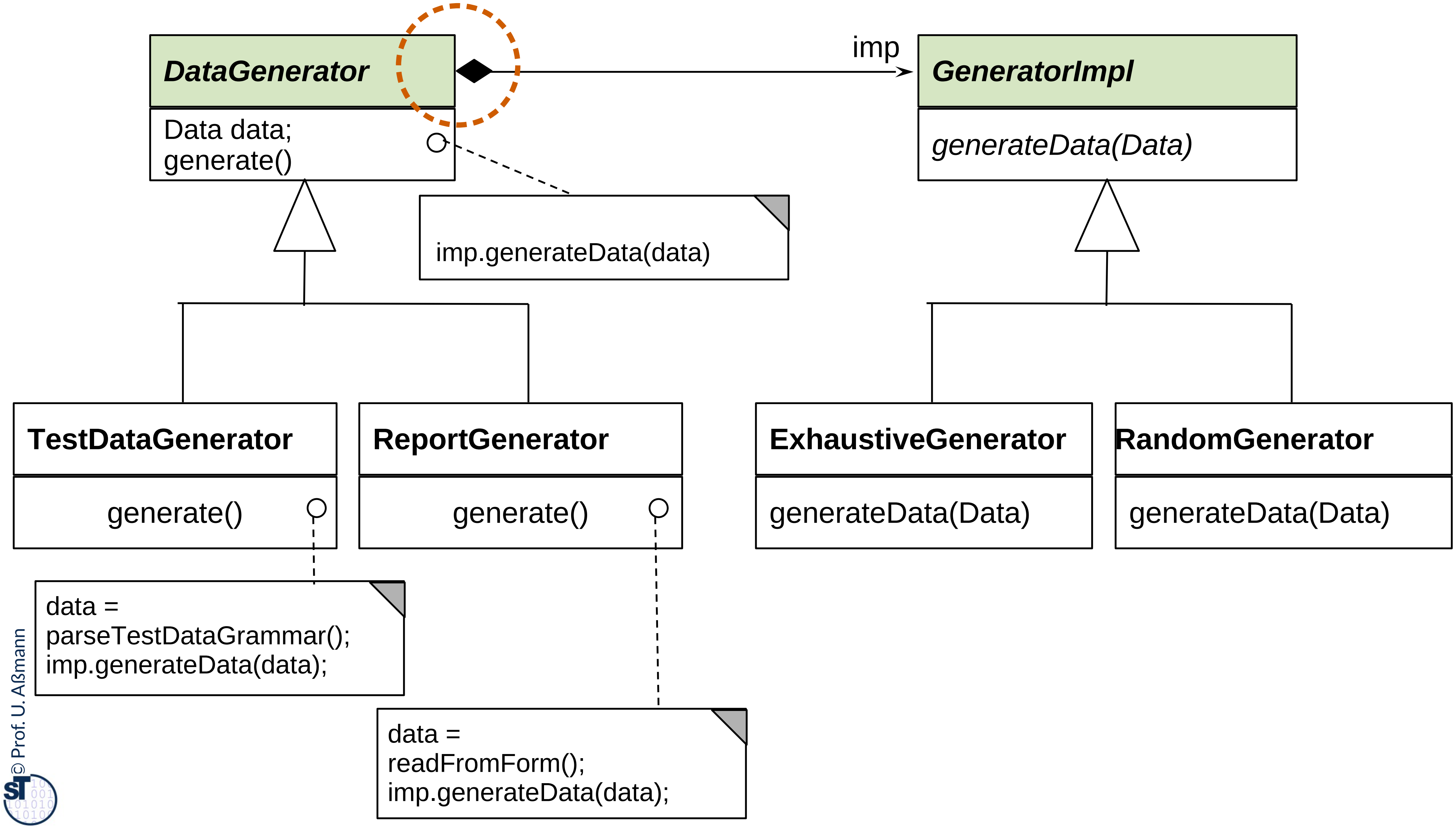


# TemplateMixin as Dimensional Mixin Variation

- Bridge is an extension of TemplateClass

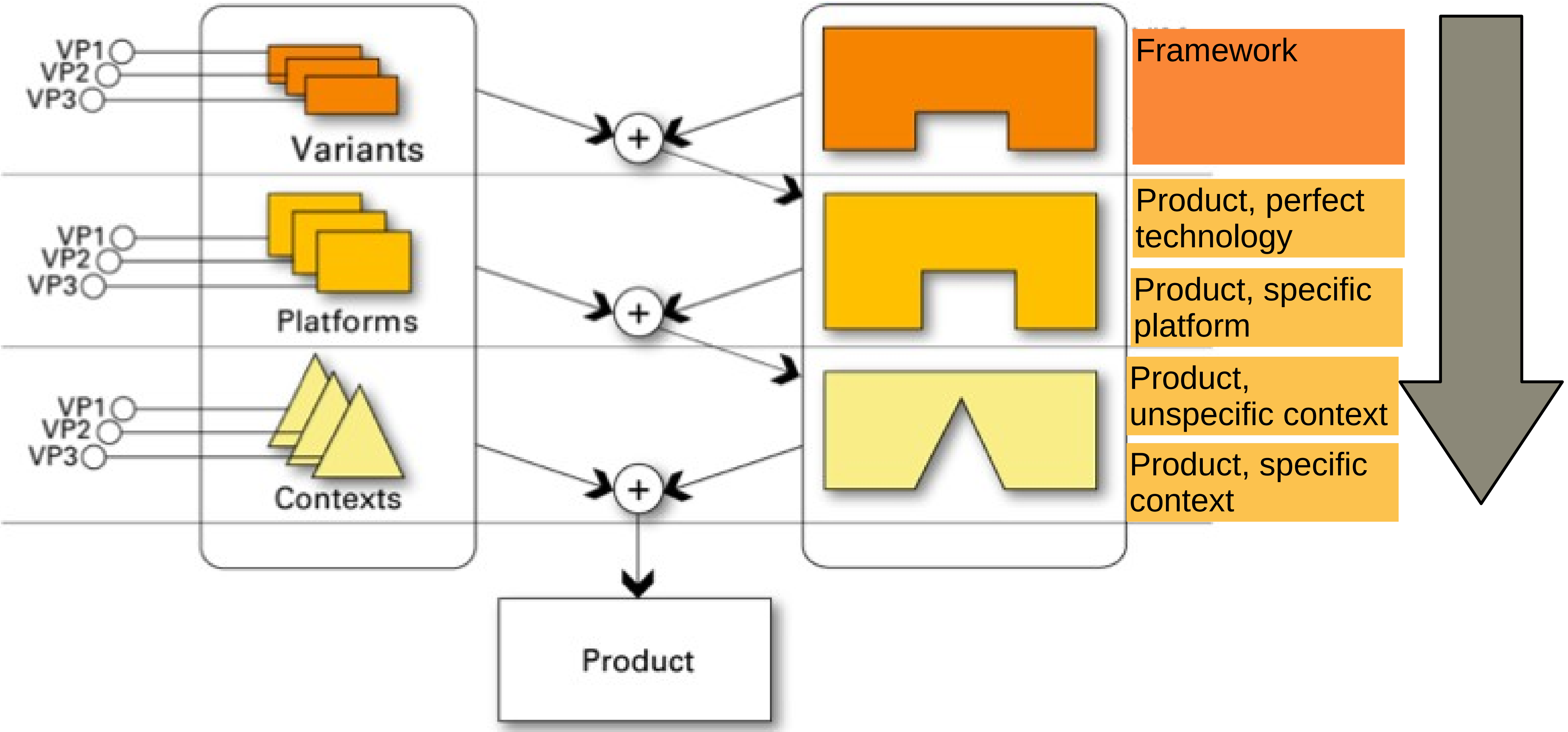


# Ex. Complex Object *DataGenerator* as Bridge



# Rpt.: 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)



Framework

Product, perfect technology

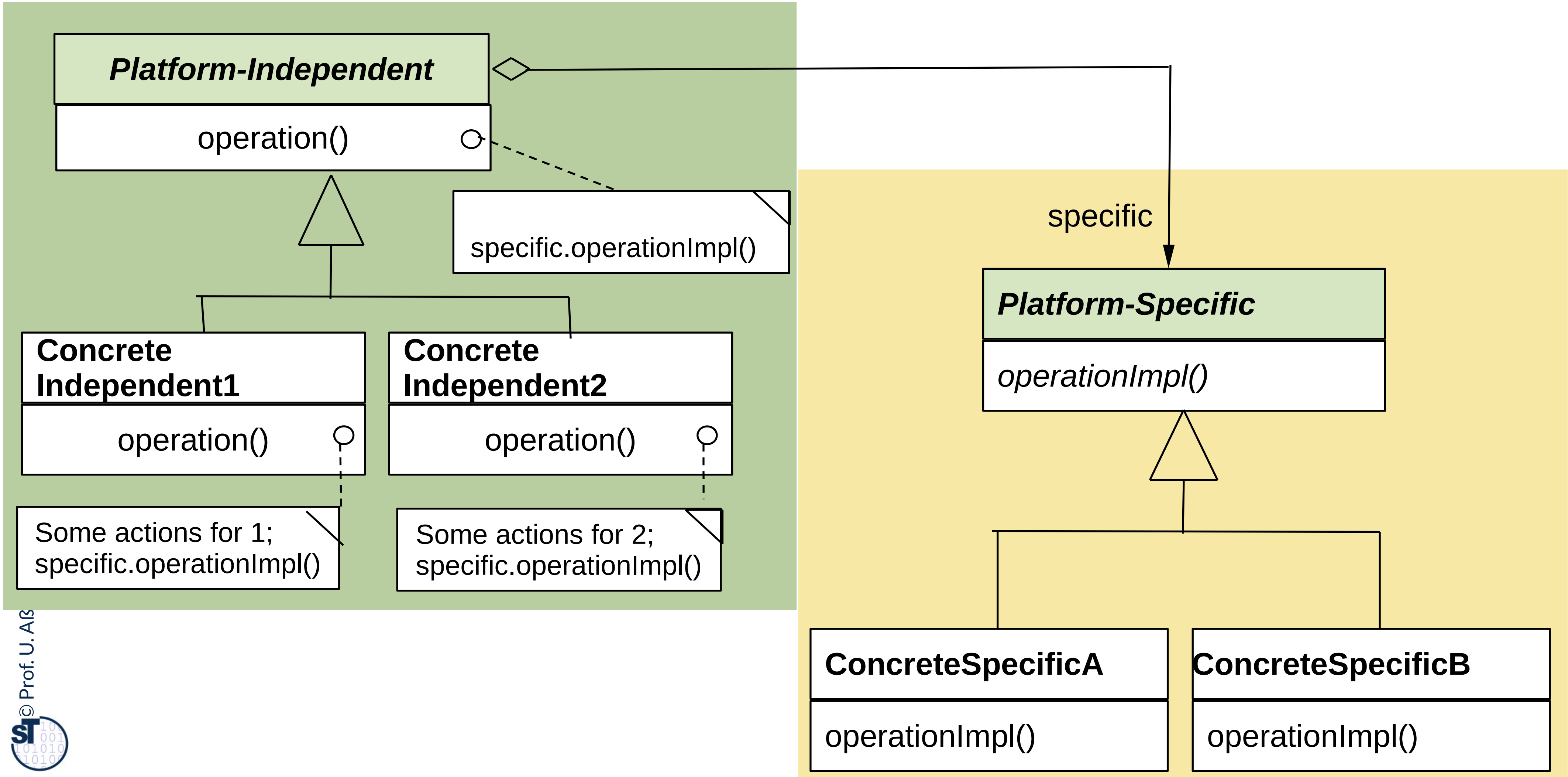
Product, specific platform

Product, unspecific context

Product, specific context

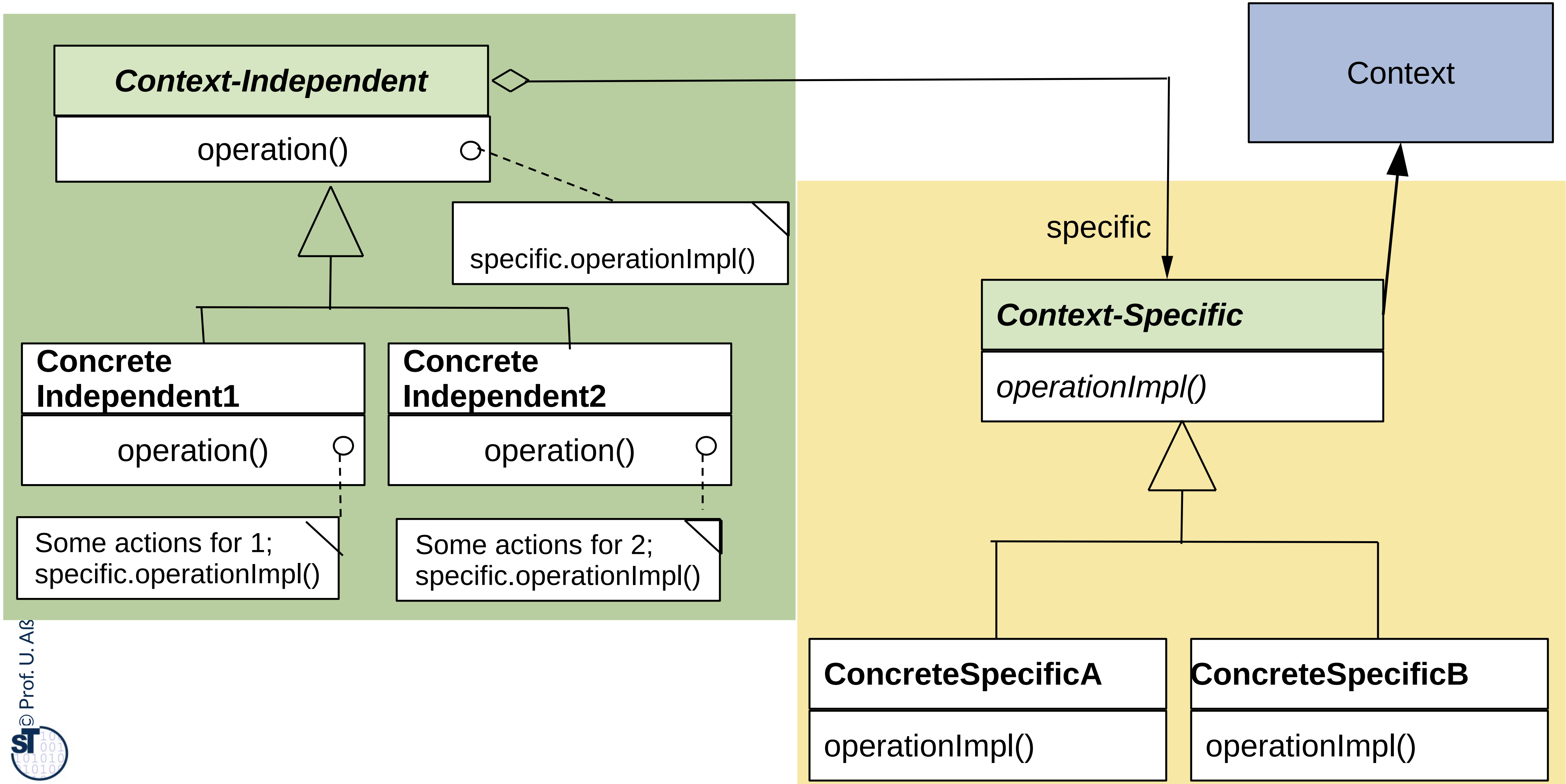
# Use of Bridge Patterns for Separation of Platform-Independent from Platform-Dependent Code

- 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

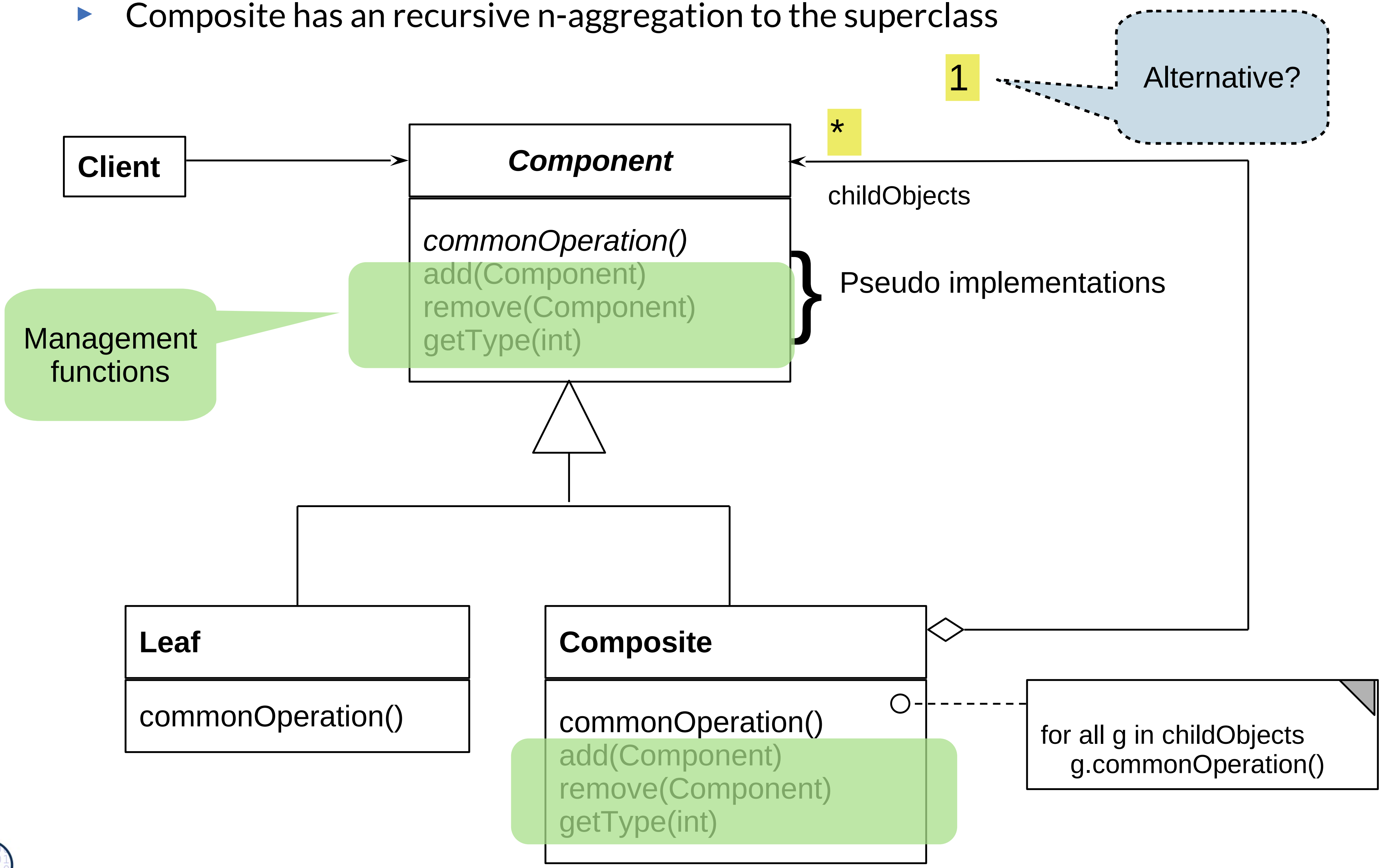
Extensibility patterns describe how to build

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

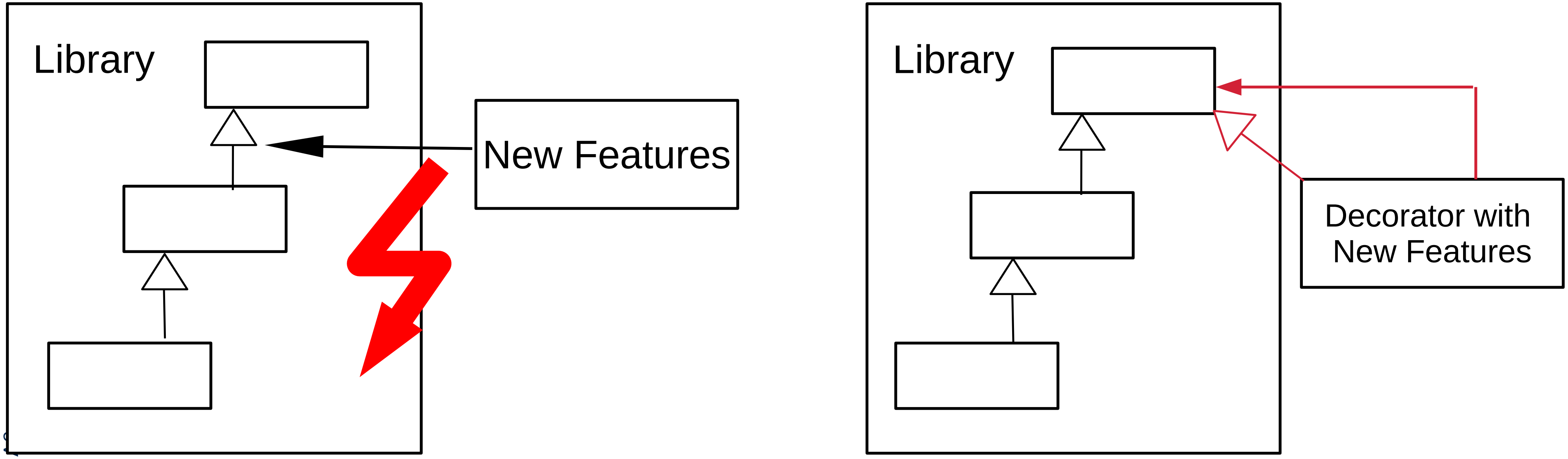


# 24.2.2. Decorator

- The “sibling” of Composite

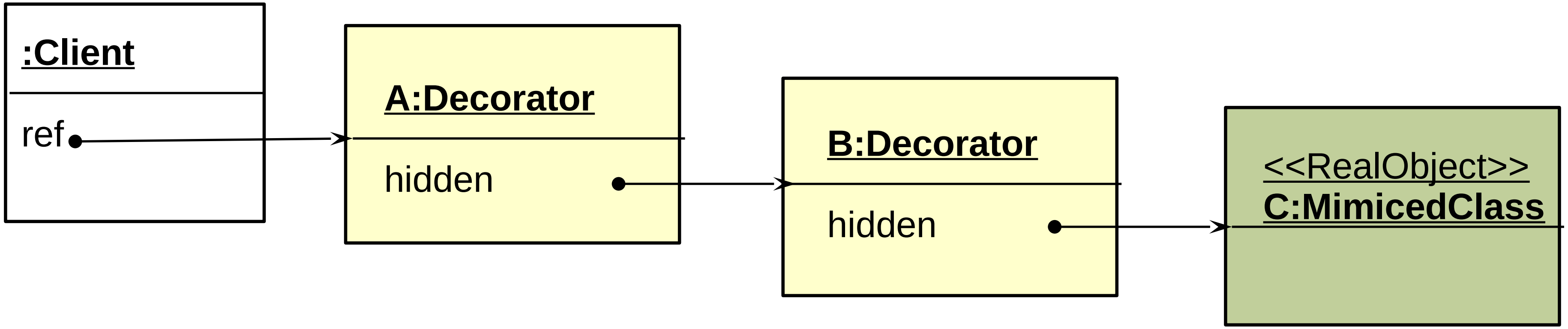
# Problem

- 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?



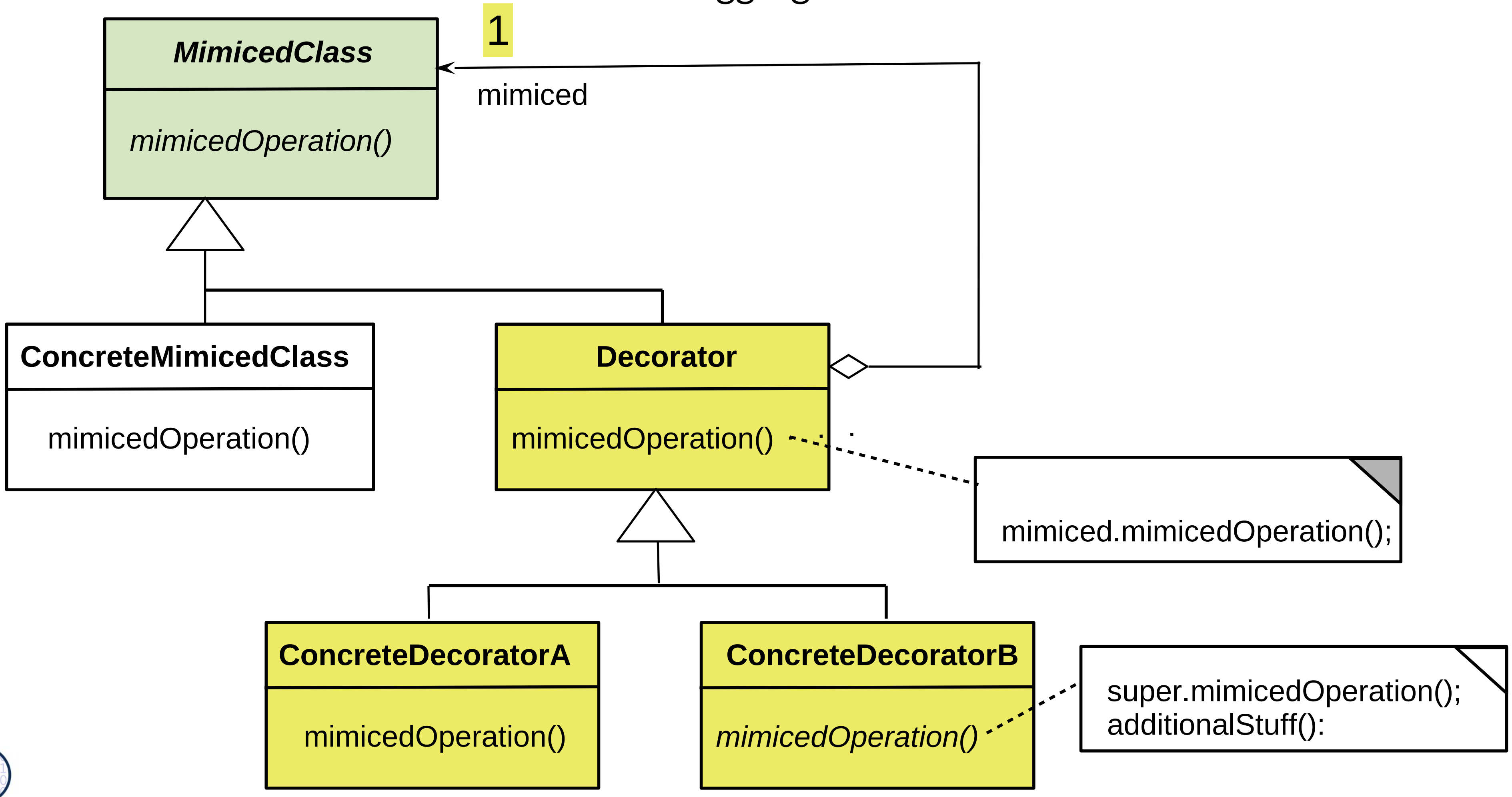
# Snapshot of Decorator Pattern

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

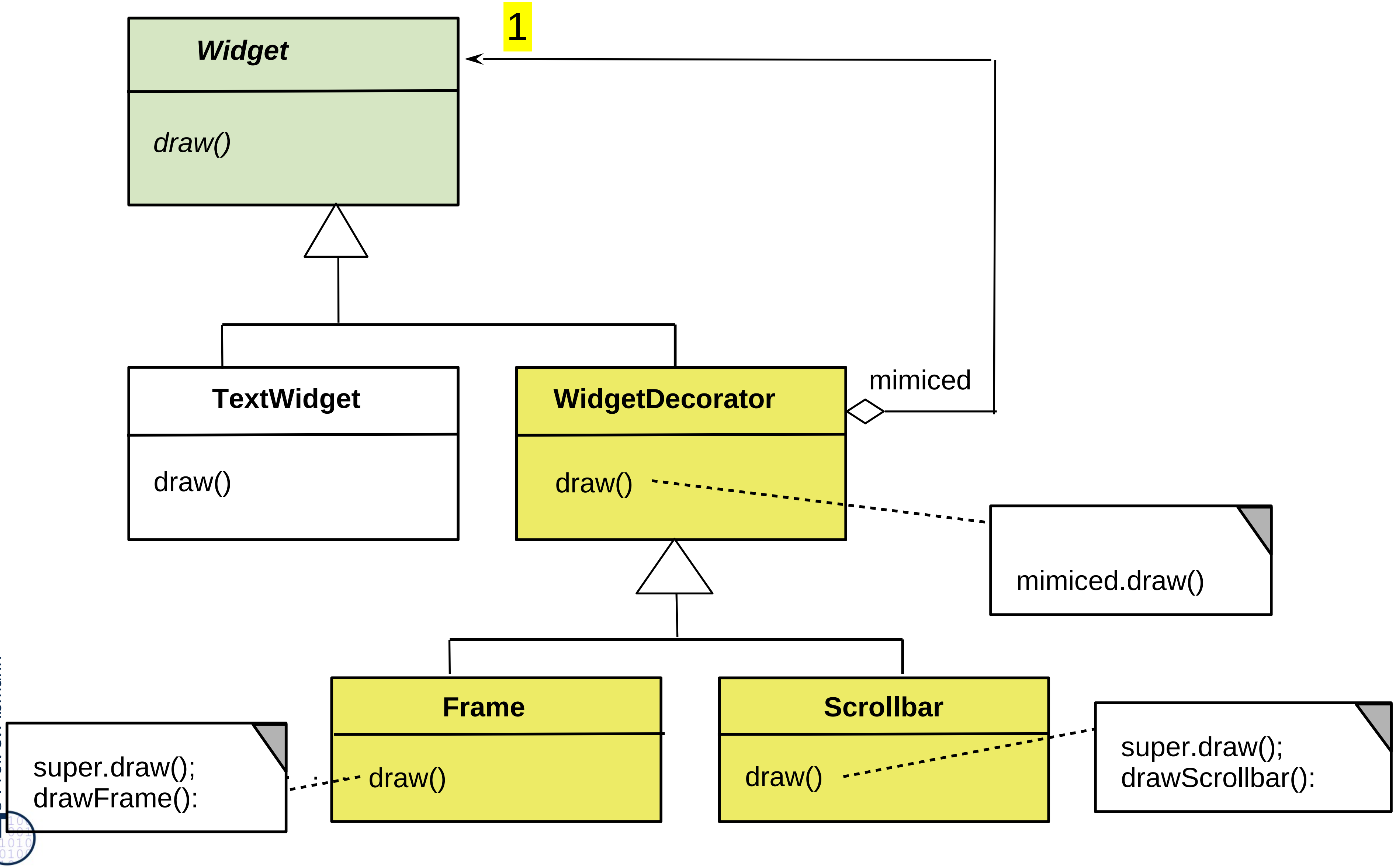


# Decorator – Structure Diagram

- 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

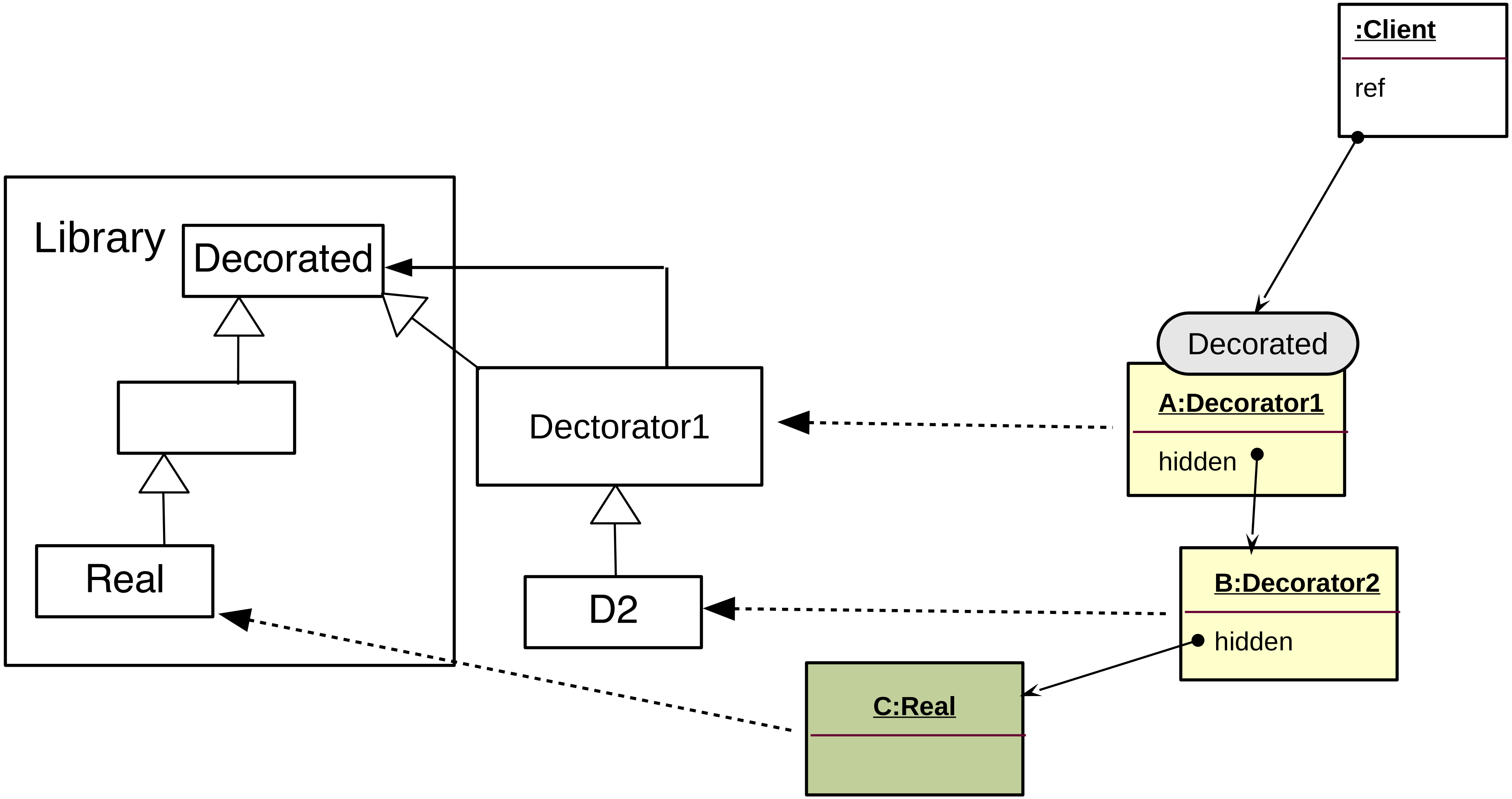


# Ex.: Decorator for Widgets



# Purpose Decorator

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

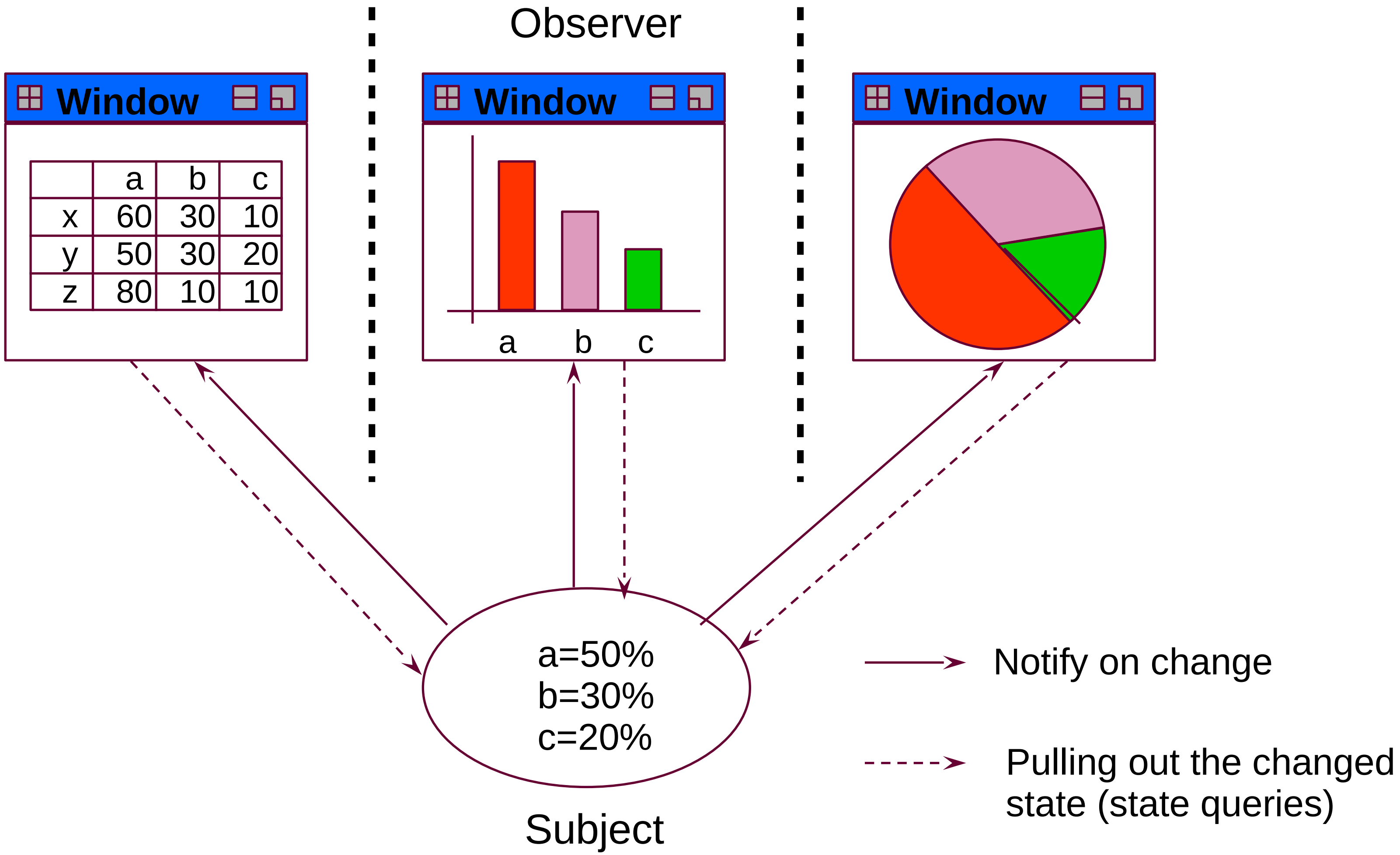


# 24.2.3 Different Kinds of Publish/Subscribe Patterns – (Event Bridge)

- 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)



Observer

|  | a | b | c |
|---|---|---|---|
| x | 60 | 30 | 10 |
| y | 50 | 30 | 20 |
| z | 80 | 10 | 10 |

a=50%
b=30%
c=20%

Subject

→ Notify on change

- - → Pulling out the changed state (state queries)

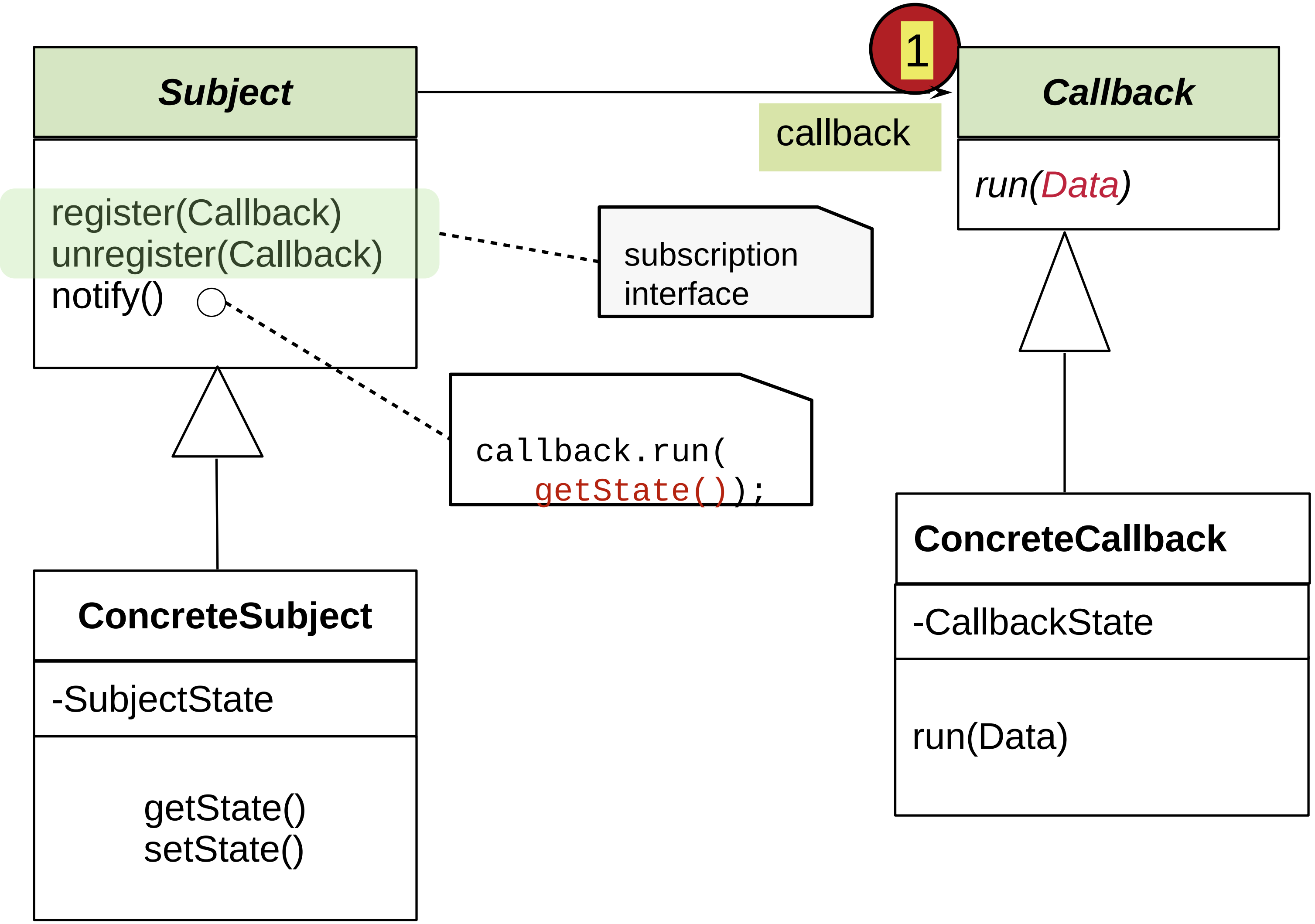
# Overview

| Variant of Pattern “Observer” | | |
|---|---|---|
| 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
- With the “pull” variants, the Observer pulls the new state from the Subject
- With the “push” variants, the Subject pushes the state to the Observer

# 24.2.3.1 Publish/Subscribe with 1 Observer: Callback

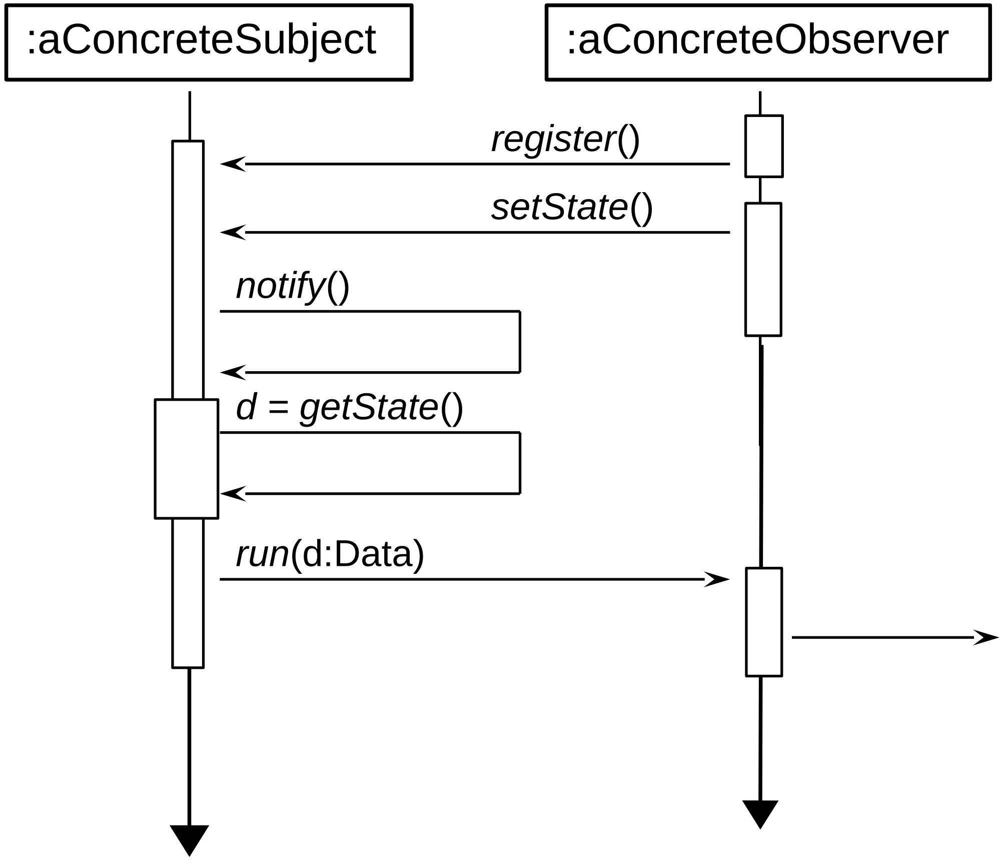
- **Callbacks** have only one observer, which is not known statically, but registered dynamically, at run time
- A (**push-)Callback** pushes its data with the call to `run`



```
callback.run(
   getState());
```

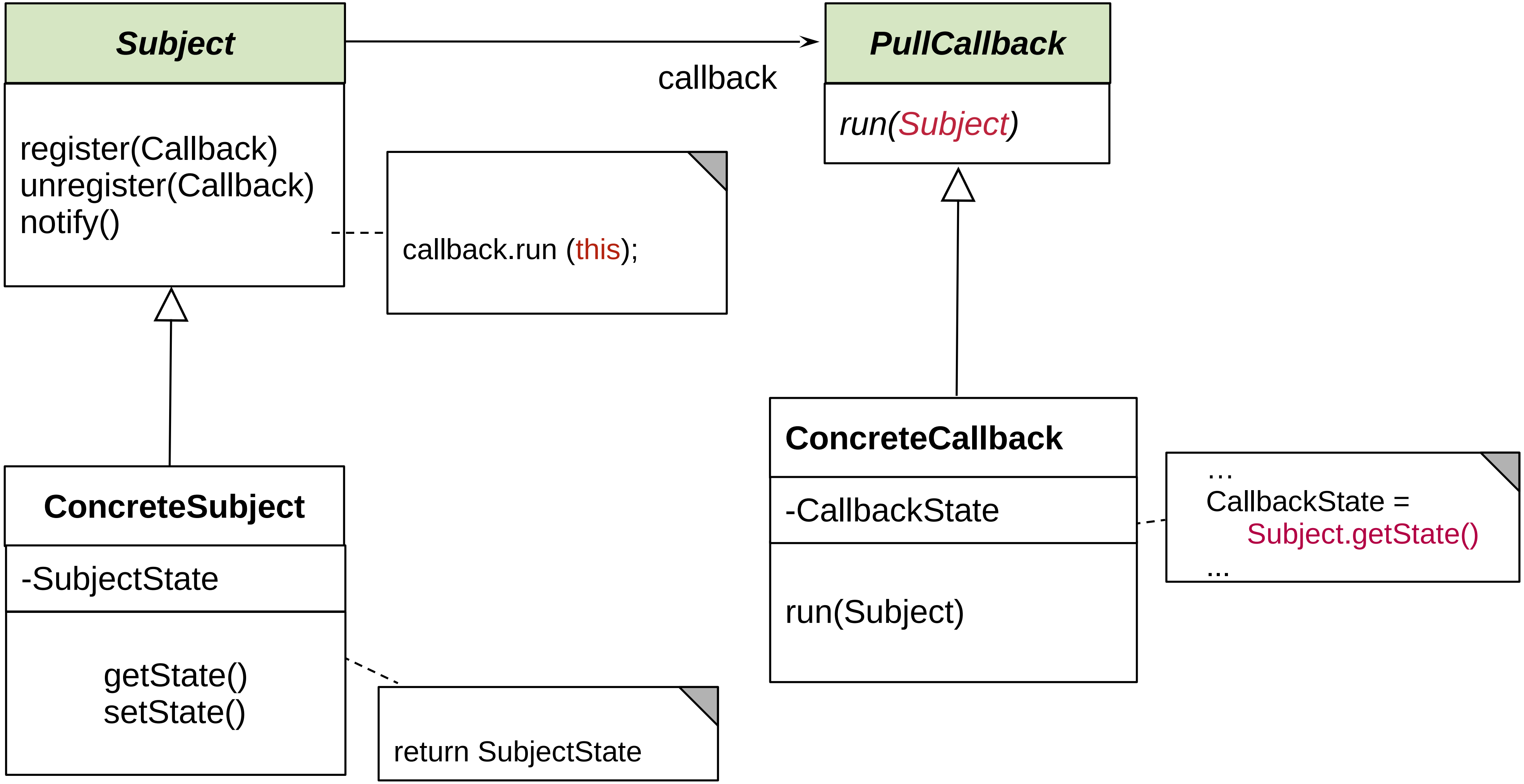
# Sequence Diagram push-Callback

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



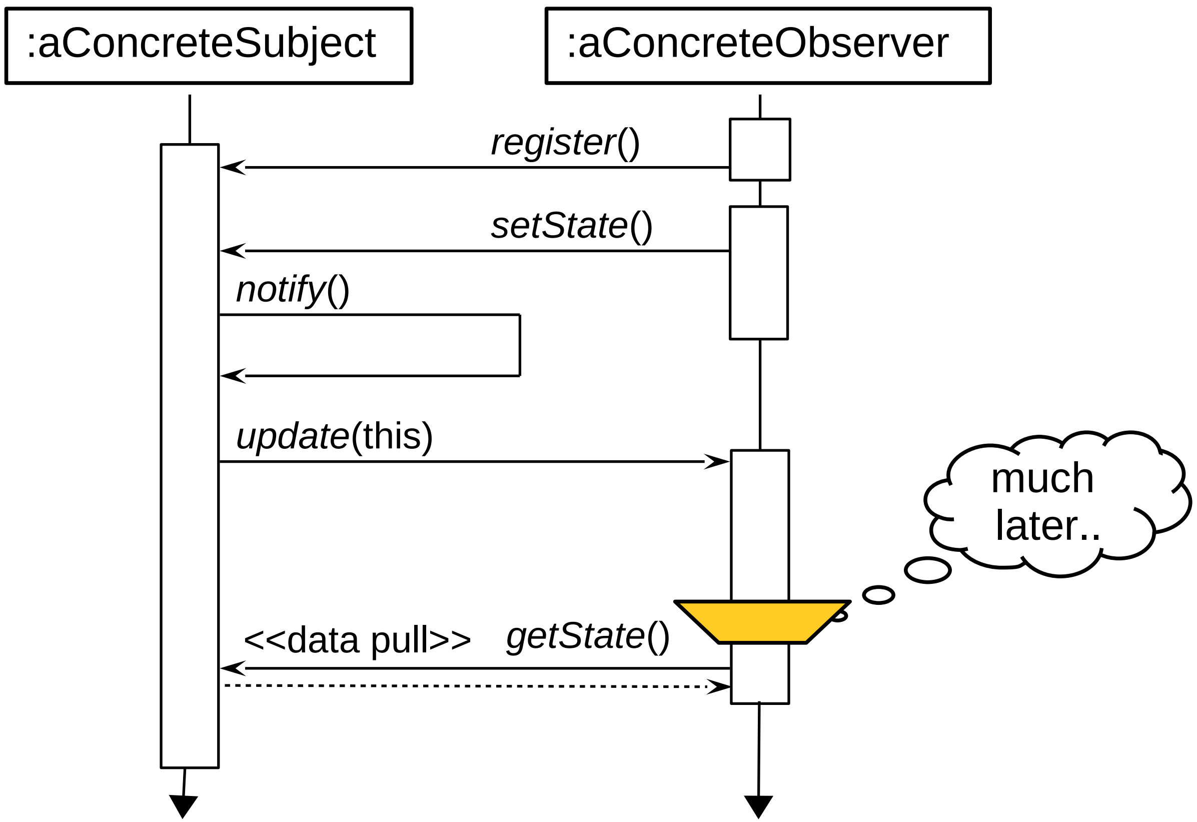
# 24.2.3.2 Structure pull-Callback (Delayed Data Transfer)

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



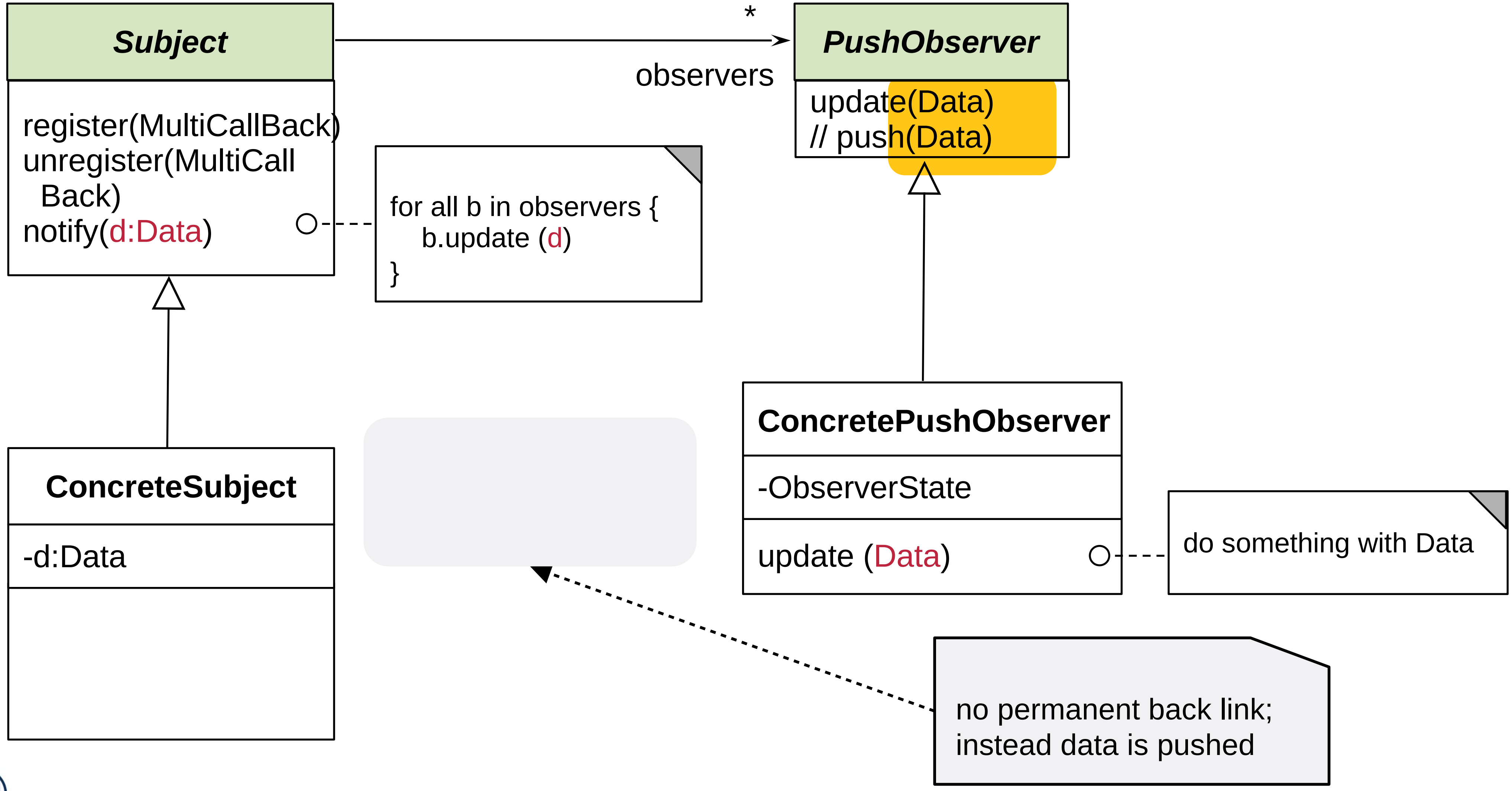
# Sequence Diagram pull-Callback

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



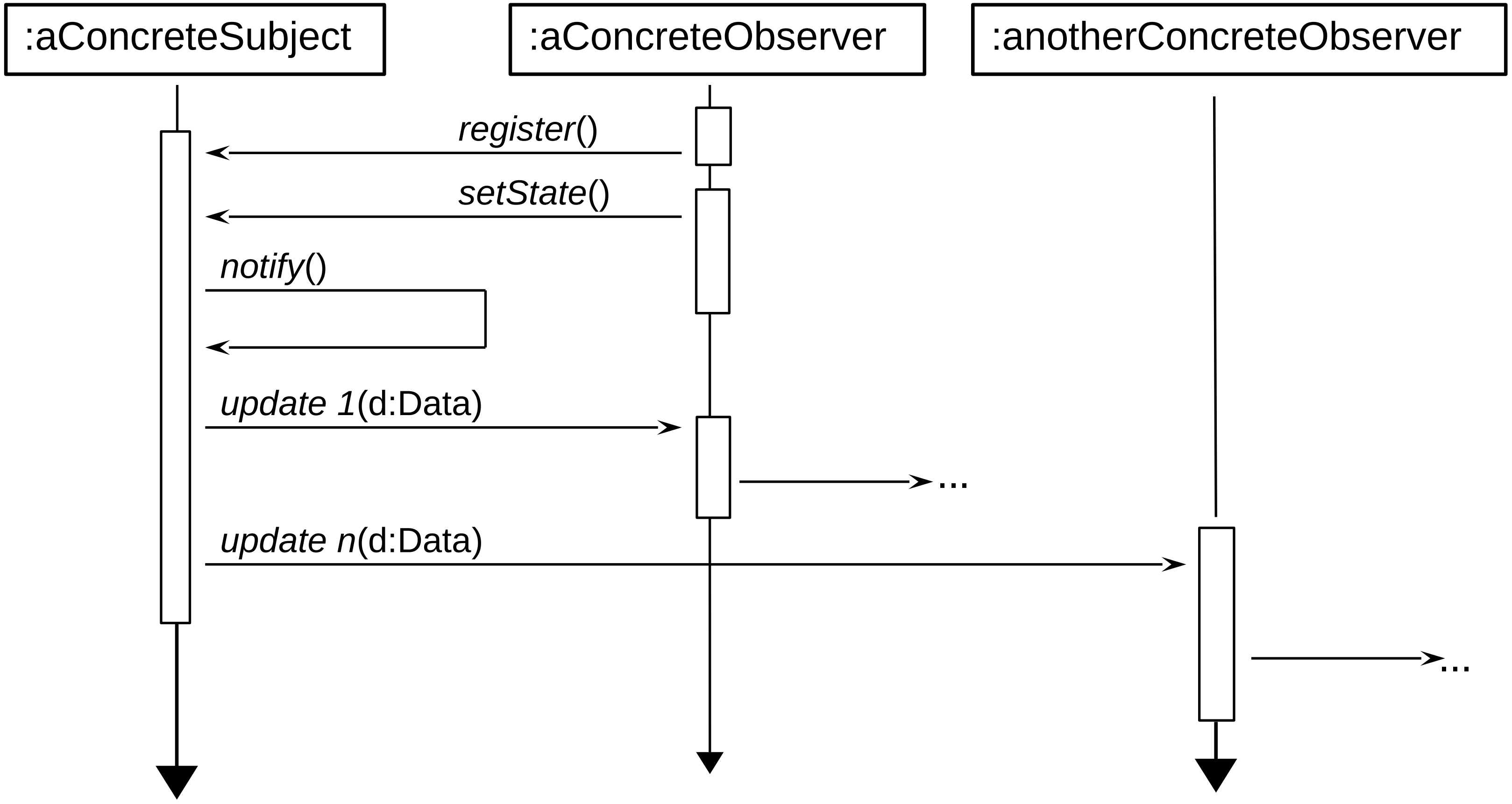
# 24.2.3.3 Structure push-Observer (Immediate Data Transfer)

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



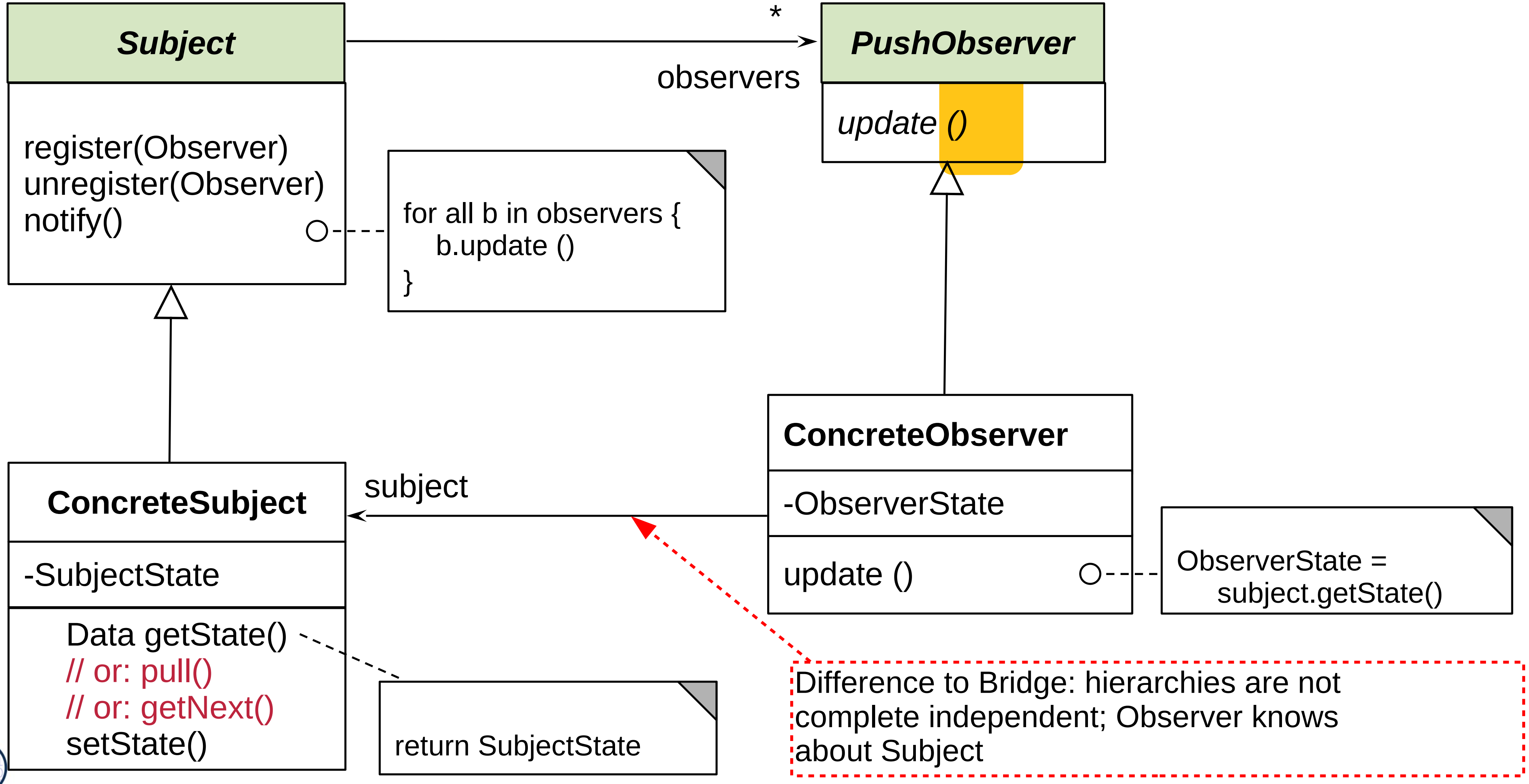
# Sequence Diagram push-Observer

- Update() transfers Data to Observer (push)



# 24.2.3.4 Pull-Observer (Delayed Data Transfer, The Gamma Variant, Rpt.)

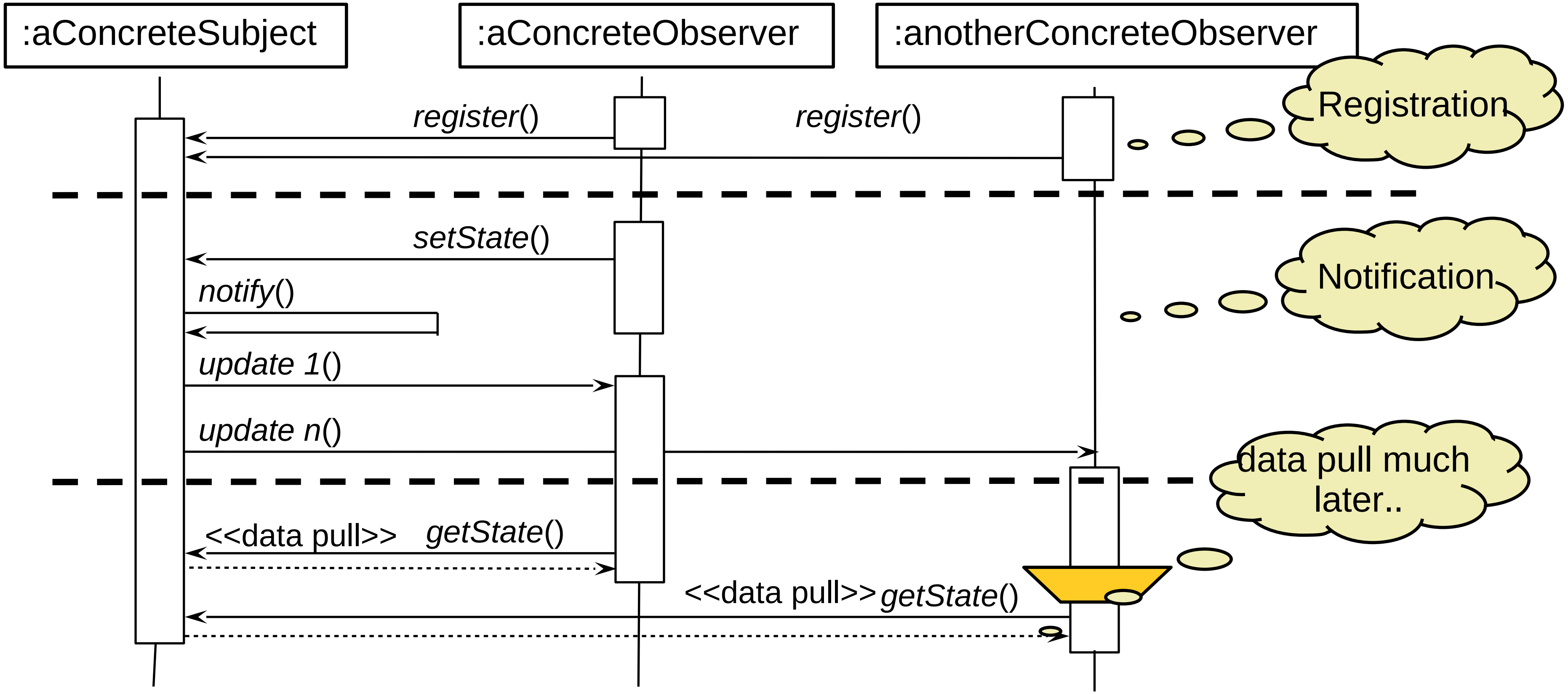
- The pull-Observer does not push anything, but pulls data later out with getState() or getNext() (same as in Iterator)
- Pulling resembles *Iterator (Stream)*, if data is pulled repeatedly



Difference to Bridge: hierarchies are not complete independent; Observer knows about Subject

# Sequence Diagram pull-Observer

- Update() does not transfer data, only an notification (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



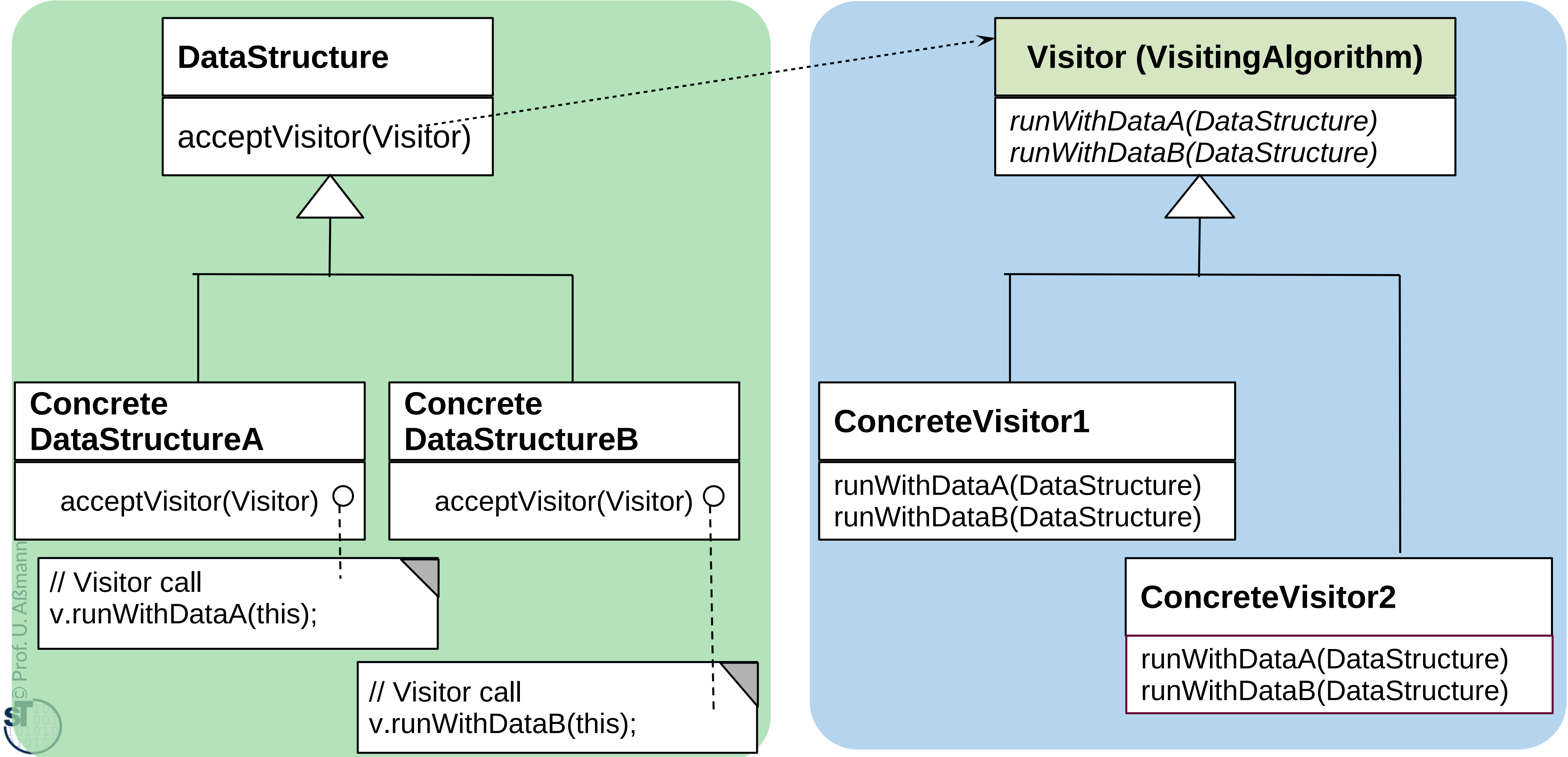
# 24.2.4. Visitor (VisitingAlgorithm)

Visitor provides an extensible family of algorithms on a data structure

Powerful pattern for modeling Materials and their Commands

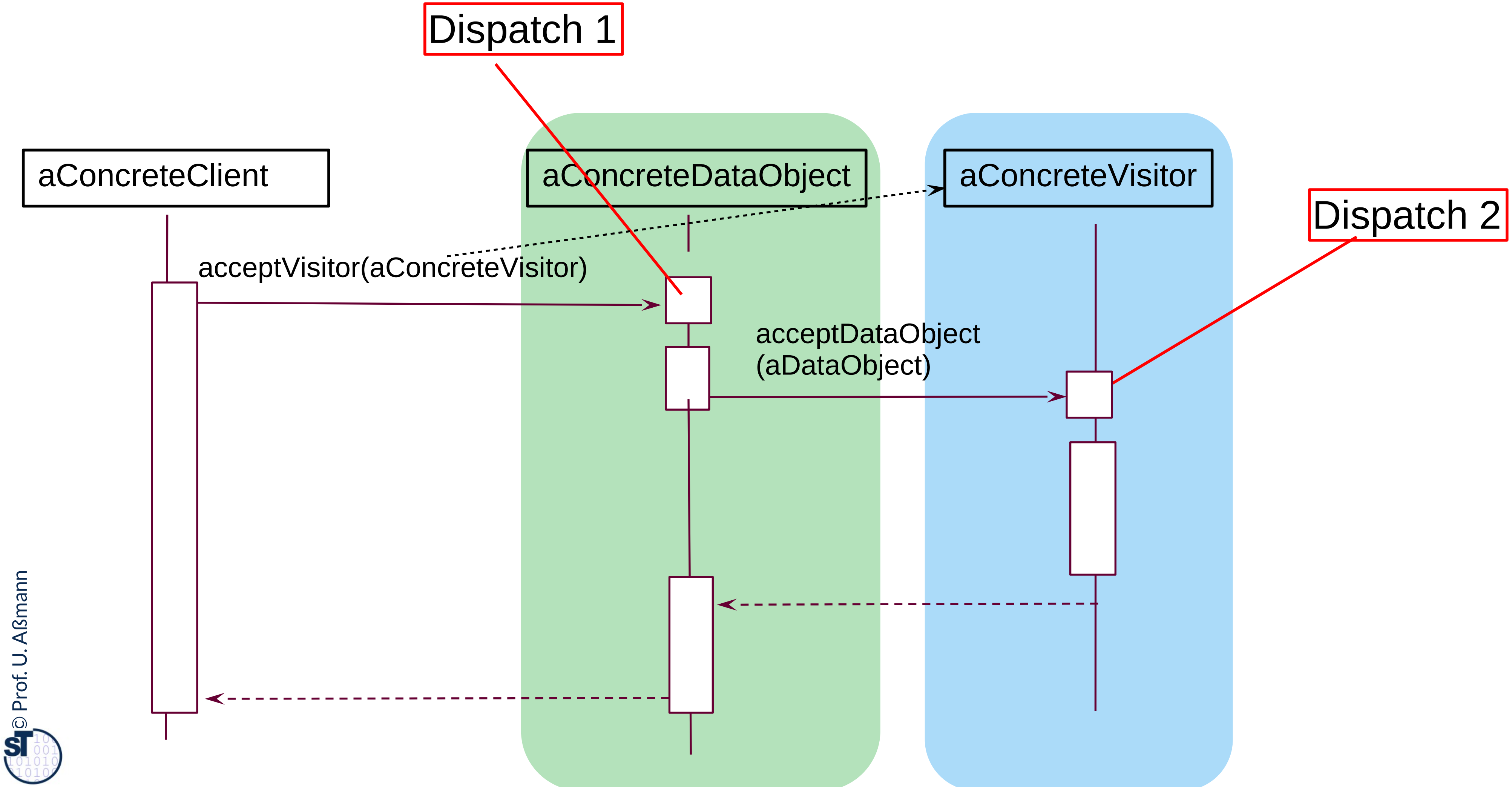
# Visitor (VisitingAlgorithm)

- 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 Command methods
- Beauty: visiting algorithms can be added without touching the DataStructure

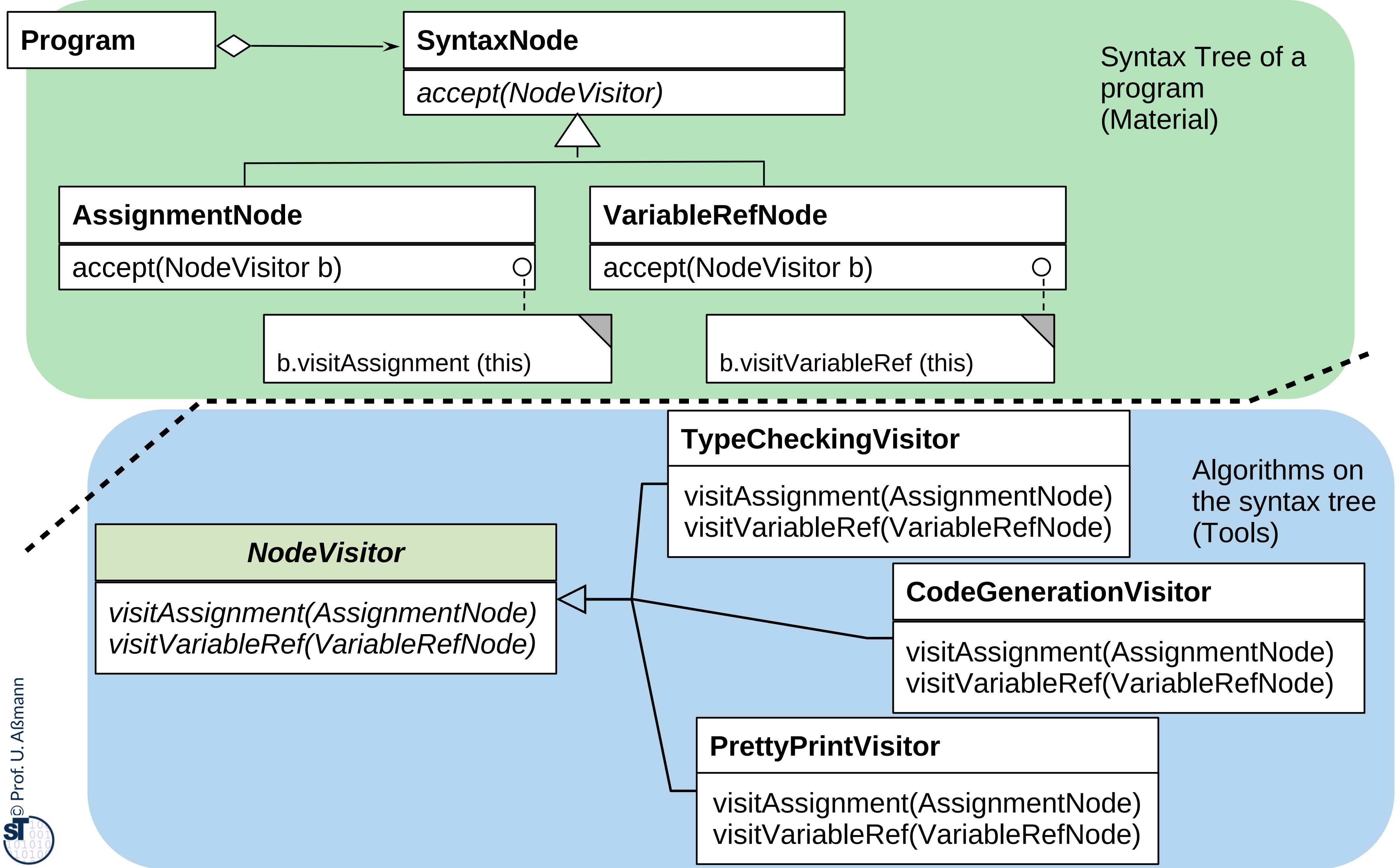


# Sequence Diagram Visitor

- First dispatch on data, then on visiting algorithm



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

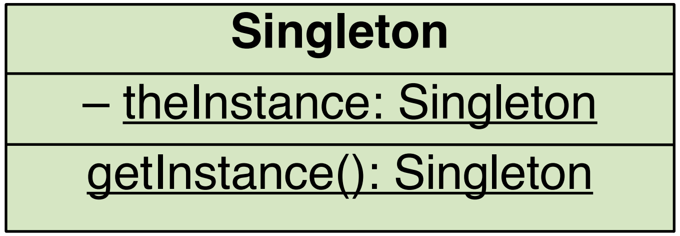

Program
SyntaxNode
accept(NodeVisitor)
AssignmentNode
accept(NodeVisitor b)
VariableRefNode
accept(NodeVisitor b)
b.visitAssignment (this)
b.visitVariableRef (this)
Syntax Tree of a program (Material)
NodeVisitor
visitAssignment(AssignmentNode)
visitVariableRef(VariableRefNode)
TypeCheckingVisitor
visitAssignment(AssignmentNode)
visitVariableRef(VariableRefNode)
CodeGenerationVisitor
visitAssignment(AssignmentNode)
visitVariableRef(VariableRefNode)
PrettyPrintVisitor
visitAssignment(AssignmentNode)
visitVariableRef(VariableRefNode)
Algorithms on the syntax tree (Tools)

# 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



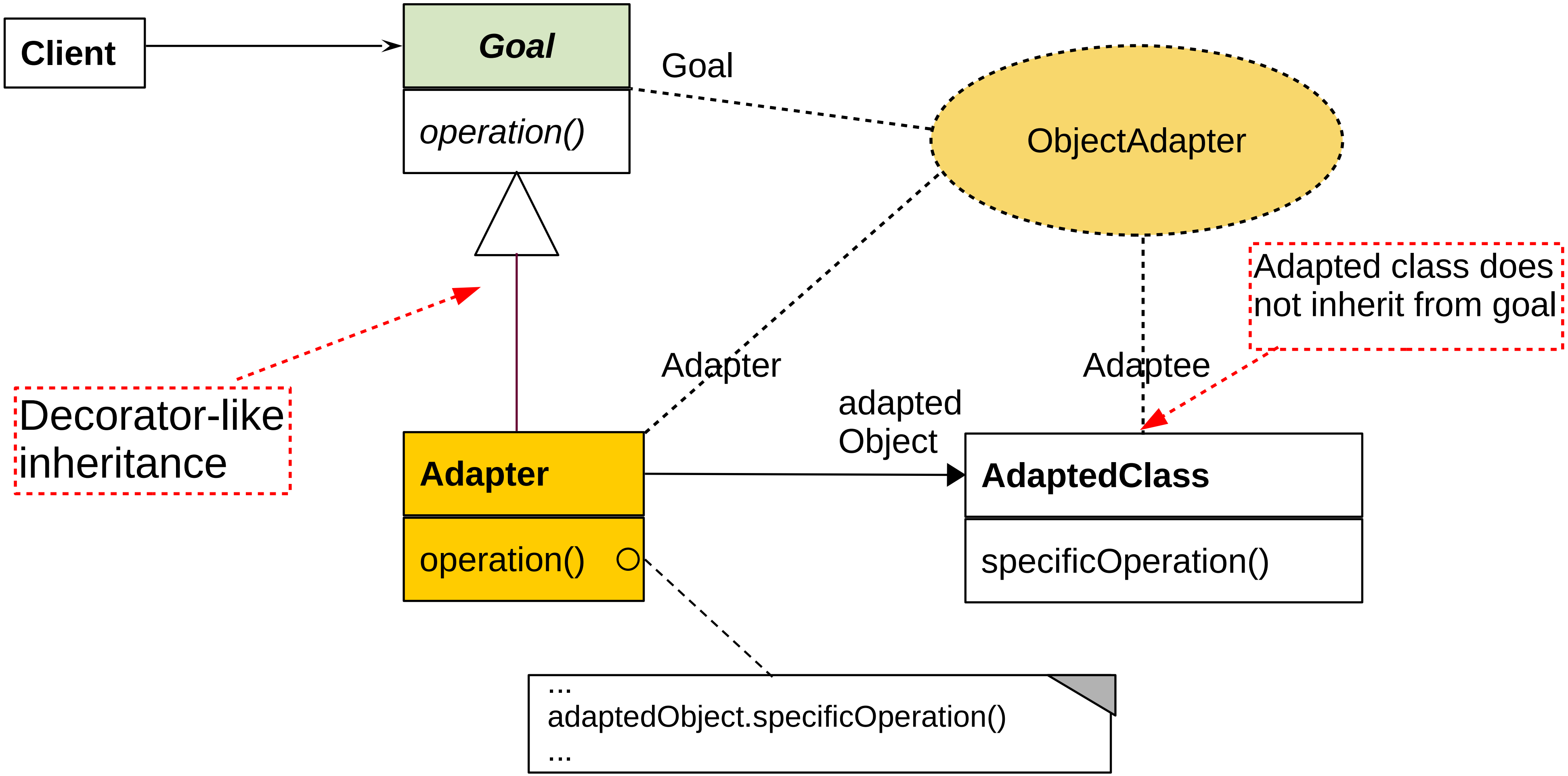
The usual constructor is invisible

```
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

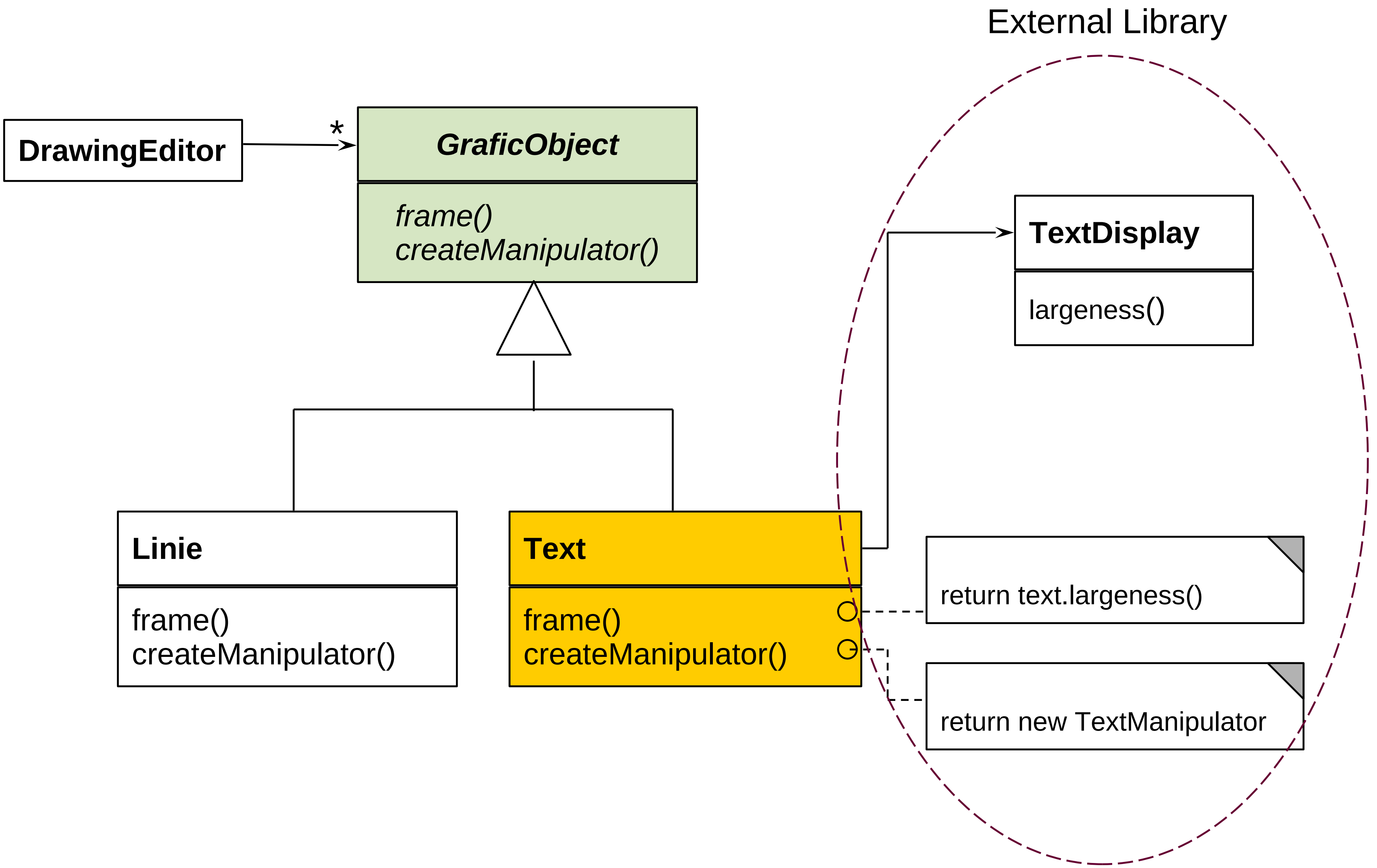
- An **object adapter** is a kind of a proxy mapping one interface, protocol, or data format to another



Decorator-like inheritance

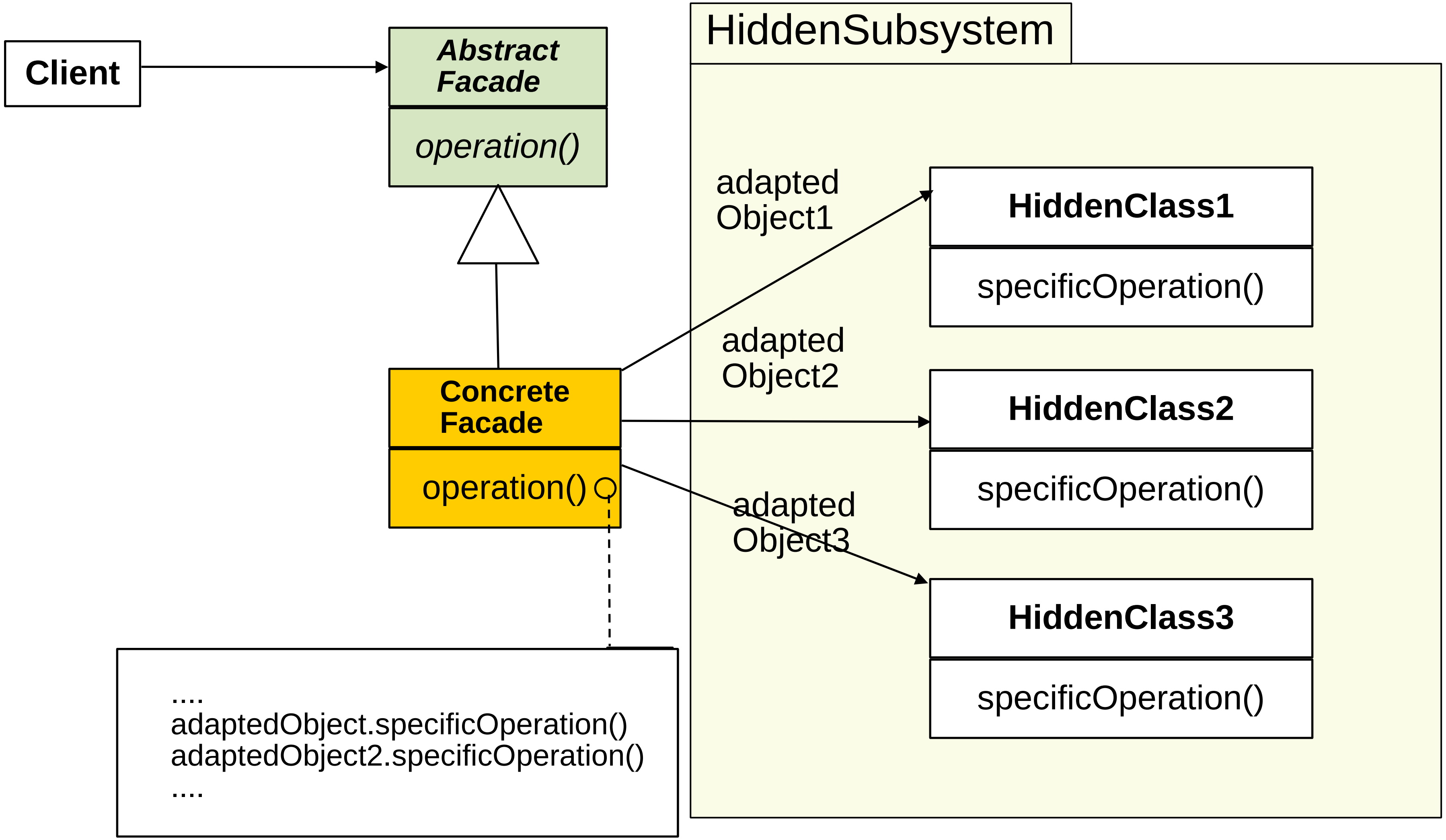
Adapted class does not inherit from goal

# Example: Use of an External Class Library For Texts



# 24.3.3 Facade Hides a Subsystem

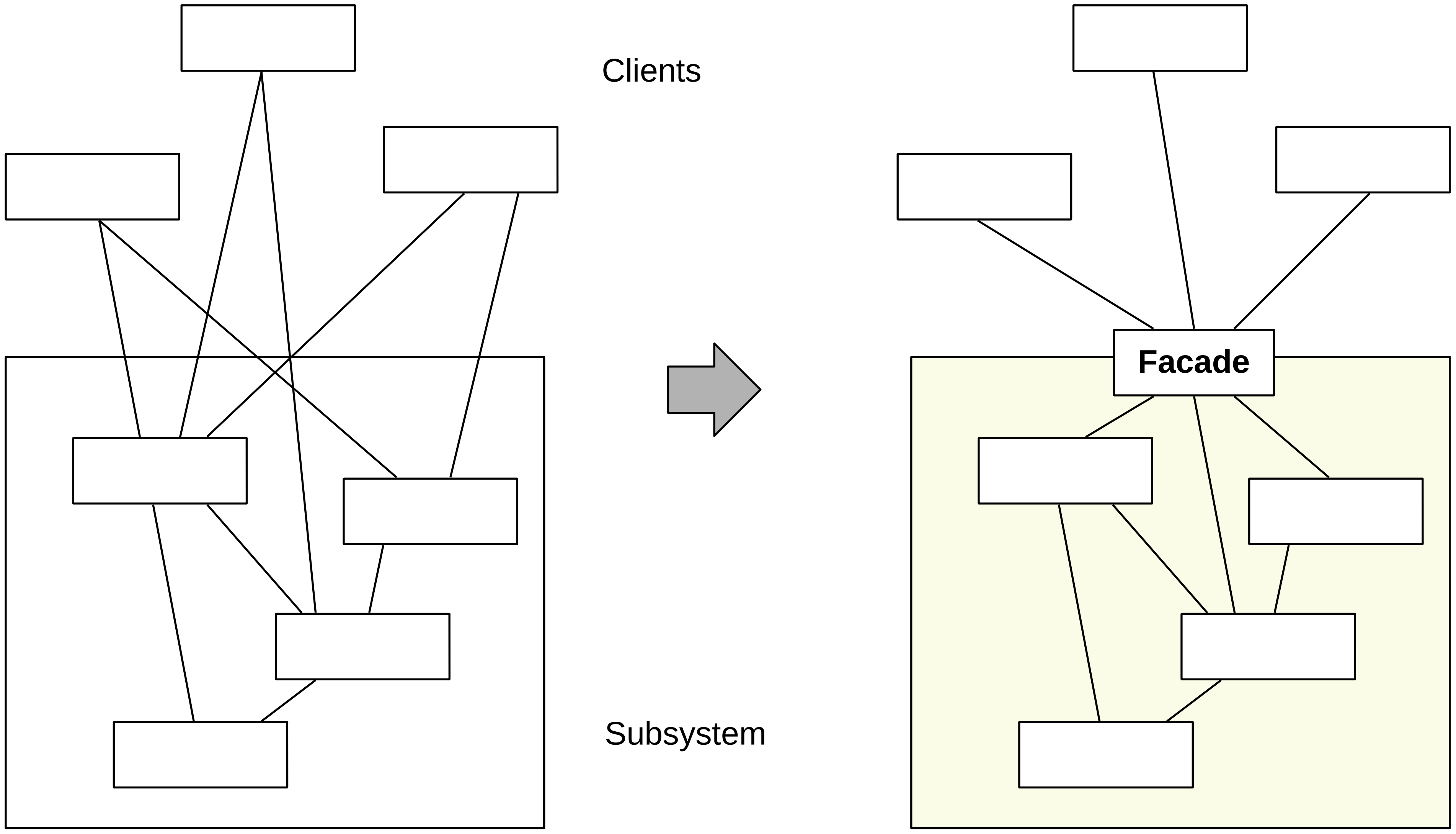
- A **facade** is a specific object adapter hiding a complete set of objects (subsystem)
  - The facade has to map its own interface to the interfaces of the hidden objects



```
....
adaptedObject.specificOperation()
adaptedObject2.specificOperation()
....
```

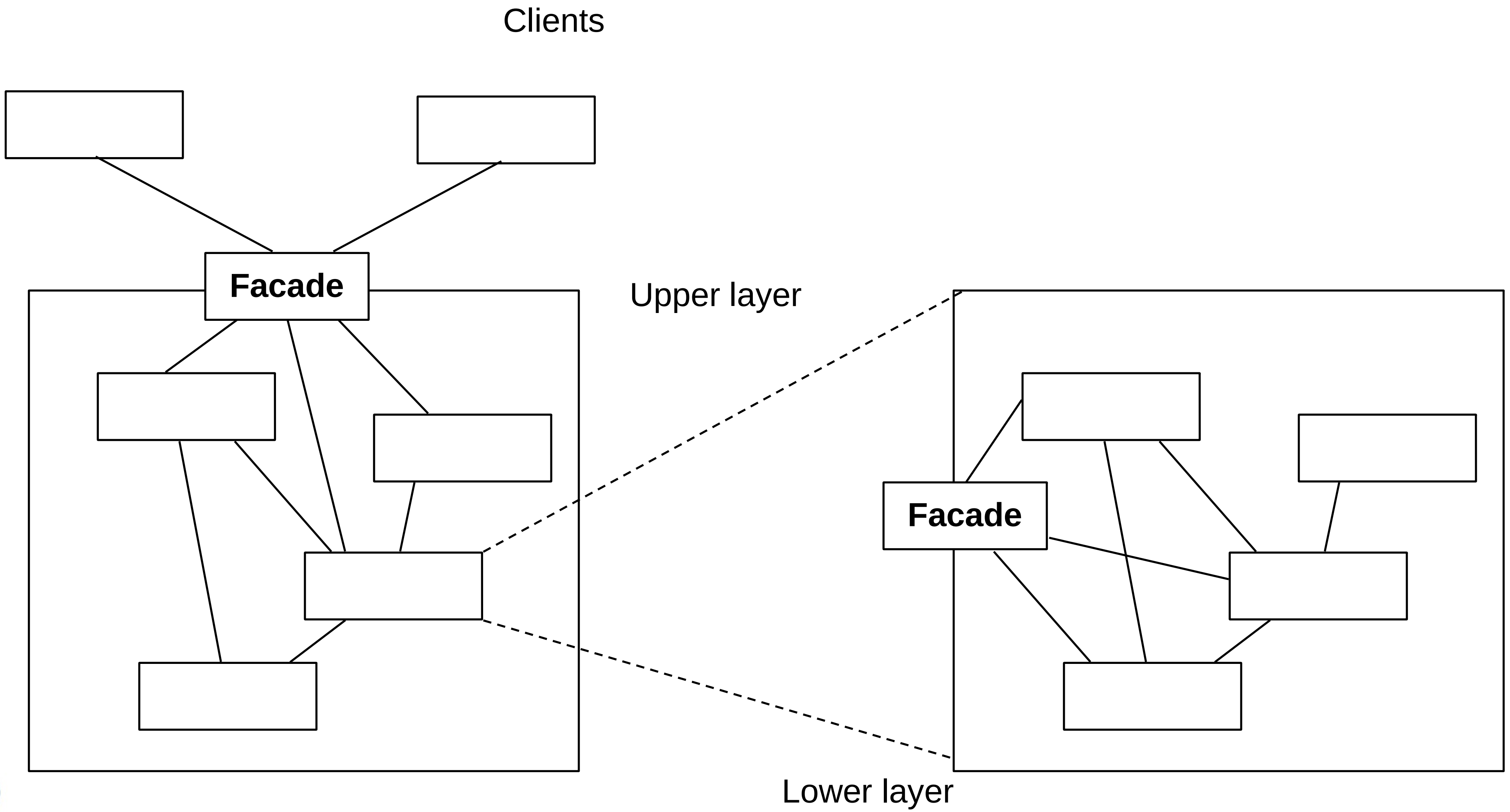
# Refactoring a Legacy System Towards a Facade

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



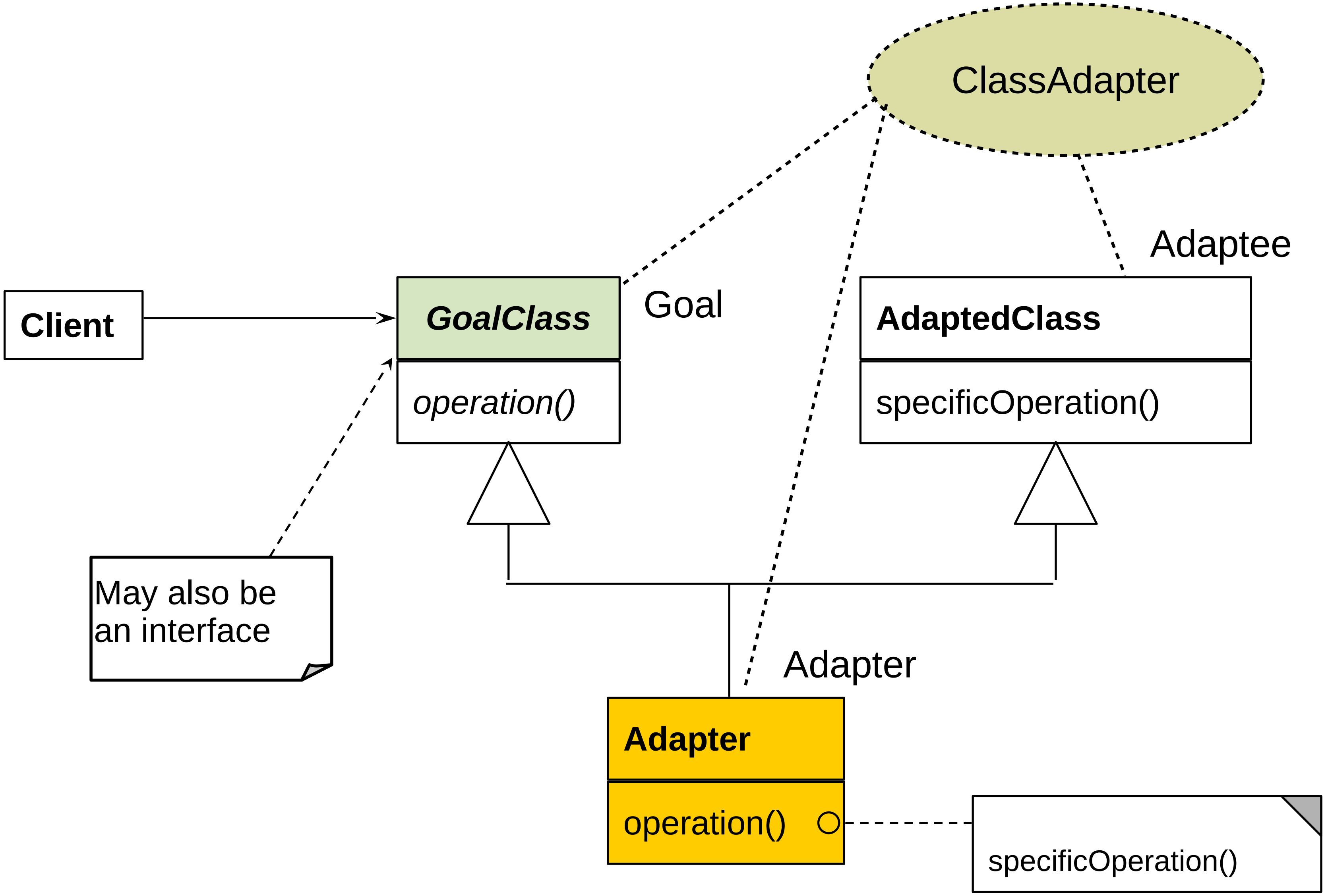
# The Layer Pattern

- 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



# 24.4 Other Patterns

# What is discussed elsewhere...

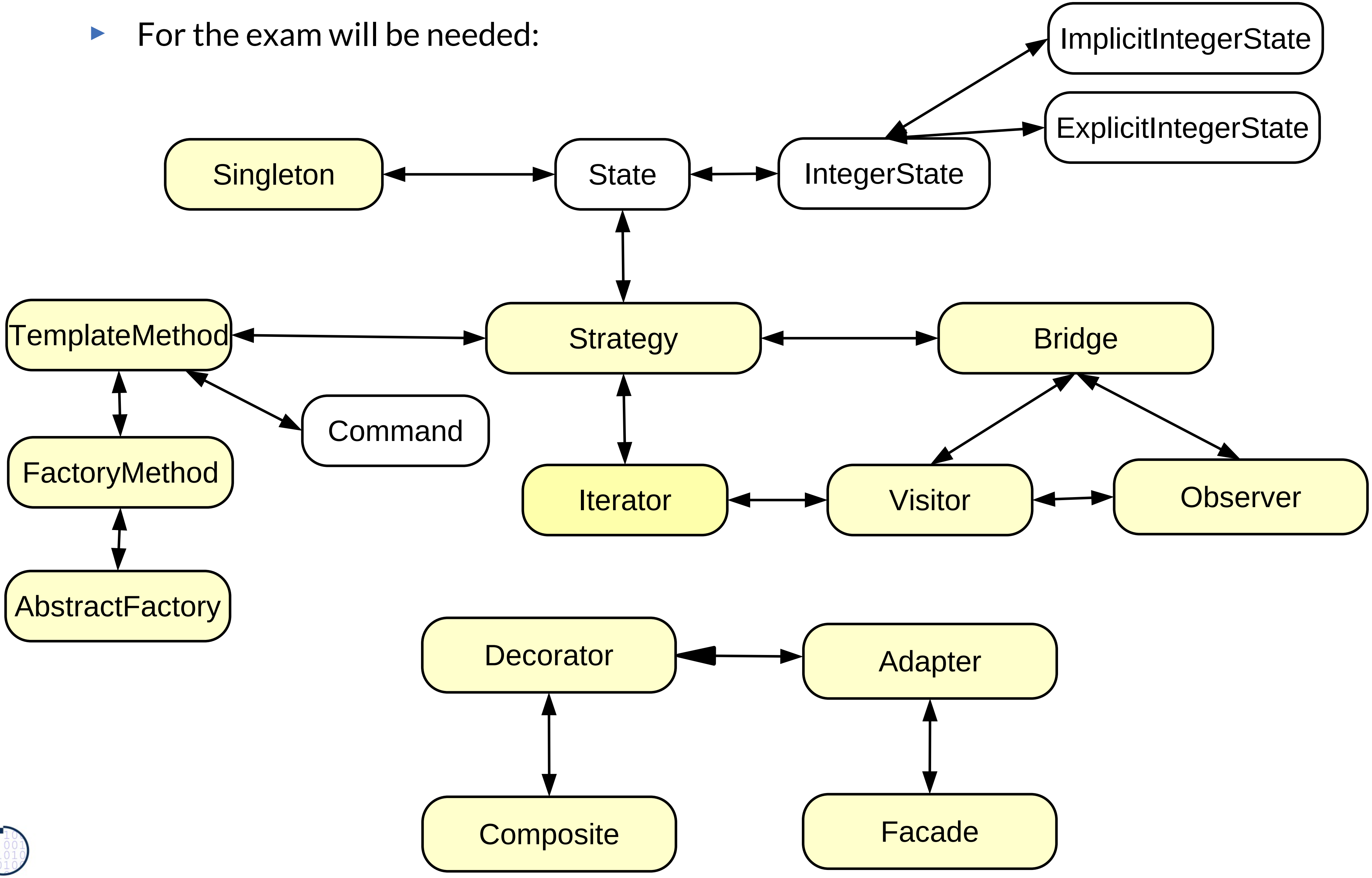
- Iterator, Sink, and Channel
- Composite
- TemplateMethod, FactoryMethod
- Command

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/Swing Library

- AWT/Swing is the GUI 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

# Why is the Frauenkirche Beautiful?

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

# 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

# The End

- Course “Design patterns and frameworks”, WS, contains more material.
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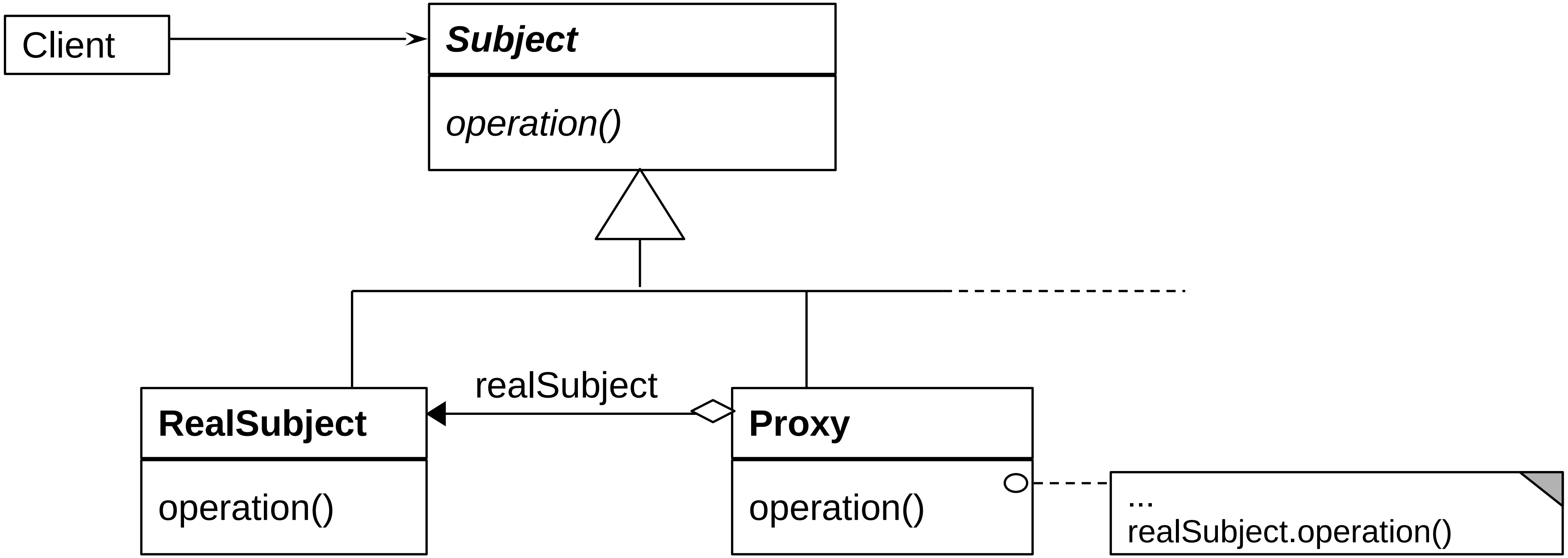
# Appendix

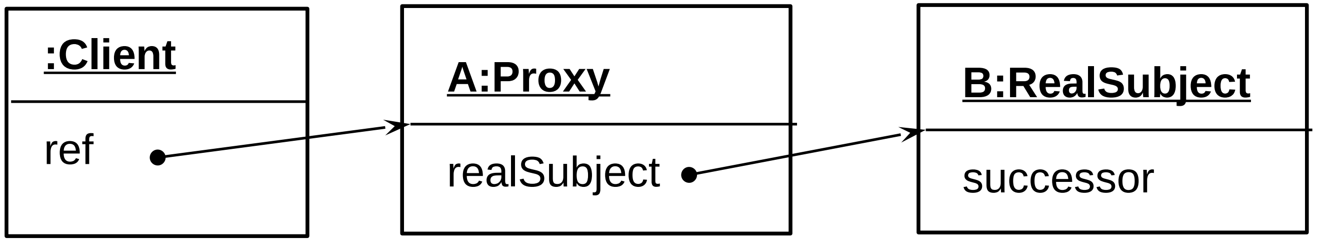
# 24.A.1 Proxy

# Proxy

- Hide the access to a real subject by a representant



Object Structure:



# Proxy

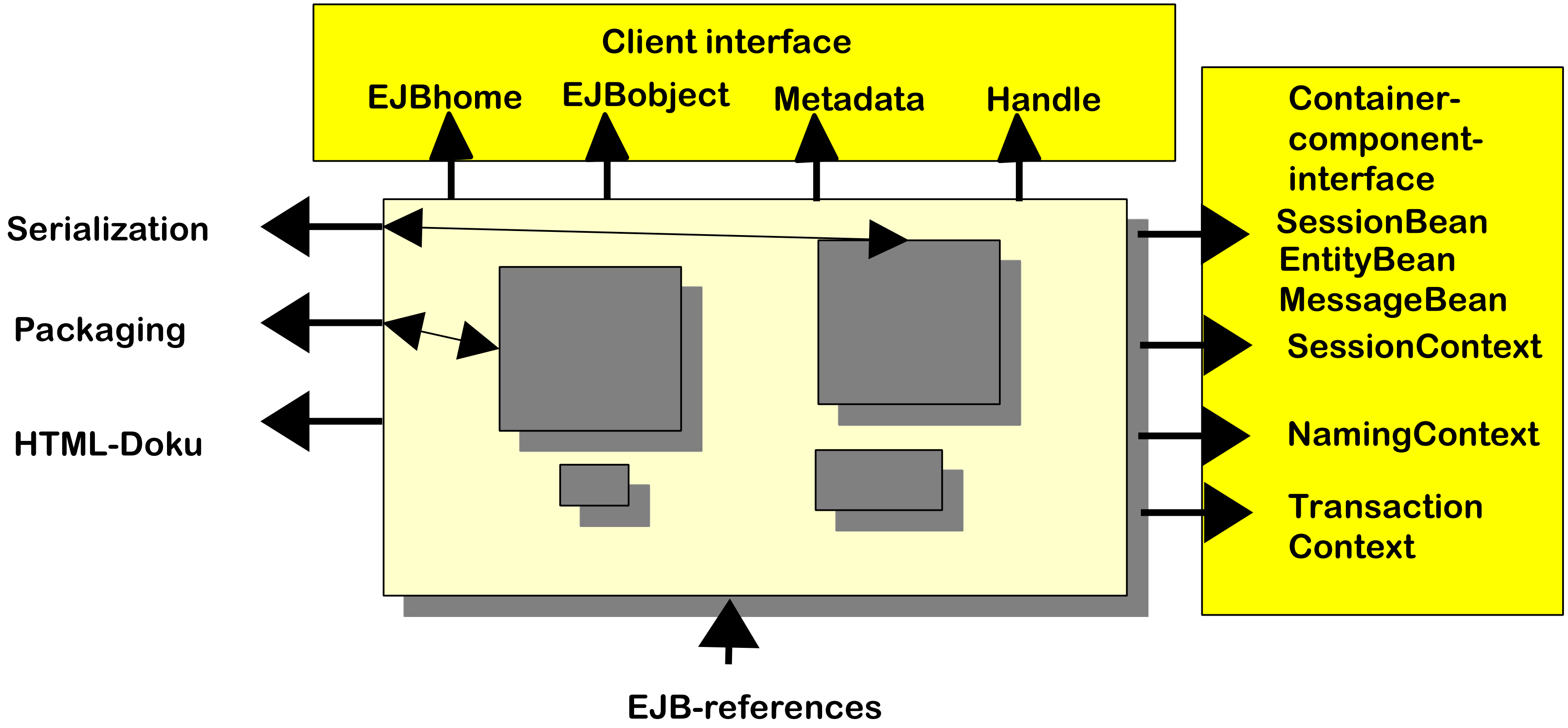
- The proxy object is a representant of an object
  - The Proxy is similar to Decorator, but it is not derived from ObjectRecursion
  - It has a direct pointer to the sister class, *not* to the superclass
  - It may collect all references to the represented object (shadows it). Then, it is a facade object 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

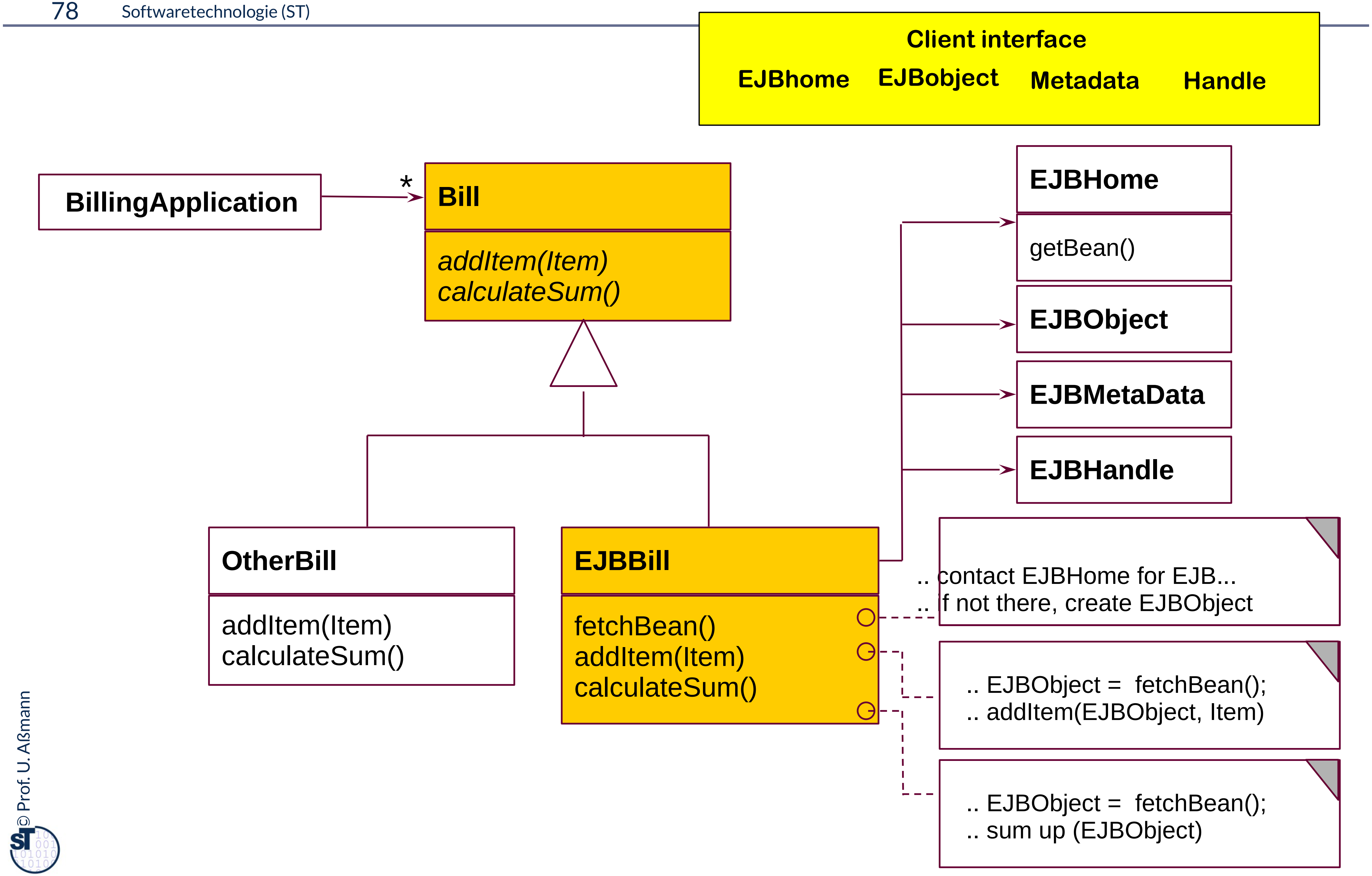
- **Filter proxy** (smart reference):
  - executes additional actions, when the object is accessed
- **Protocol proxy**:
  - Counts references (reference-counting garbage collection
  - Or implements a synchronization protocol (e.g., reader/writer protocols)
- **Indirection proxy** (facade proxy):
  - 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

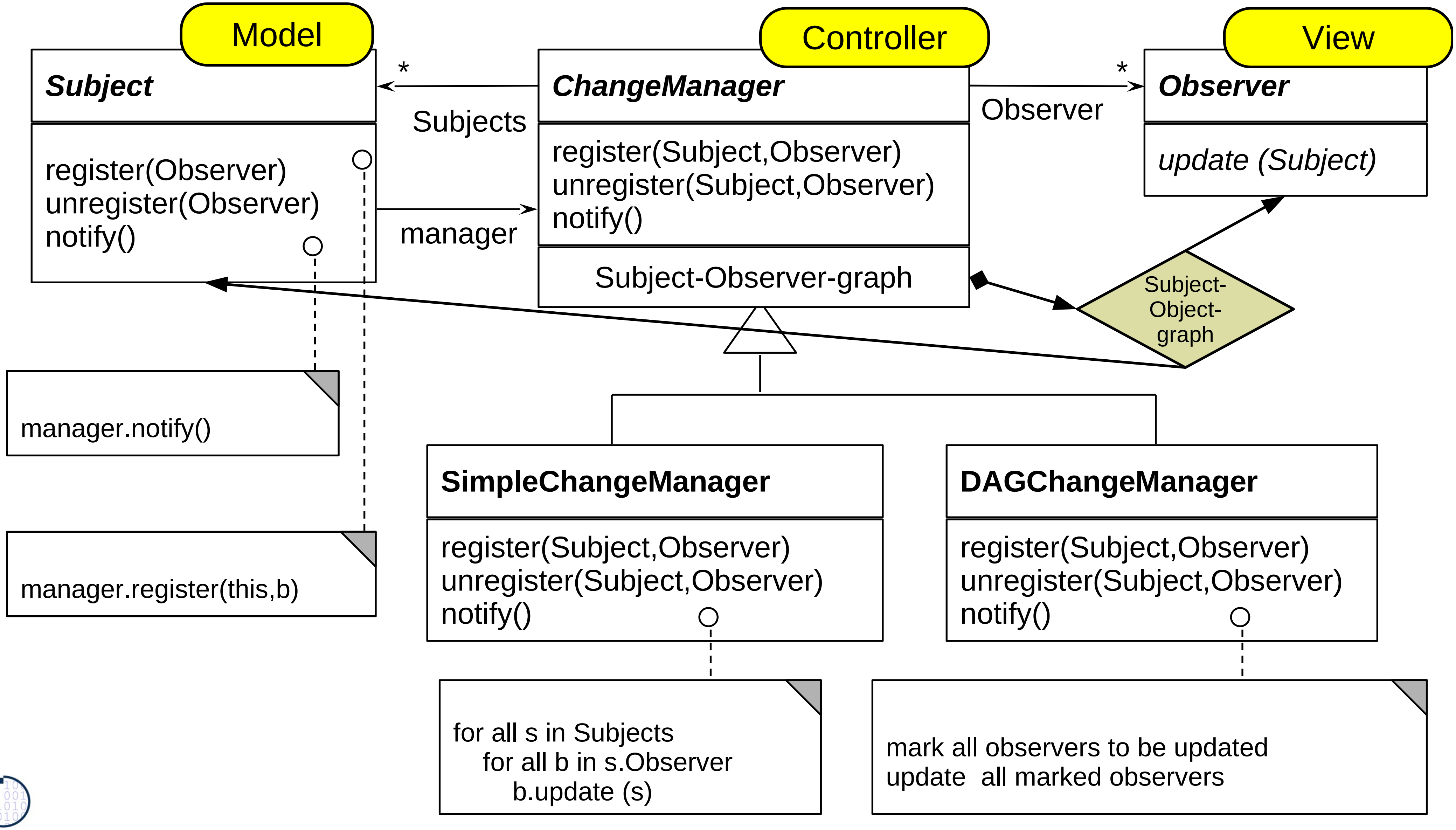
- Adapters and Facades are often used to adapt components-off-the-shelf (COTS) to applications
- For instance, an EJB-adapter allows for reuse of an Enterprise Java Bean in an application
- -> course Component-Based Software Engineering (SoSe)



# EJB Adapter

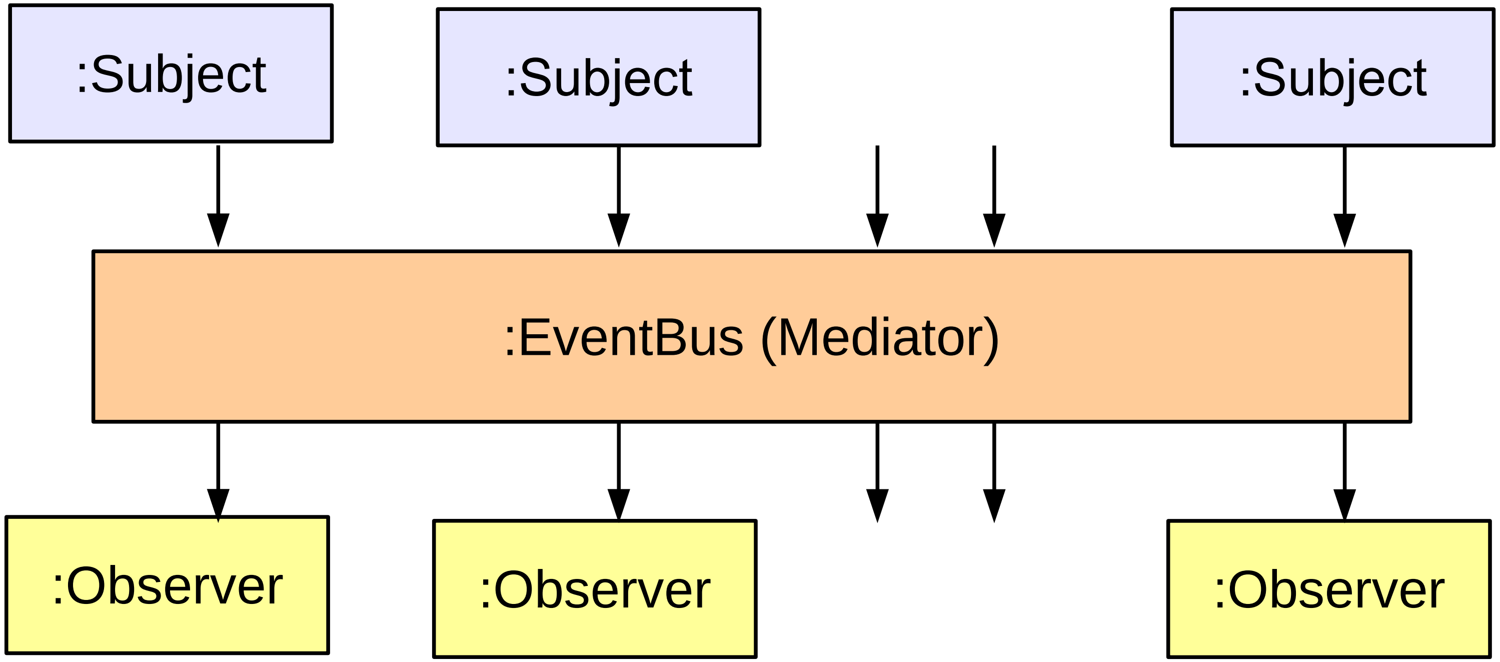

Client interface
EJBhome
EJBobject
Metadata
Handle
BillingApplication
*
Bill
addItem(Item)
calculateSum()
OtherBill
addItem(Item)
calculateSum()
EJBBill
fetchBean()
addItem(Item)
calculateSum()
EJBHome
getBean()
EJBObject
EJBMetaData
EJBHandle
.. contact EJBHome for EJB...
.. if not there, create EJBObject
.. EJBObject = fetchBean();
.. addItem(EJBObject, Item)
.. EJBObject = fetchBean();
.. sum up (EJBObject)

# 24.A.2 Observer with ChangeManager (EventBus)



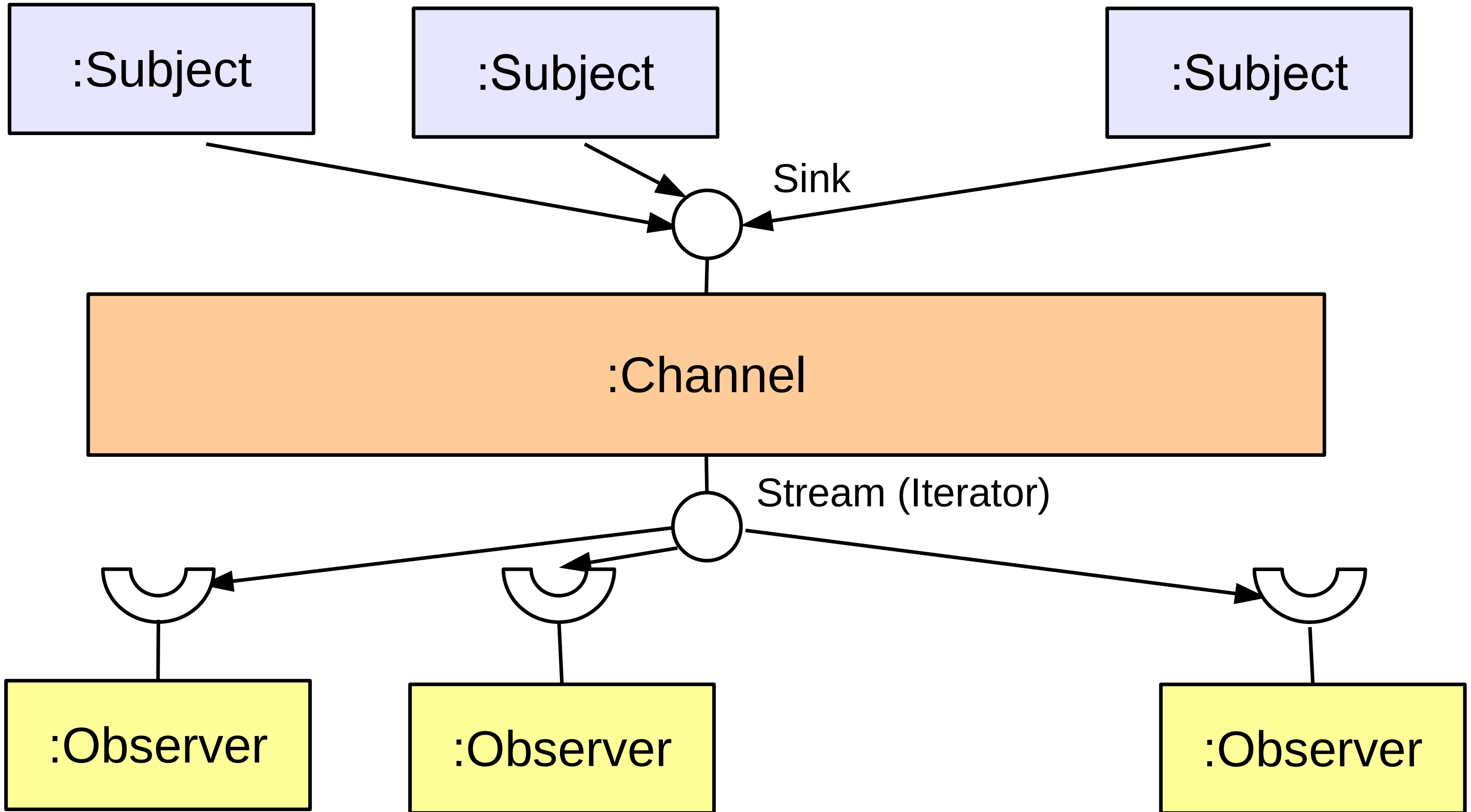
# Observer with ChangeManager is also Called Event-Bus

- 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



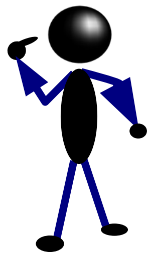
# A Variant of EventBus is the n:m-Channel

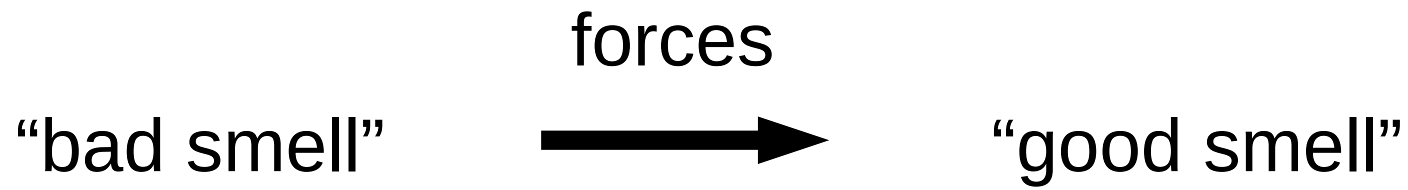
- push-Subjects and pull-Observers can be connected by Channel, to emphasize the continuous pushing and pulling
- Then Subjects write the Sink of the Channel and Observers pull the Stream of the Channel
  - Channel has a buffer



# What Does a Design Pattern Contain?

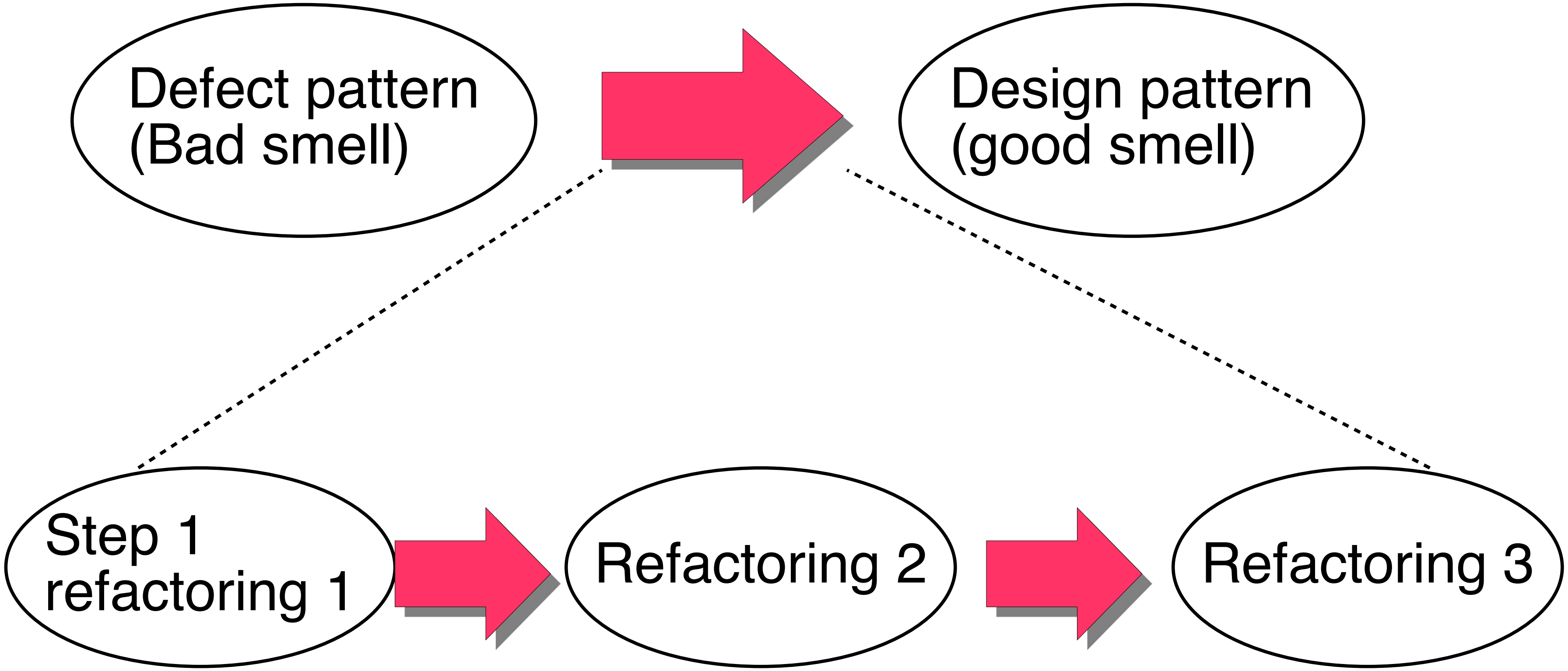
- A part with a “bad smell”
  - A structure with a bad smell
  - A query that proved a bad smell
  - A graph parse that recognized a bad smell
- A part with a “good smell” (standard solution)
  - A structure with a good smell
  - A query that proves a good smell
  - A graph parse that proves a good smell
- 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

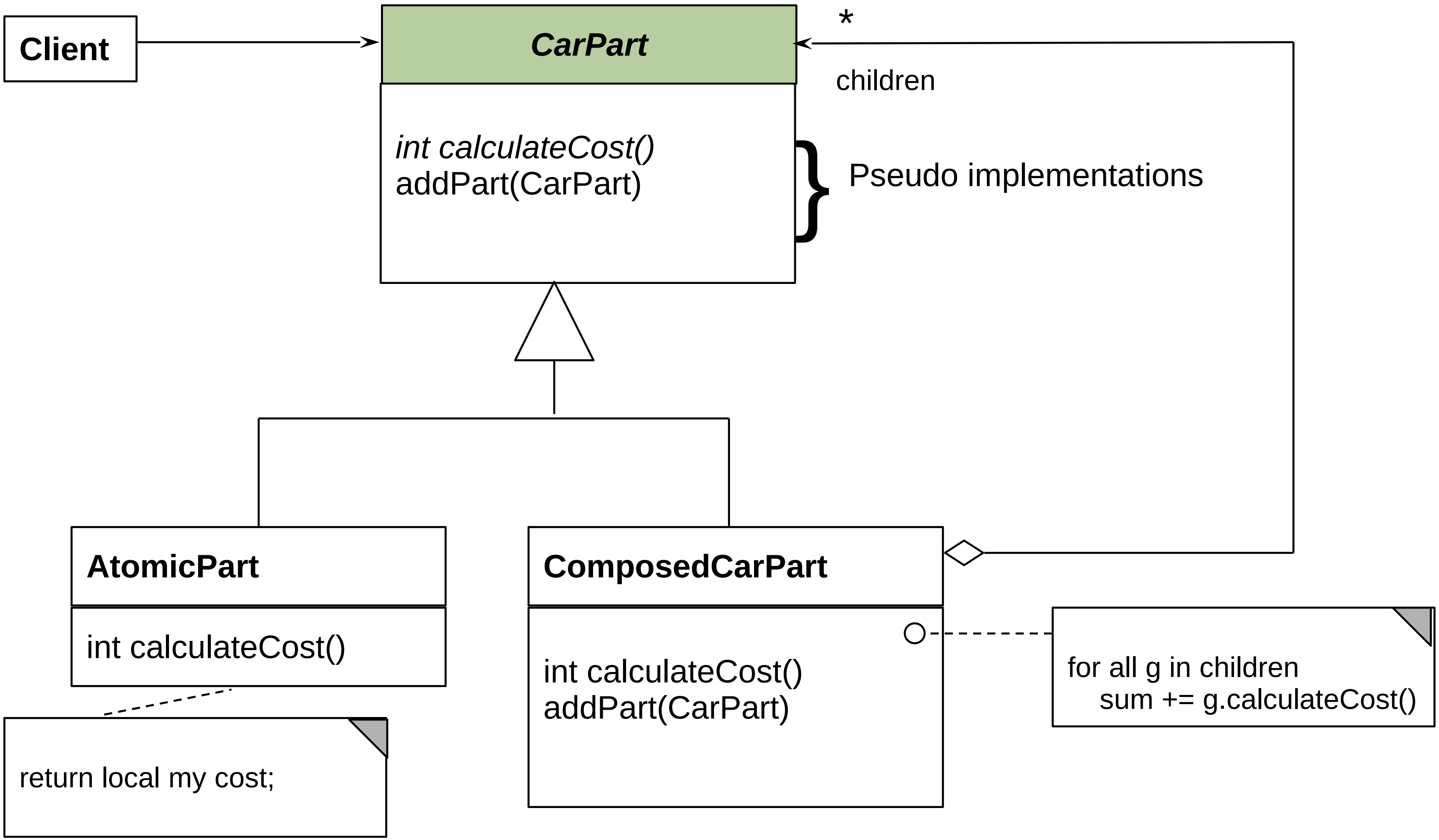


# Structure for Design Pattern Description (GOF Form)

- 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 (piecelists, or part lists)



# 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;
  }
```

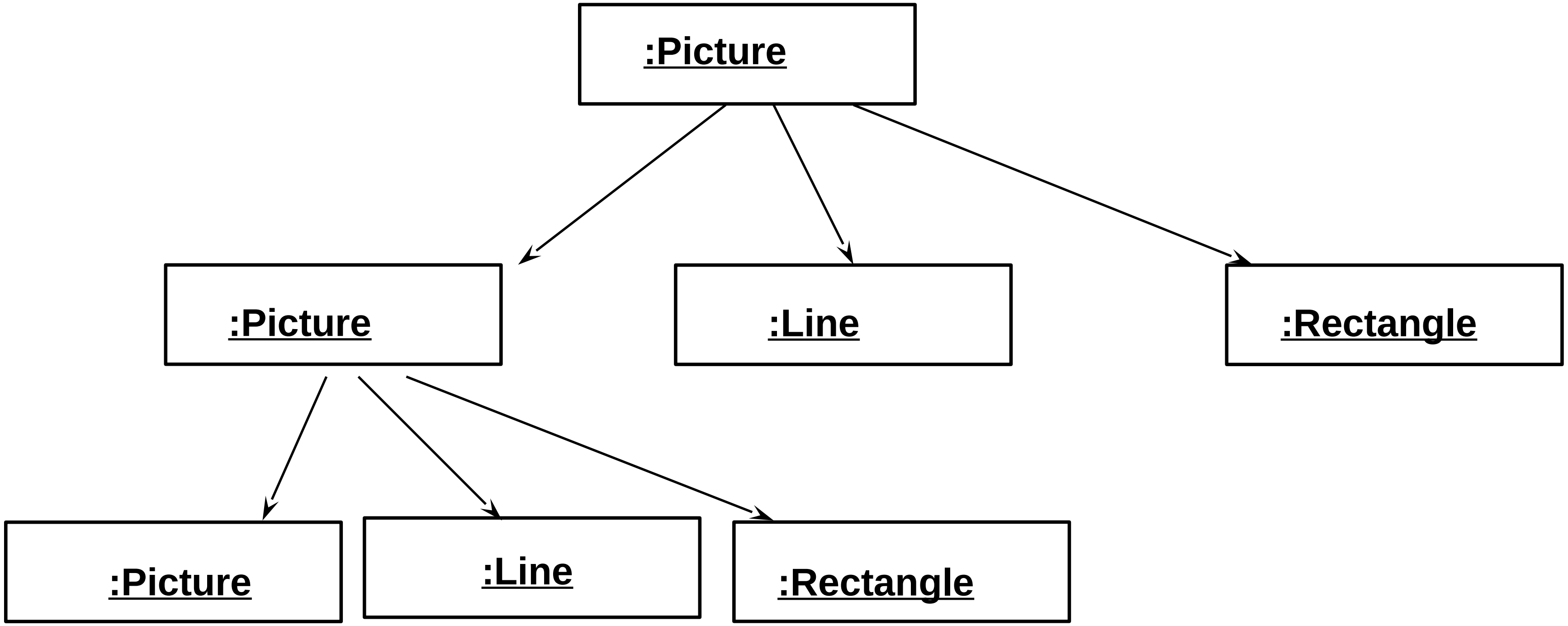
```
class AtomicCarPart extends CarPart {
   int calculateCost() { return  myCost; }
  void addPart(CarPart c) {
      /// impossible, dont do anything
   }
}
class Screw extends AtomicCarPart {
    int myCost = 10;
}
class SteeringWheel extends AtomicCarPart {
  int myCost = 200;
}
```

```
// 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()