24. Entwurfsmuster für Produktfamilien

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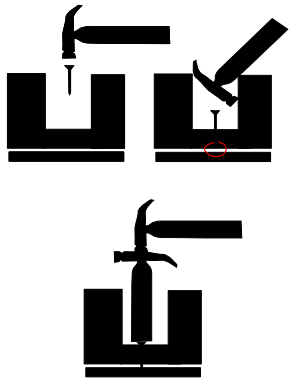
1) Patterns for Variability
2) Patterns for Extensibility
3) Patterns for Glue
4) Other Patterns
5) Patterns in AWT

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” (WS) wiederkehrt.
Mit der Bitte um Verständnis.

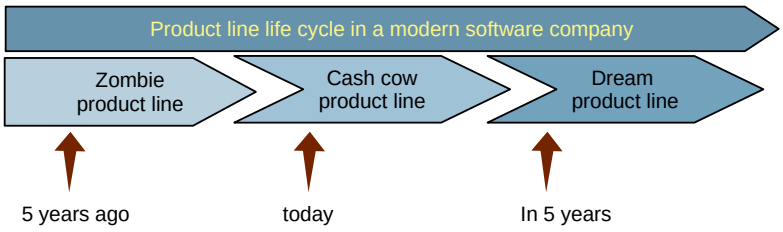
Obligatory Literature

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



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: Add new features**
  - Software must change
- **Glue: Adapt to overcome architectural mismatches**
  - Coupling software that was not built for each other



Producing a product family (product line) is a successful business model for companies. Therefore, a systematic design towards product lines can be a decisive economic factor in the life of a company.

In a company, usually 2-3 product lines are active at the same time:

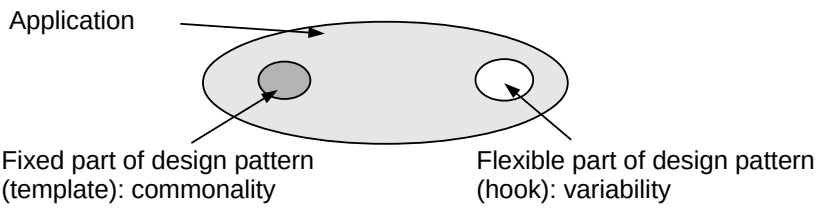
• The “zombie” product line is the one of the past, from which no new products are created, but old products are in use and must be

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

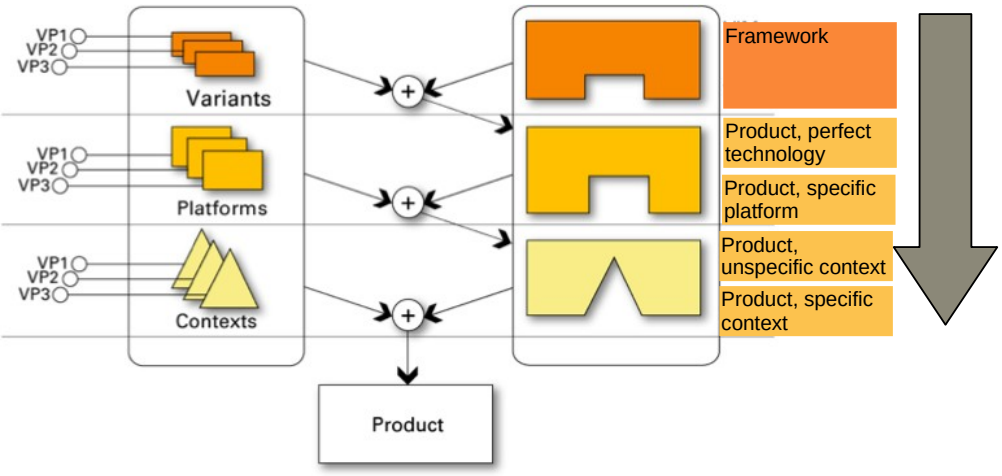
Commonalities and Variabilities

- A variability design pattern describes
  - Code *common* to several applications
    - Commonalities lead to *frameworks* of *product lines*
  - Code *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)



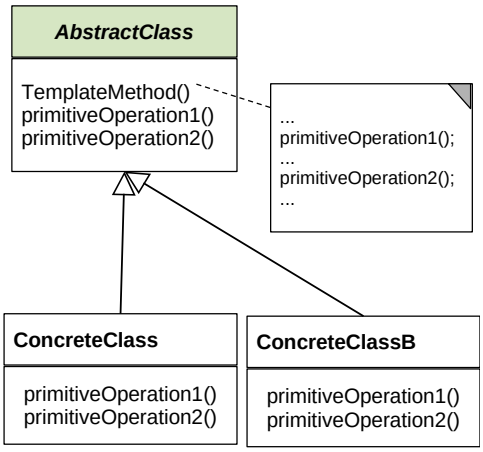
Why Do We Need Variability?

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



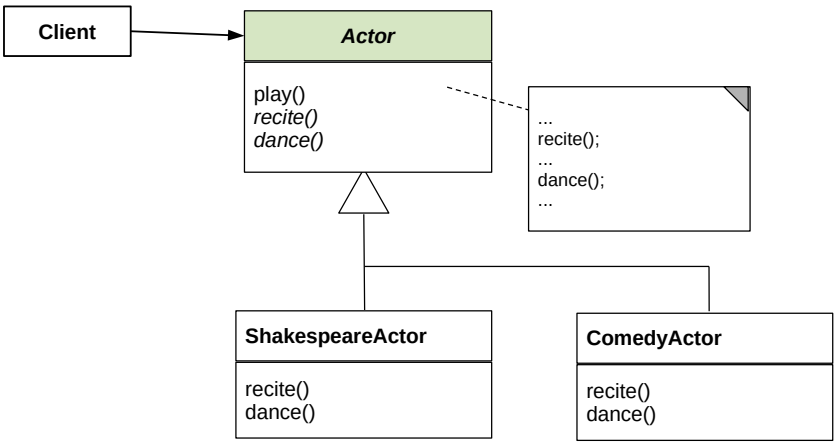
TemplateMethod Pattern is a Variability Design Pattern (Rpt.)

- 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



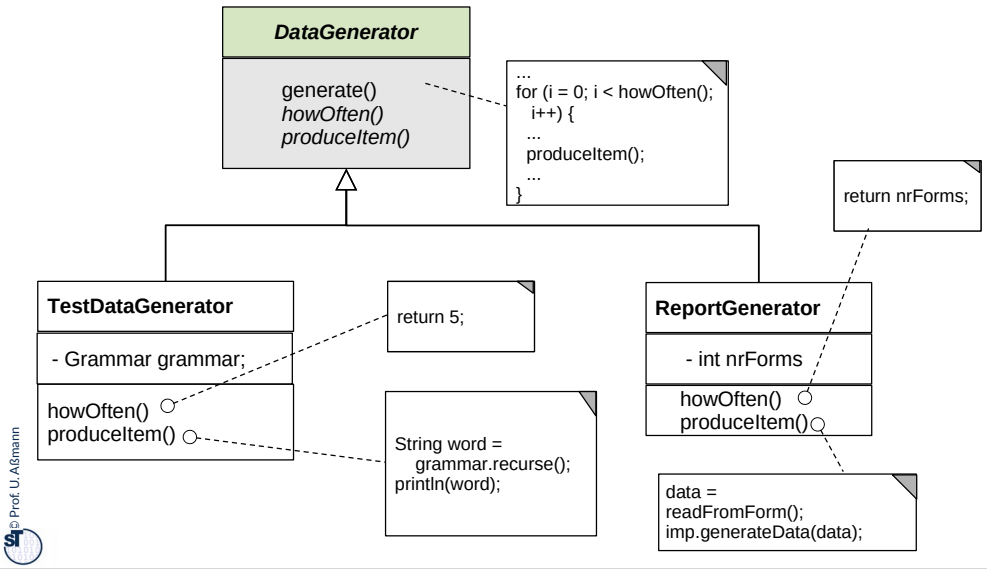
Actors and Genres as Template Method

- 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



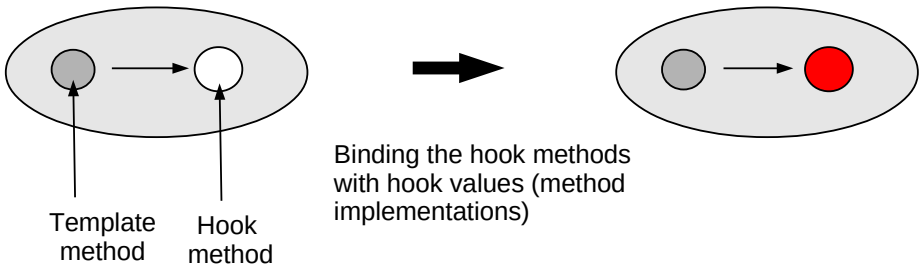
Running Example: A Data Generator

- Parameterizing a data generator by frequency and kind of production



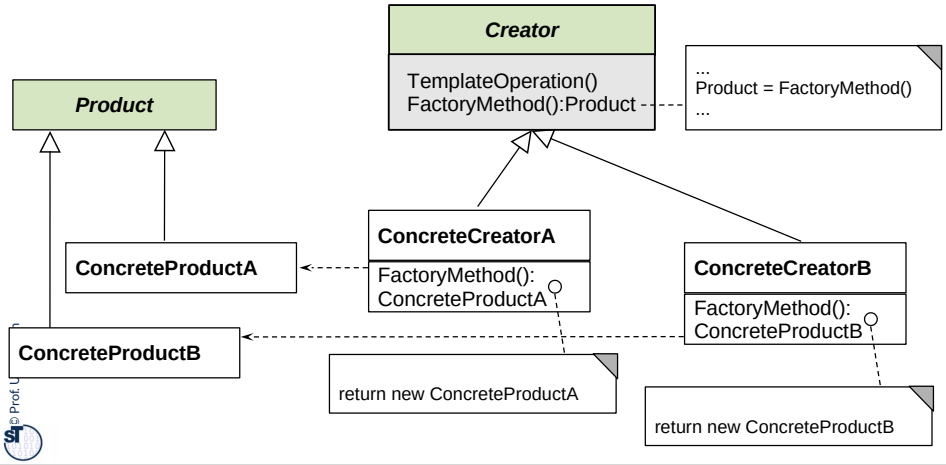
Variability with TemplateMethod

- **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.)

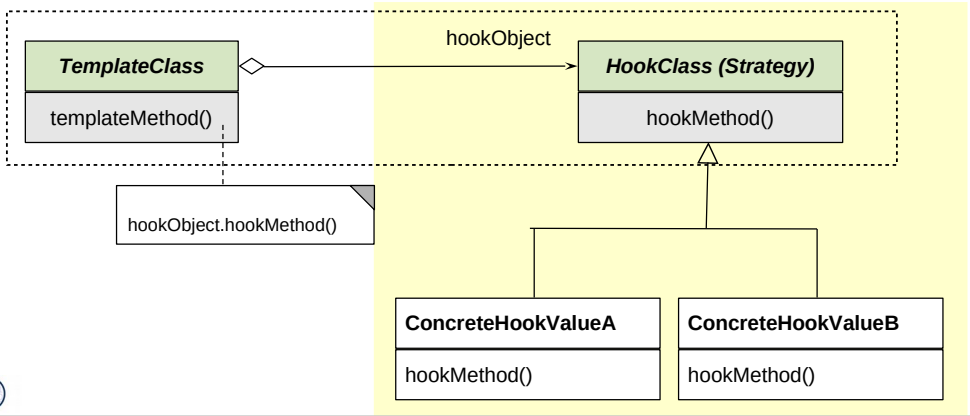
- FactoryMethod is a variant of TemplateMethod
- A FactoryMethod is a polymorphic constructor



24.1.3 Strategy (Template Class)

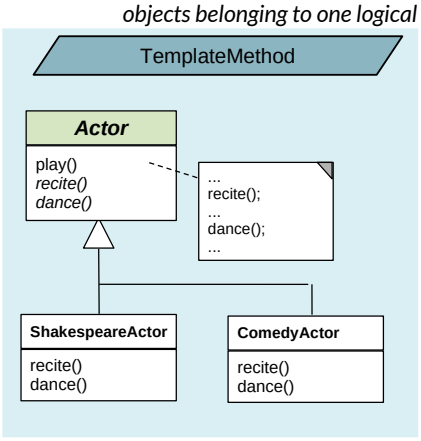
Strategy (also called Template Class)

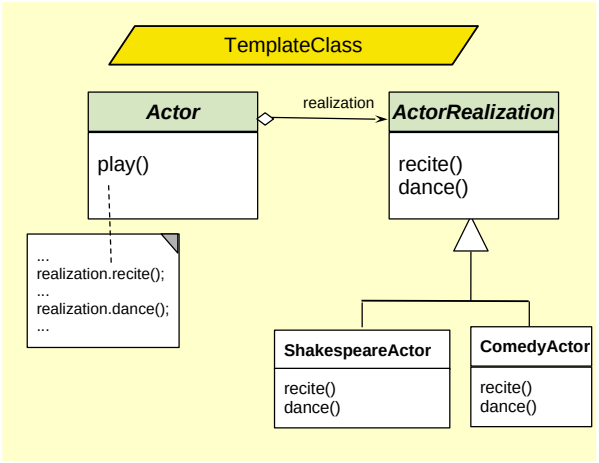
- The template method and the hook method are found in different classes
- Similar to TemplateMethod, but
  - Hook objects and their hook methods can be exchanged at run time
  - Exchanging several methods (a set of methods) at the same time
  - Consistent exchange of several parts of an algorithm, not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



Actors as Template Method

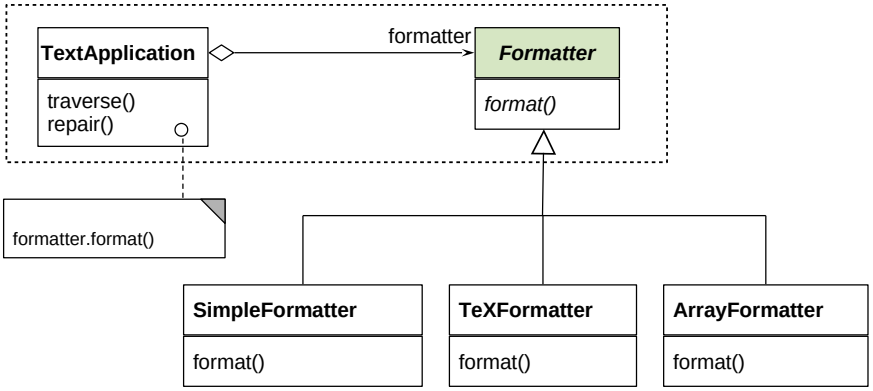
- TemplateMethod creates *one* run-time object; TemplateClass creates *two physical objects belonging to one logical object*





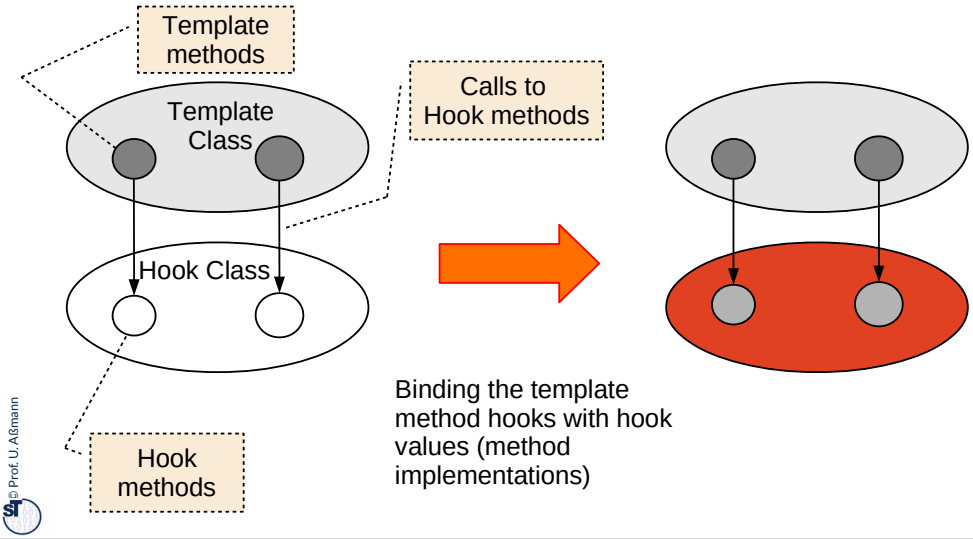
Example for Strategy

- 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

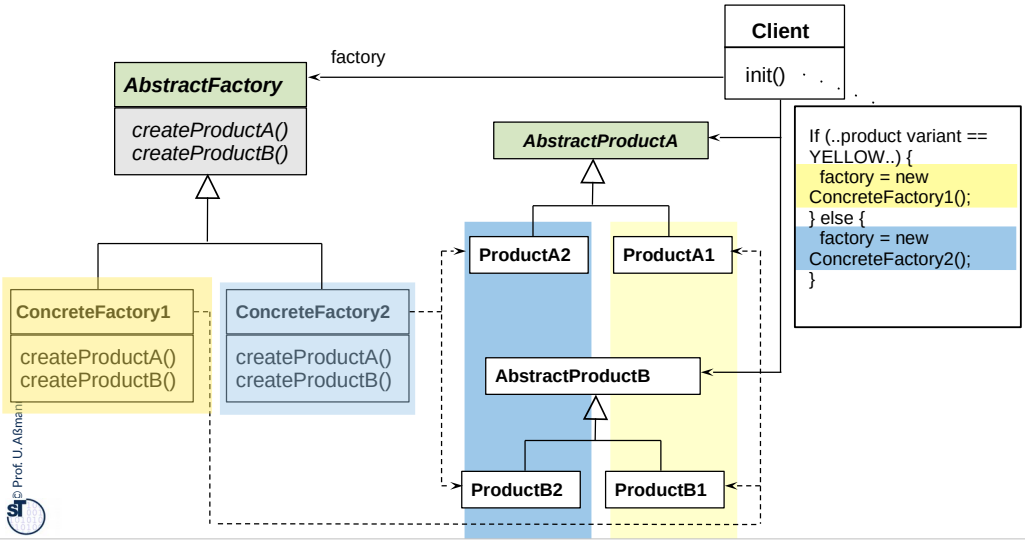
- Binding the hook class of a Strategy means to derive a concrete subclass from the **abstract hook superclass,** providing the implementation of the hook method



24.1.4. Factory Class

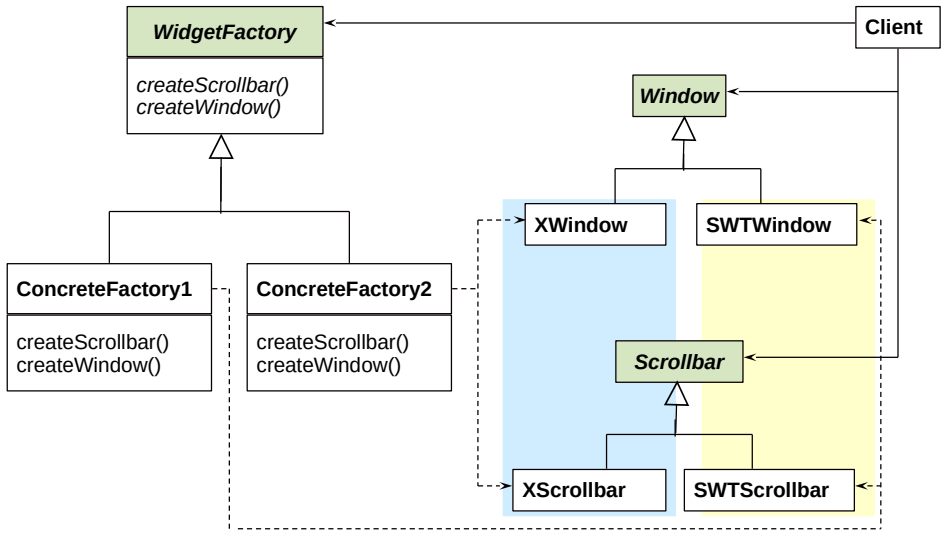
24.1.4 Factory Class (Abstract Factory)

- 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

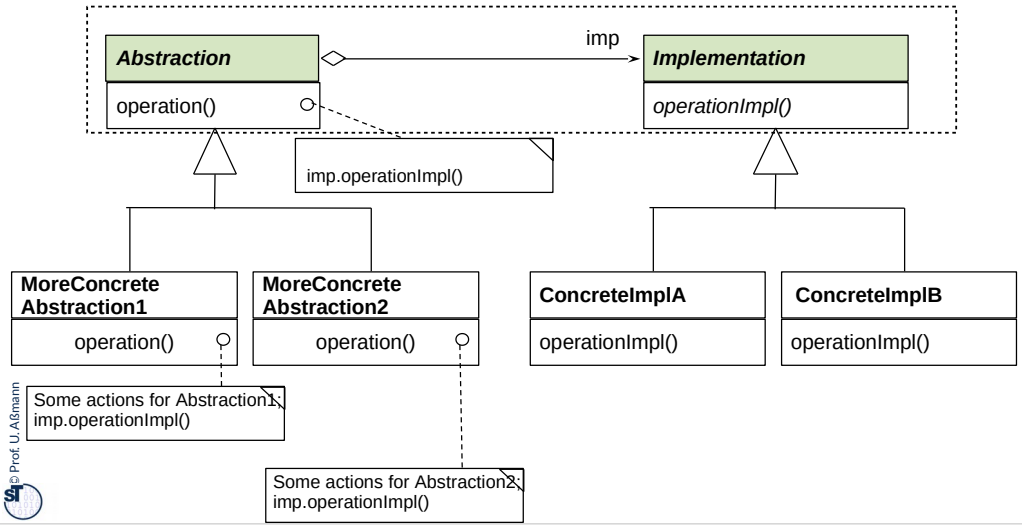
- Consistently varying a family of widgets

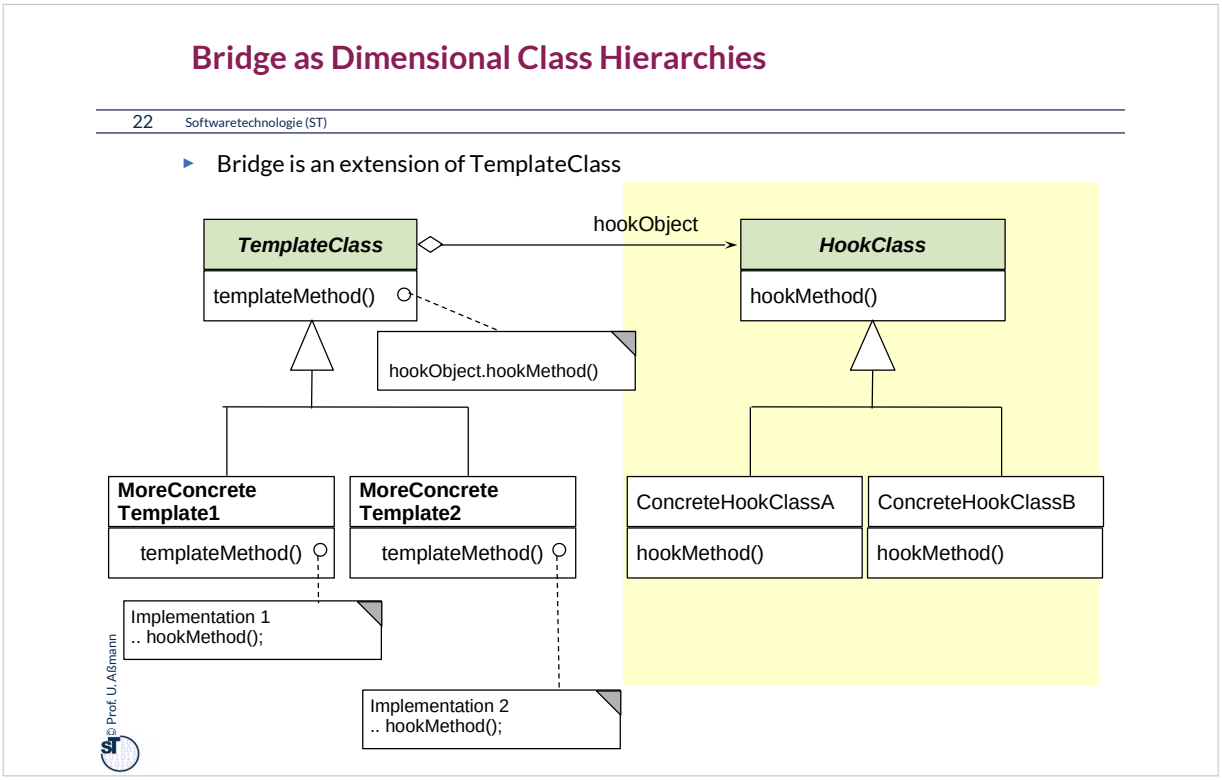


24.1.5 Bridge (Dimensional Class Hierarchies)

Bridge for Complex Objects (GOF-Version)

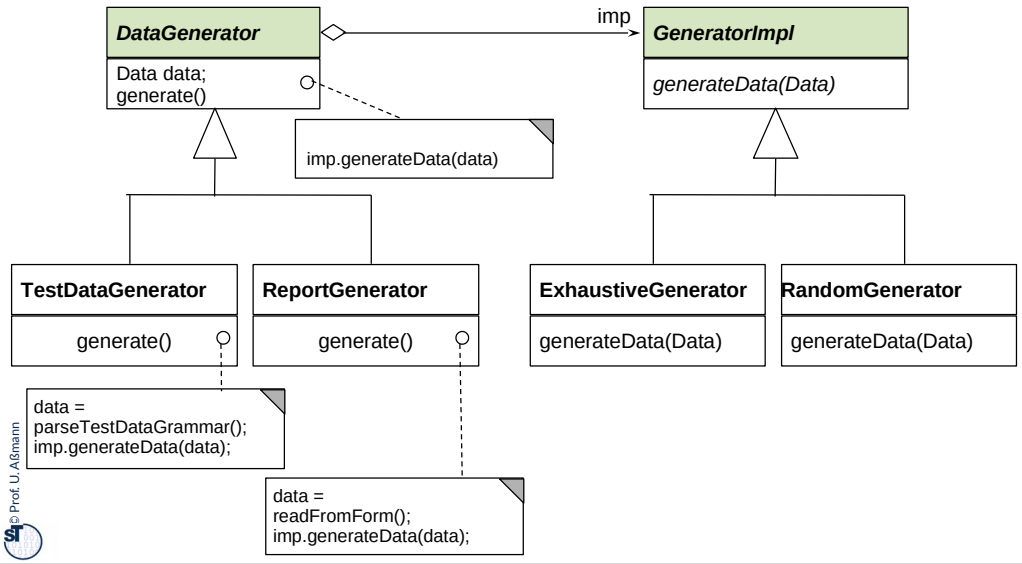
- A **Bridge** represents a *complex object* with two layers
- The left hierarchy (upper layer) is called *abstraction hierarchy*, the right hierarchy (lower layer) is called *implementation*





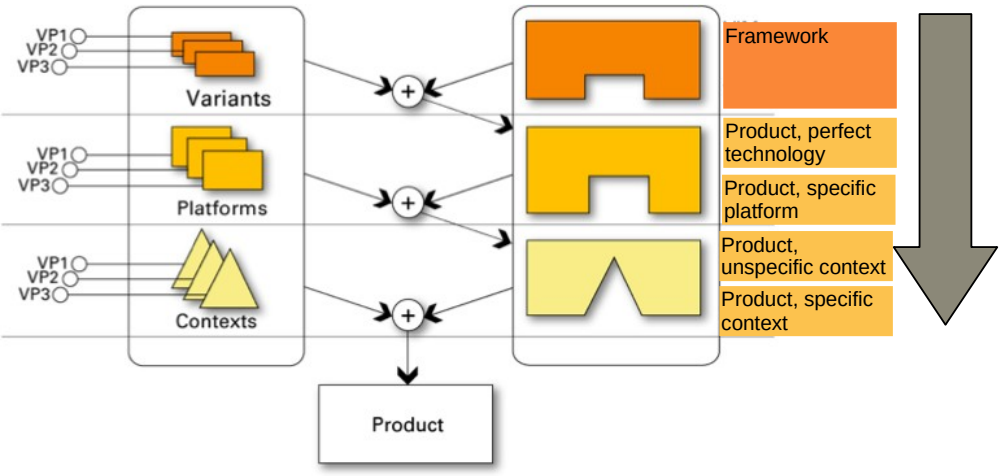
- A Bridge varies also the template class in a class hierarchy
  - The sub-template classes can adapt the template algorithm
  - Important: the sub-template classes must fulfil the contract of the superclass
    - Although the implementation can be changed, the interface and visible behavior must be the same
- Both hierarchies can be varied independently
  - Factoring (orthogonalization)
  - Reuse is increased
- Basis for patterns
  - Observer, Visitor

Ex. Complex Object *DataGenerator* as Bridge



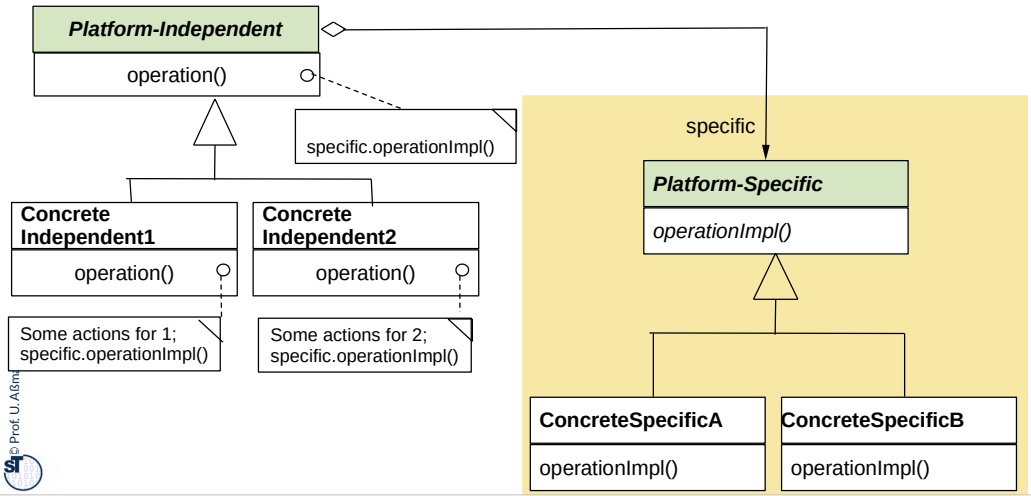
Rpt.: Why Do We Need Variability?

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



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



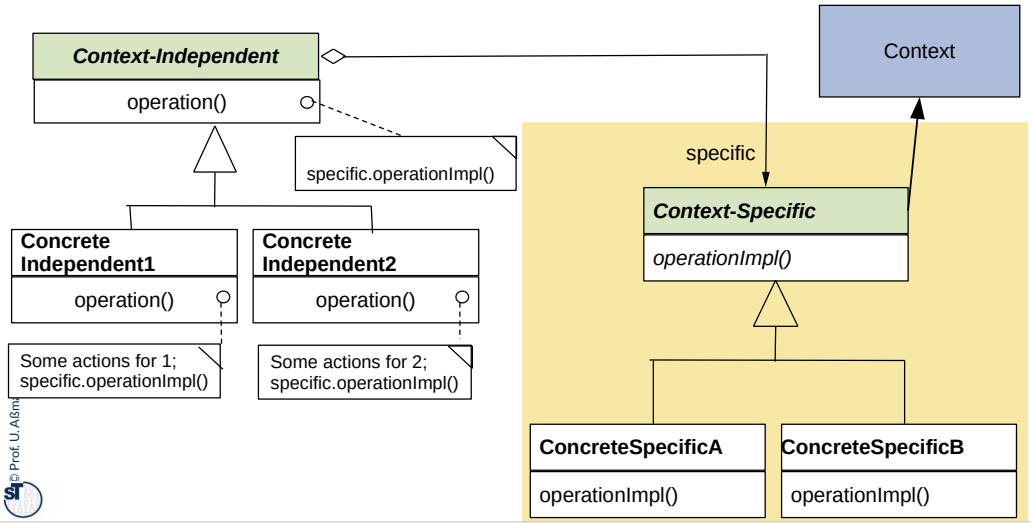
Bridges can hide inside platform-specific code (in the hook object).

Whenever the software should be ported to a new platform, a new variant of the hook class must be programmed. Splitting the platform-independent from the platform-specific code enables the developer to reuse the platform-independent code for many platforms.If all objects in a program are programmed with “platform bridges”, the software is very easy to port to new platforms.

Bridge is one of the most important patterns for software product lines.

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



Bridges can hide inside context-specific code that is *varied dynamically* (in the hook object).

Whenever the software should work differently in a new dynamic context, the hook object can be varied dynamically.

Bridge is one of the most important patterns for *dynamic* software product lines.

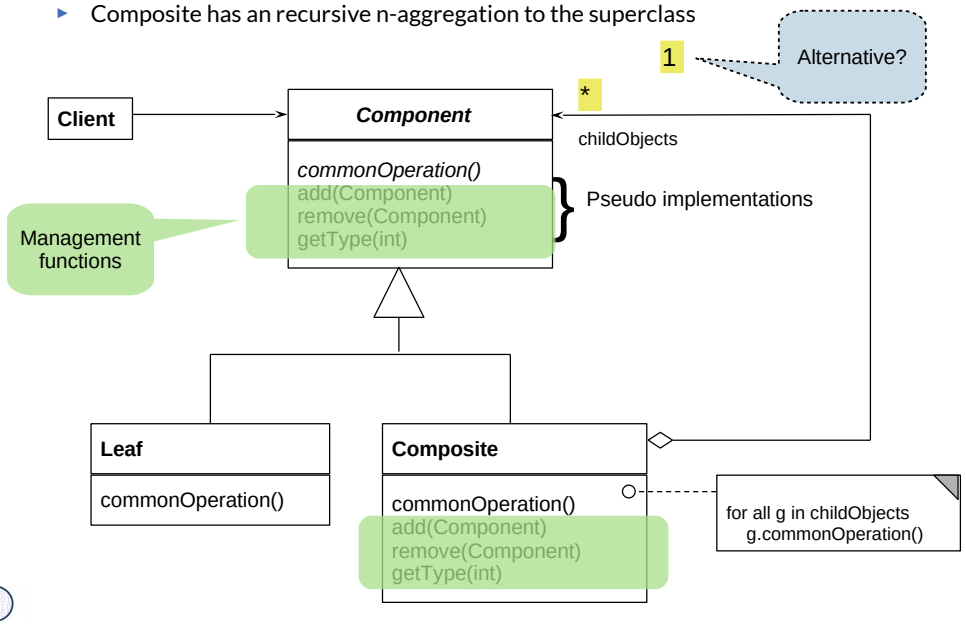
24.2) Patterns for Extensibility

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

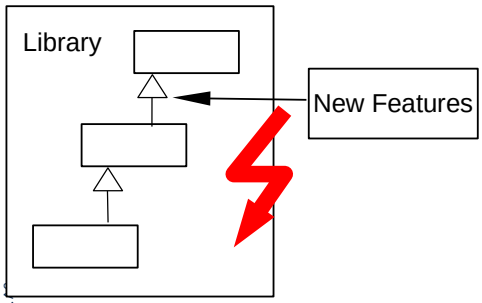


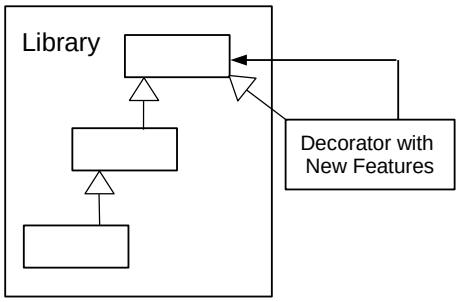
24.2.2. Decorator

- The “sibling” of Composite

Problem

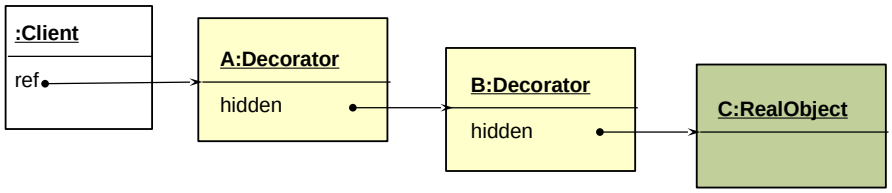
- How to extend an inheritance hierarchy of a library that was bought in binary form?
- How to avoid that an inheritance hierarchy becomes too deep?





Snapshot of Decorator Pattern

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



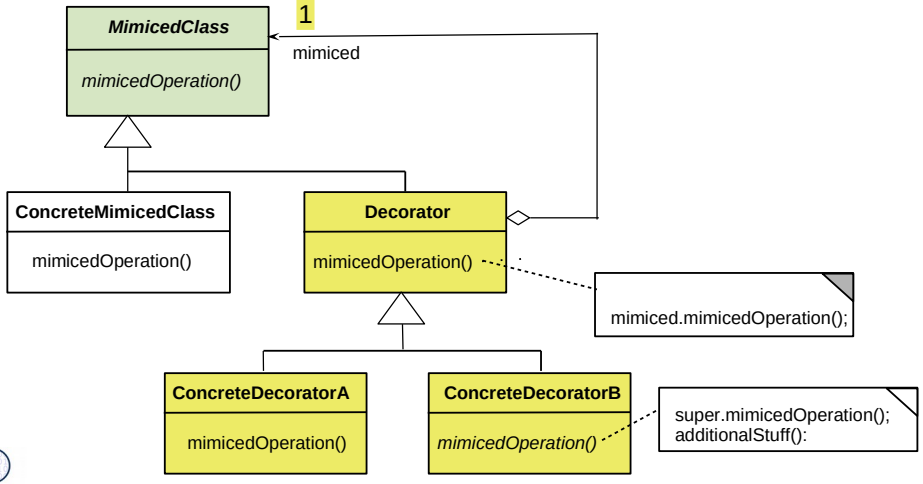
While traversing from the client to the Real Object, one passes all skin objects. Before recursing, an *prologue code (climbing down code)* is executed. After recursing, an *epilogue code (climbing up code)* is executed.

Prologue and epilogue code *wrap* the next object in the line.

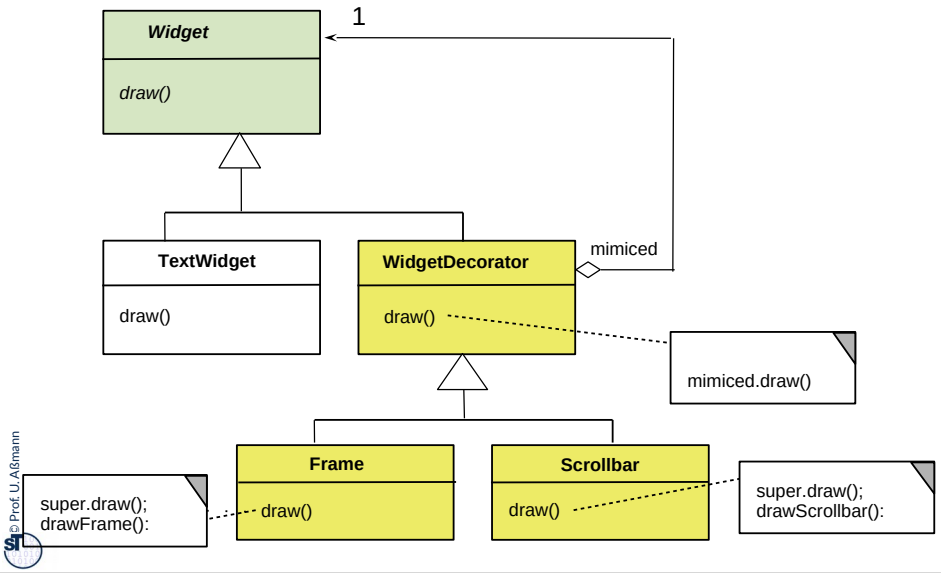
All skin objects belong logically to the real object, though being physically different.

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



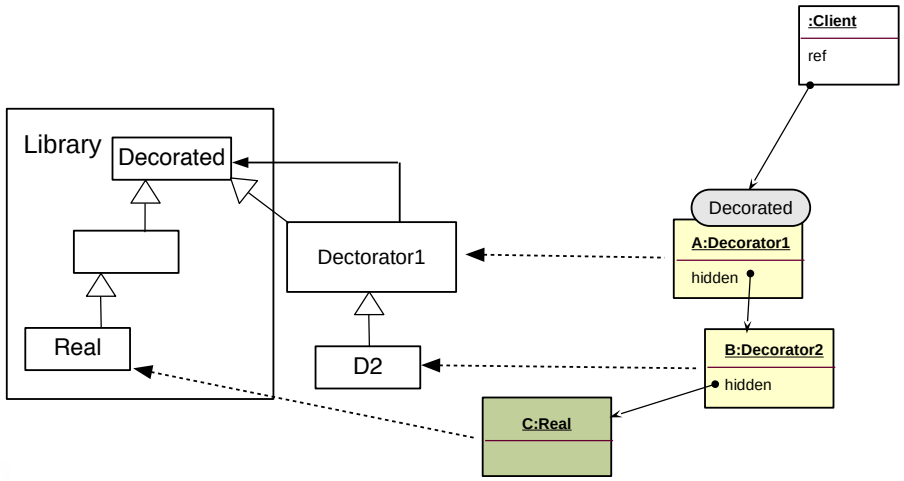
Ex.: Decorator for Widgets



Decorator is frequently used in the implementation of widget hierarchies in GUI.

Purpose Decorator

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



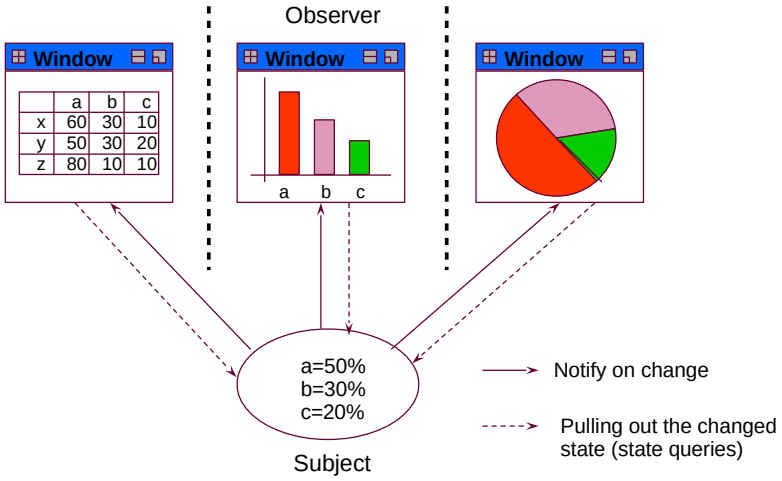
A combined class-object diagram shows how decorator class hierarchies determine the form *of the skin object lists*.

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)



Publish/Subscribe Patterns describe dynamic communications. For modern applications, they are indispensible.

Overview

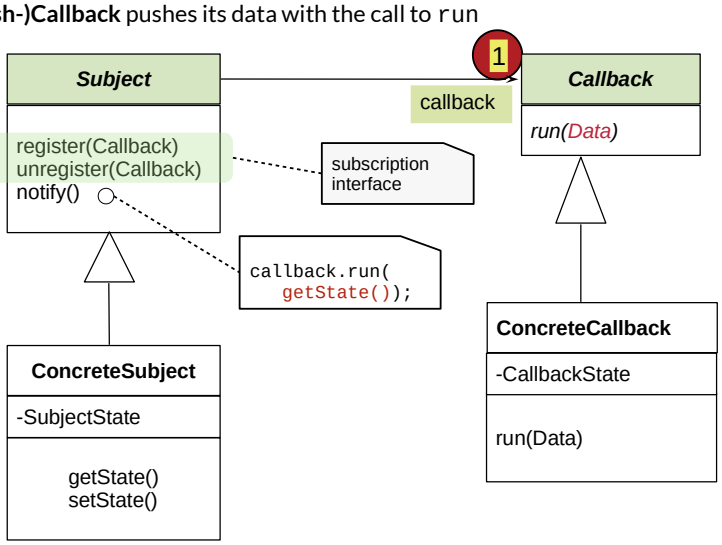
Push		Data is flowing with the call to “update”
	Callback	1 observer
	Observer	n observer
Pull		Data is pulled on demand
	Callback	1 observer
	Observer	n observer

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

pull-Observer, the “normal” Observer from the GOF book, combines the registration of several observers with the pull of the changed state of the Subject. Therefore, it is the most complicated pattern of the 4 Publish/Subscribe Patterns discussed here.

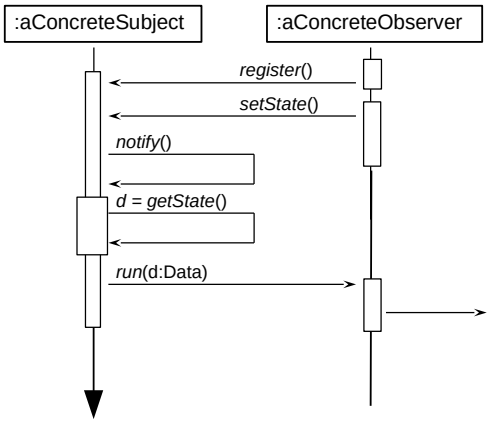
24.2.3.1 Publish/Subscribe with 1 Observer: Callback

- **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`



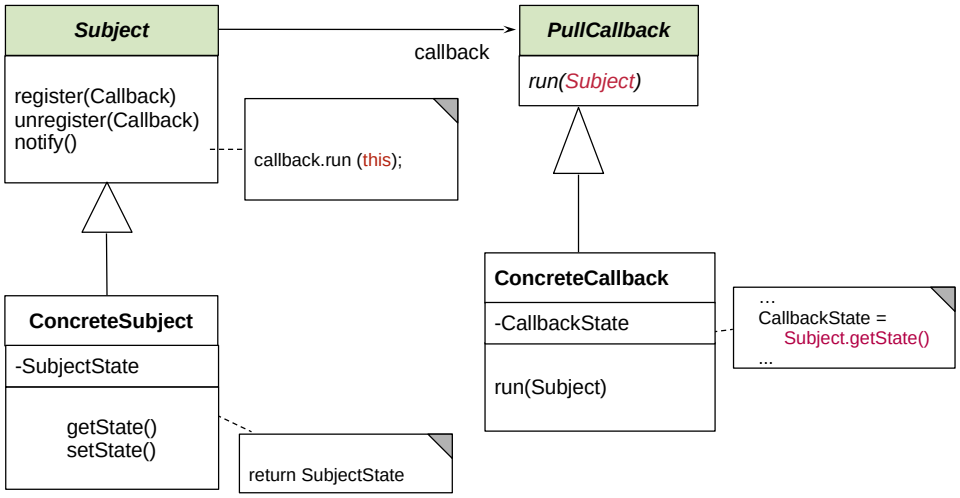
Sequence Diagram push-Callback

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



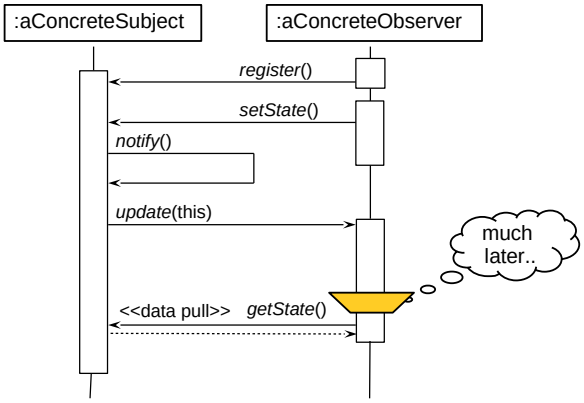
24.2.3.2 Structure pull-Callback (Delayed Data Transfer)

- 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



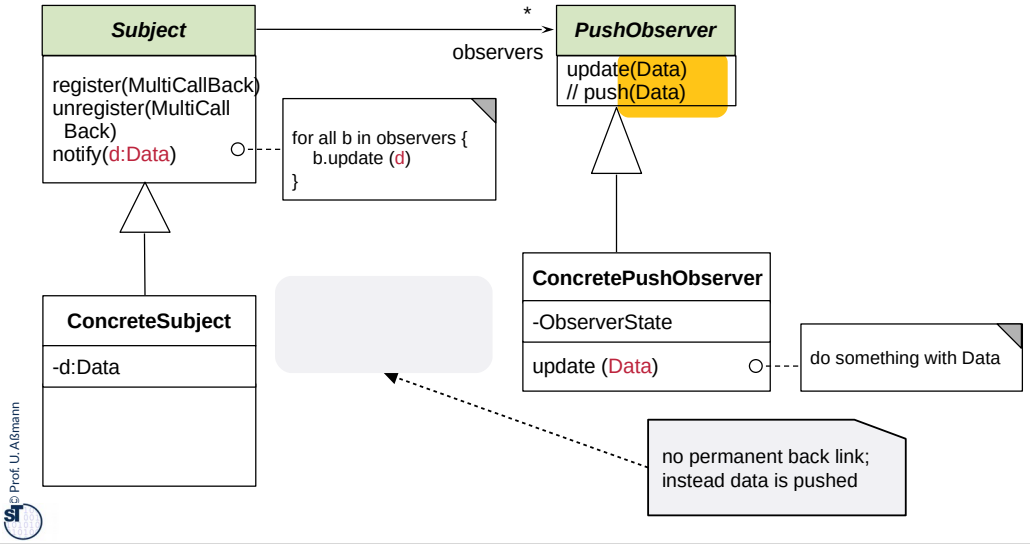
Sequence Diagram pull-Callback

- 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

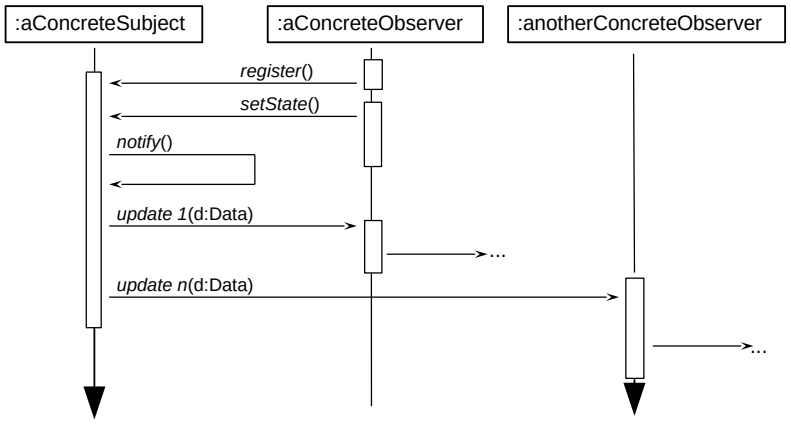


If the amount of data that is to be transferred from the subjec to the observers is small, pushing the data with the update is no problem.

However, when the data is huge, its transport might be done in vain. Then, it is better to let the observer decide when to pull the data. This leads to the pull-Observer.

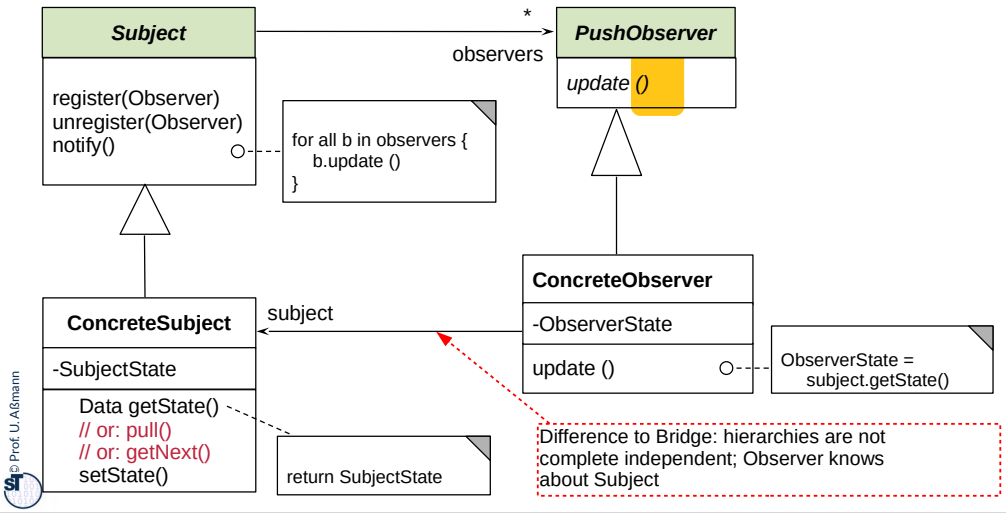
Sequence Diagram push-Observer

- 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

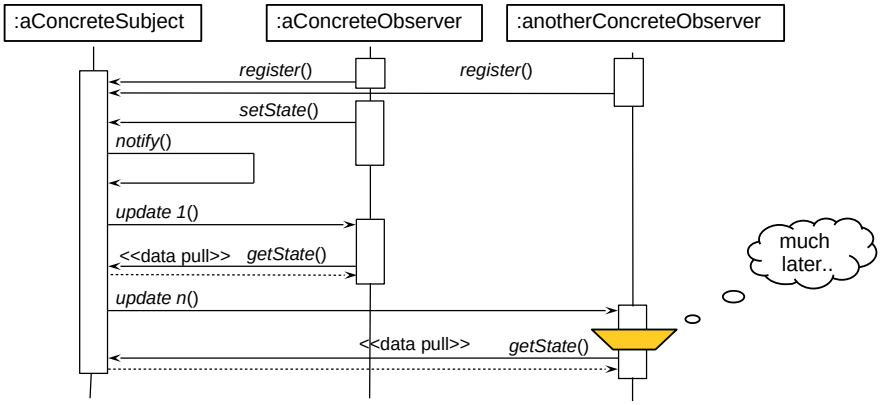


The Observer from GOF can also be called EventBridge, because it resembles a Bridge on which update events are transferred.

If the observer pulls data several times, the pattern becomes very similar to Iterator.

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



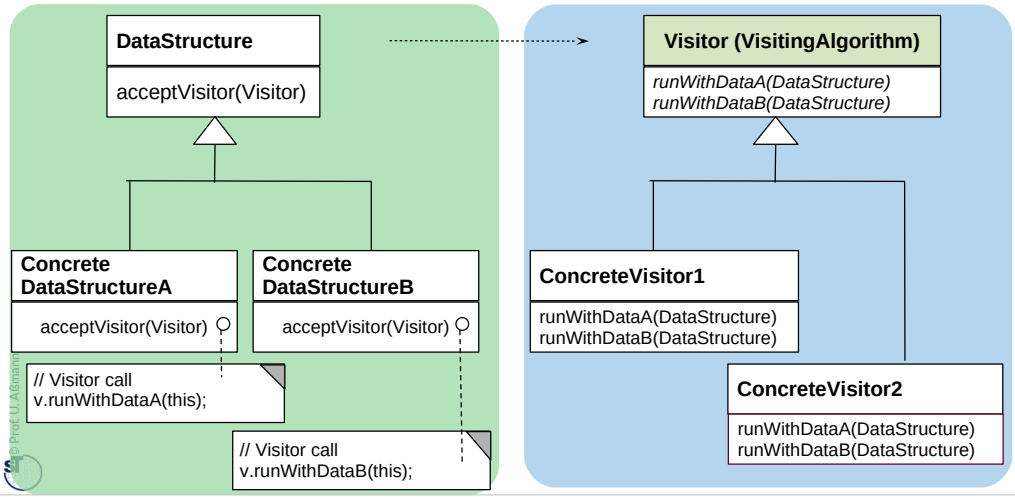
24.2.4. Visitor

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



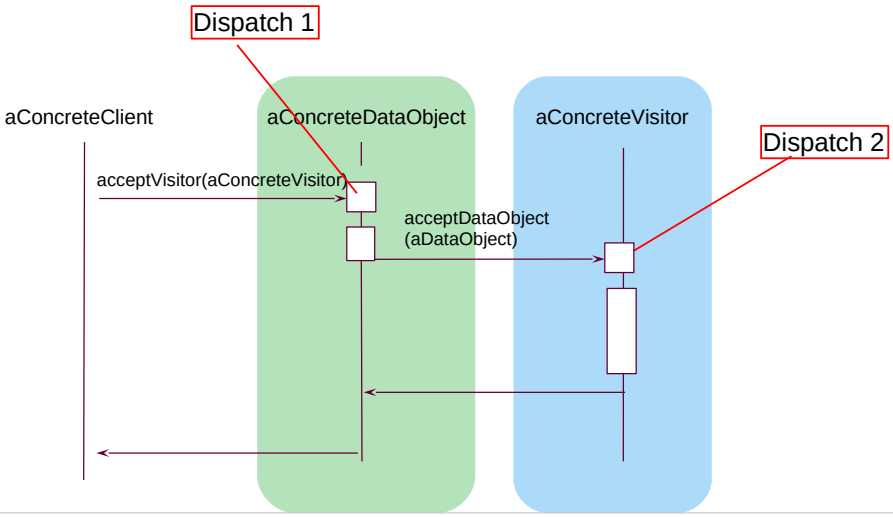
Visitor is a somewhat obscure pattern. The usual principle of object-orientation tells us to *encapsulate algorithms with data*. The only reason to split off the visiting algorithms from the data is to be able to extend the set of algorithms over time, or if this extension cannot be foreseen.

For instance, if a new customer wants a new feature of a product, a Visitor hierarchy can be extended very easily, without retesting the DataStructure hierarchy nor the old visiting algorithms, because they all stay the same.

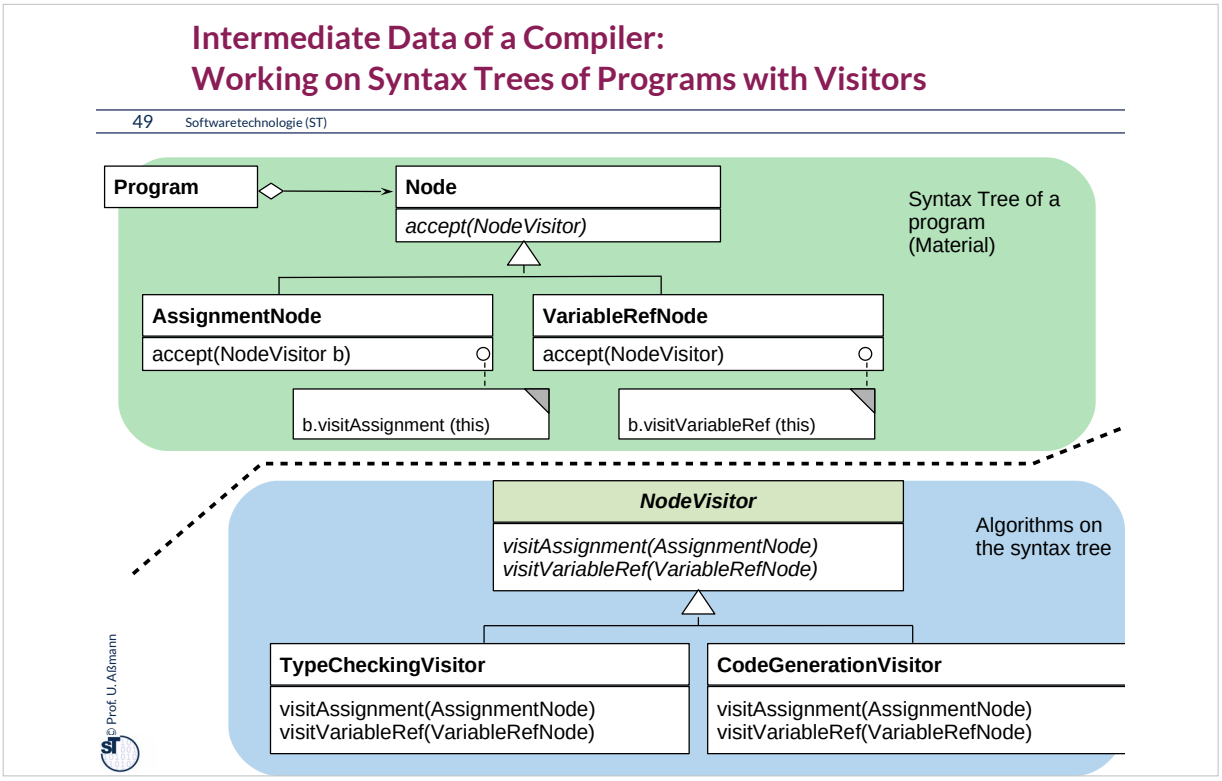
Therefore, Visitor is an evolution pattern.

Sequence Diagram Visitor

- First dispatch on data, then on visiting algorithm



"Double dispatch" is offered in some programming languages as a language concept ("multi-methods"). In such a programming language, the Visitor pattern is built in.



Syntax Trees are a central data structure in compilers, refactoring tools, integrated development environments like Eclipse. Syntax trees represent the programs you write. Software tools work on syntax trees.

Therefore, Visitor appears in all tools for software development.

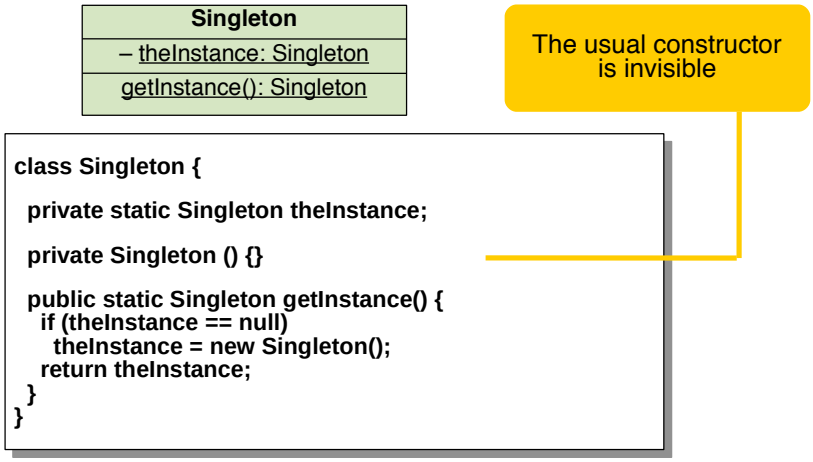
Usually, also all forms of documents (text documents, slides, spreadsheets, pdf documents, etc.) can be represented by syntax trees. Thus, syntax trees are also a central data structure in Word-like editors, Powerpoint-like slide editors, Spreadsheet tools, Acrobat-readers....

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)

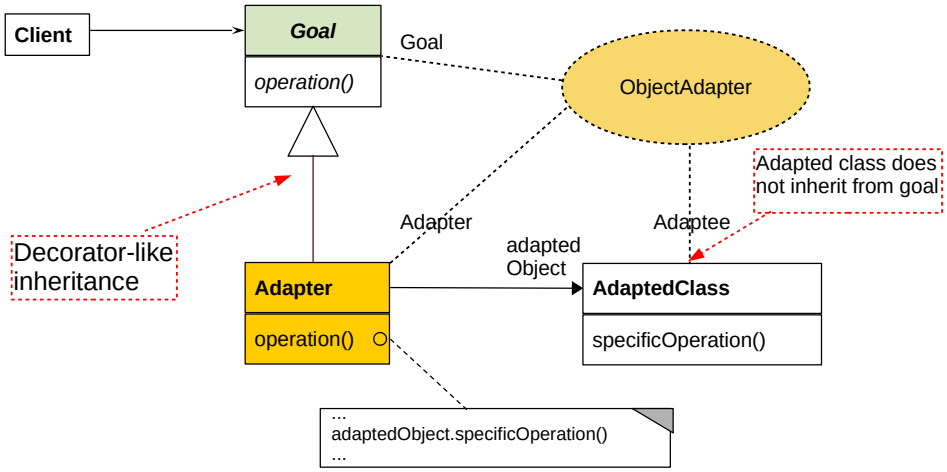
- Problem: Store the global state of an application
  - Ensure that only *one* object exists of a class



24.3.2 Adapter

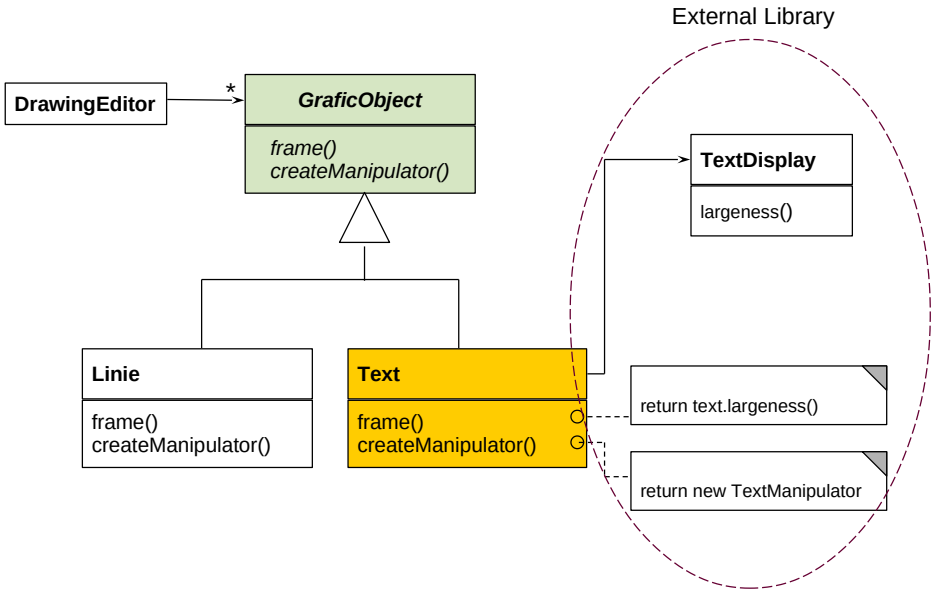
Object Adapter

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



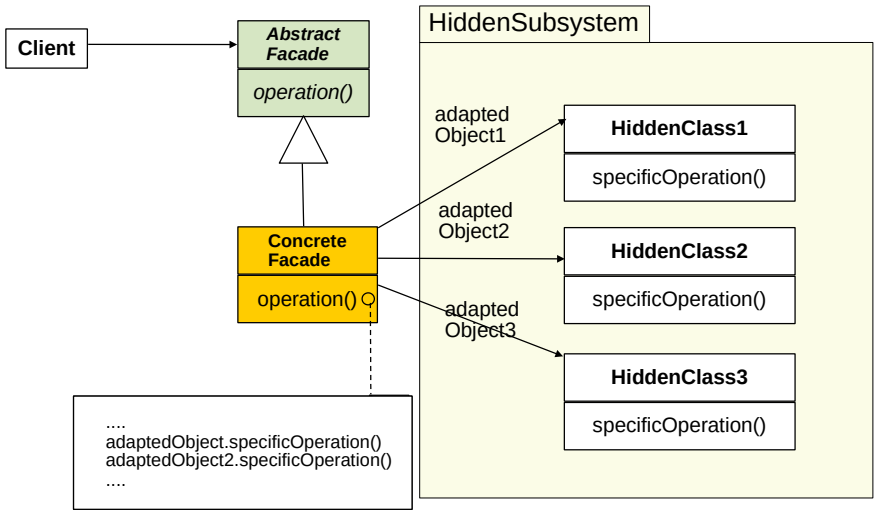
Adapter is one of the most useful patterns when an old system should be coupled to new classes. Adapter adapt interfaces, data formats and protocols.

Example: Use of an External Class Library For Texts



24.3.3 Facade Hides a Subsystem

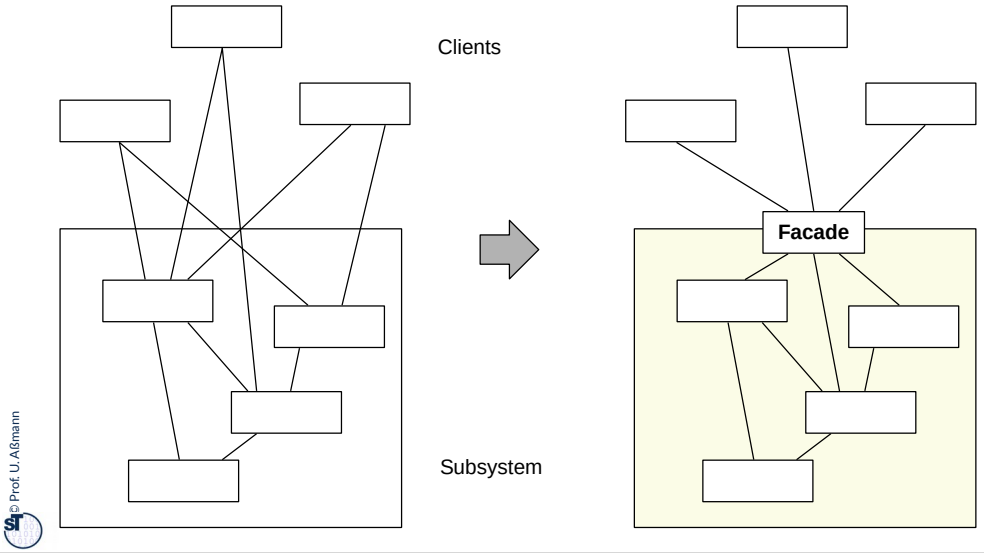
- A **facade** is a specific object adapter hiding a complete set of objects (subsystem)
  - The facade has to map its own interface to the interfaces of the hidden objects



Facades are very much linked with layers, an architectural concept (architectural style).

Refactoring a Legacy System Towards a Facade

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



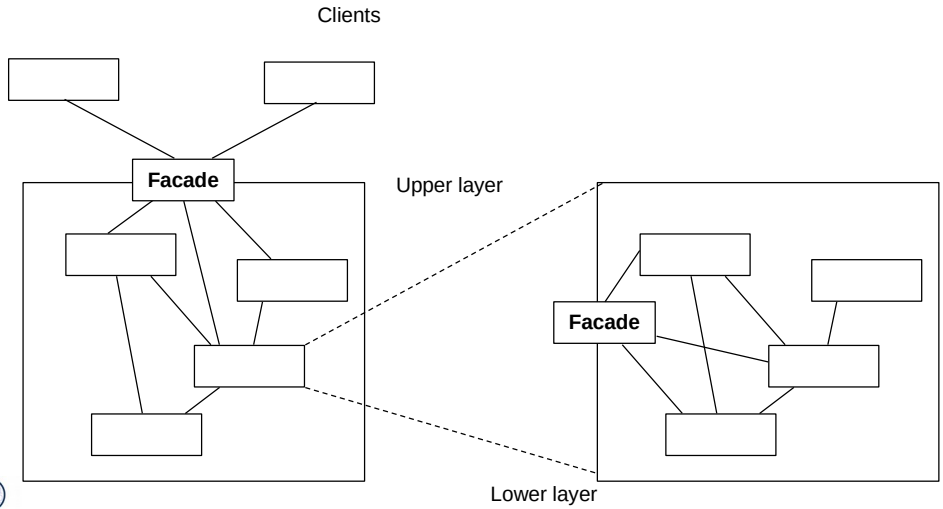
One of the most important restructuring operations in old systems is to introduce modules, subsystems, or packages by encapsulating them by a facade object.

Then, the subsystem can be exchanged behind the facade, and no client will be disturbed.

In the situation of the left side, this is not possible, because too many explicit dependencies exist from the subsystem to the clients.

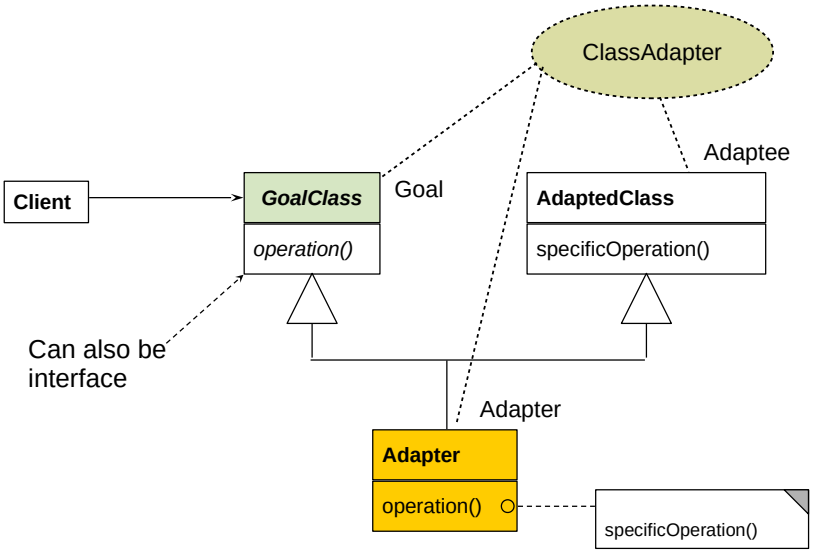
The Layer Pattern

- 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...

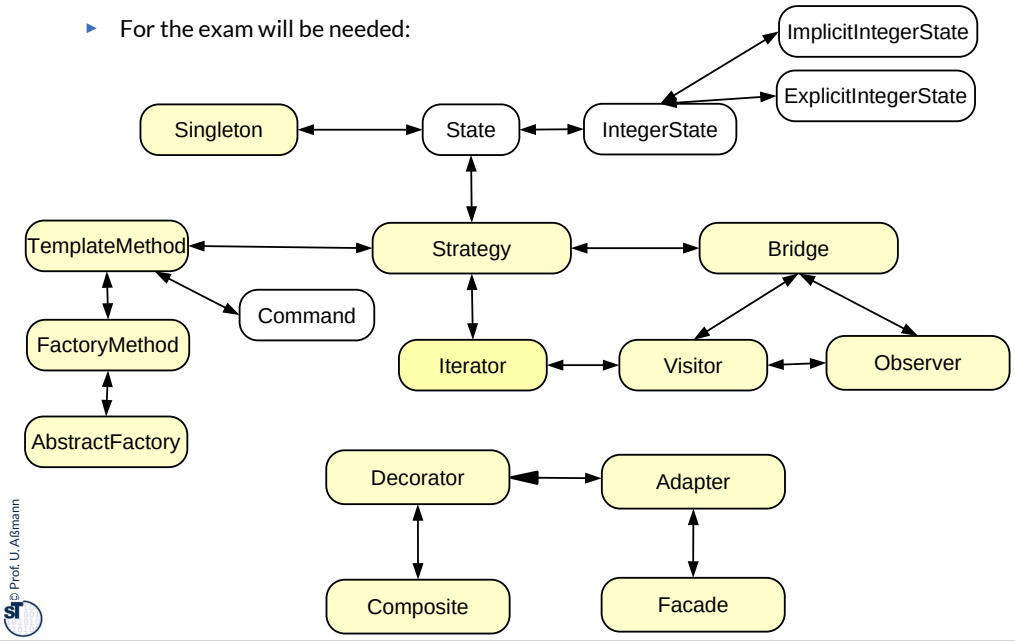
- Iterator, Sink, and Channel
- Composite
- TemplateMethod, FactoryMethod
- Command

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:



The yellow marked patterns will be important for the exam.

Try to find out a “beauty feature” for every pattern: Why does the pattern describe a beautiful solution for a standard ugly problem?

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

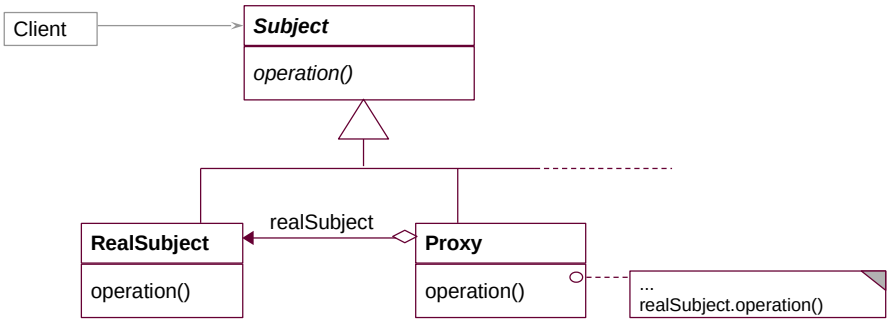
What Have We Learned?

- 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

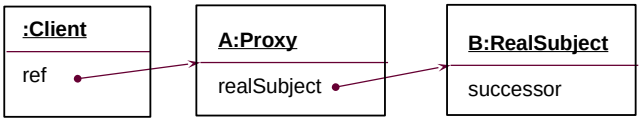
24.A.1 Proxy

Proxy

- Hide the access to a real subject by a representant



Object Structure:



Proxy

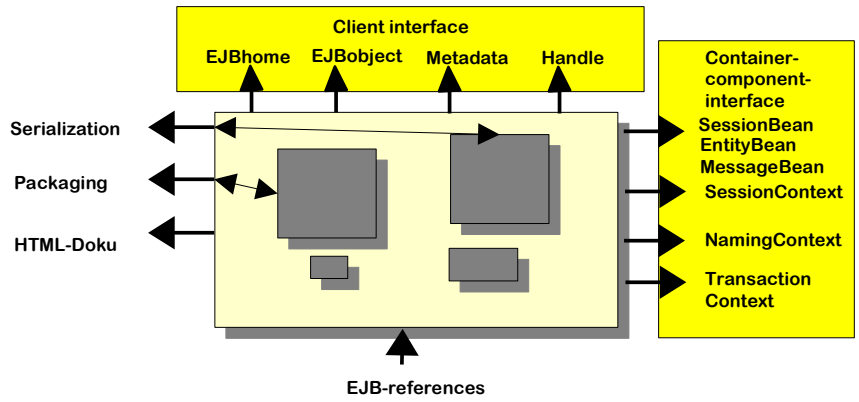
- The proxy object is a representant of an object
  - The Proxy is similar to Decorator, but it is not derived from ObjectRecursion
  - It has a direct pointer to the sister class, *not* to the superclass
  - It may collect all references to the represented object (shadows it). Then, it is a facade object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

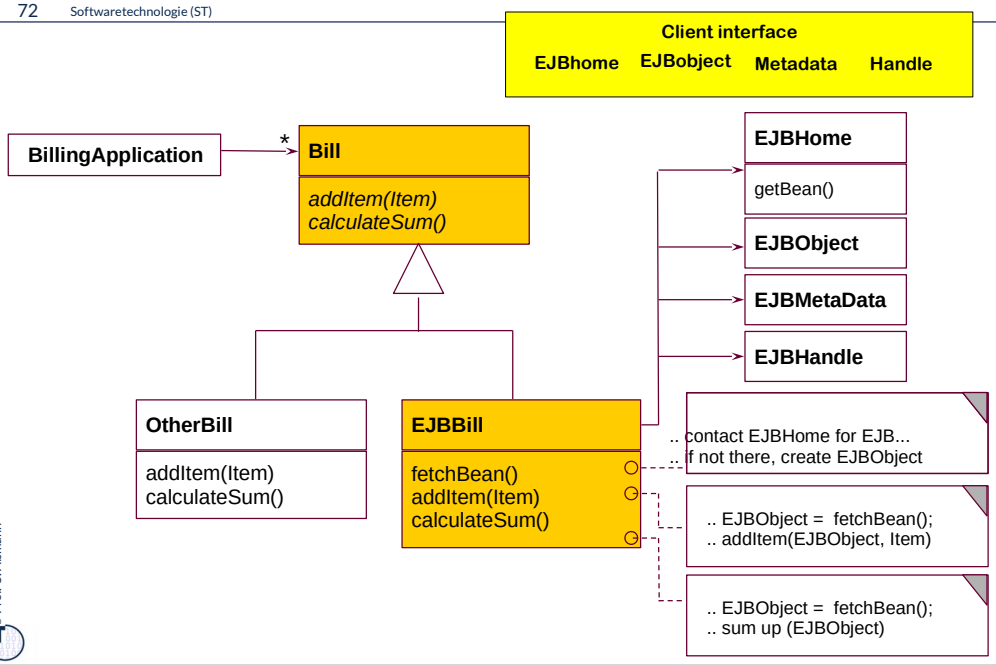
- **Filter proxy** (smart reference):
  - executes additional actions, when the object is accessed
- **Protocol proxy**:
  - Counts references (reference-counting garbage collection
  - Or implements a synchronization protocol (e.g., reader/writer protocols)
- **Indirection proxy** (facade proxy):
 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

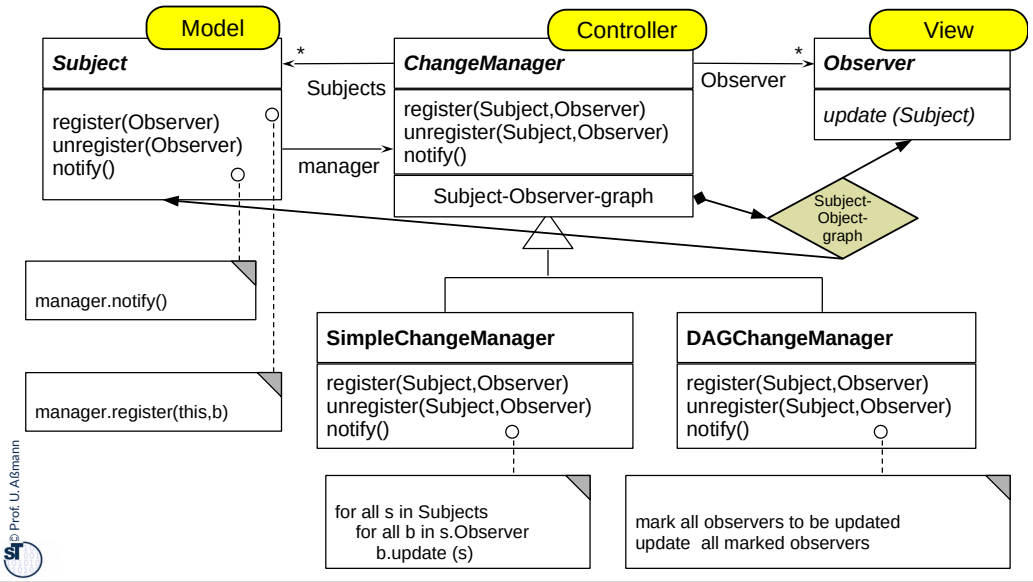
- Adapters and Facades are often used to adapt components-off-the-shelf (COTS) to applications
- For instance, an EJB-adapter allows for reuse of an Enterprise Java Bean in an application



EJB Adapter

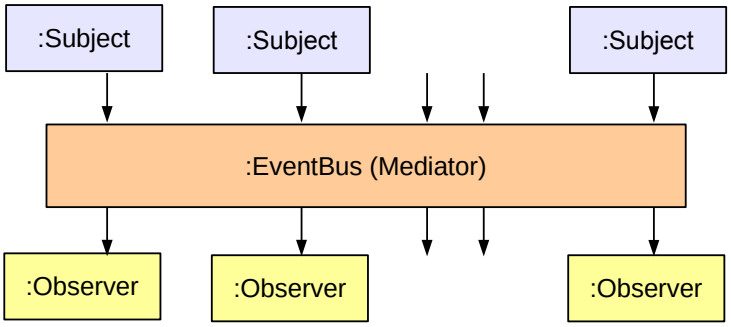


24.A.2 Observer with ChangeManager (EventBus)



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.
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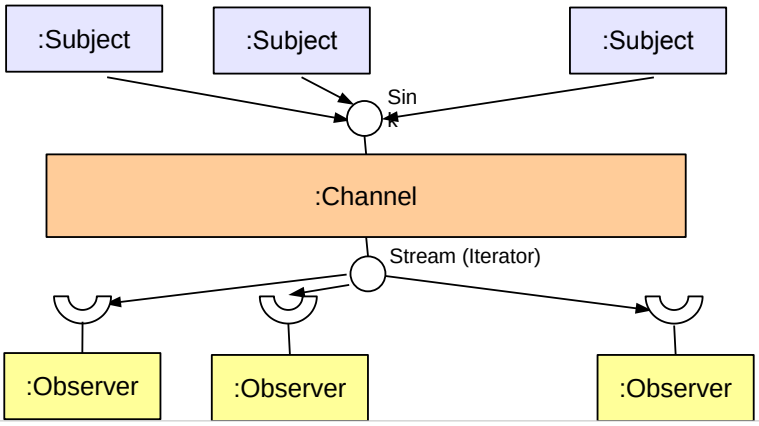
24.2.3.7 A Variant of EventBus is the Channel

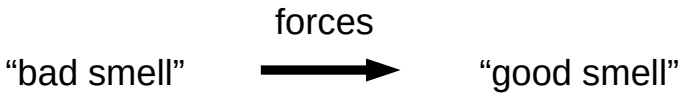
- push-Subjects and pull-Observers can be connected by Channel, to emphasize the continuous pushing and pulling
- Then Subjects write the Sink of the Channel and Observers pull the Stream of the Channel
  - Channel is a buffer



Appendix

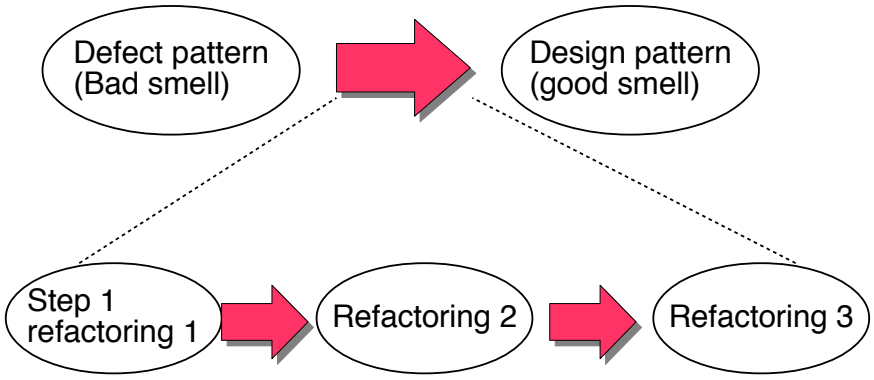
What Does a Design Pattern Contain?

- 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

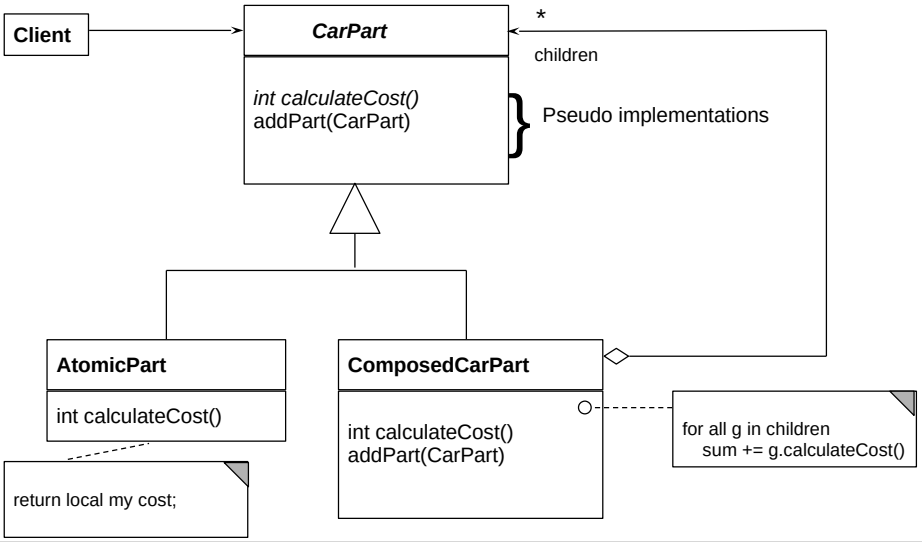


Structure for Design Pattern Description (GOF Form)

- 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)

Piece lists (Stücklisten) are usually hierarchic, i.e., should be called “piece trees” or “Stückbäume”.

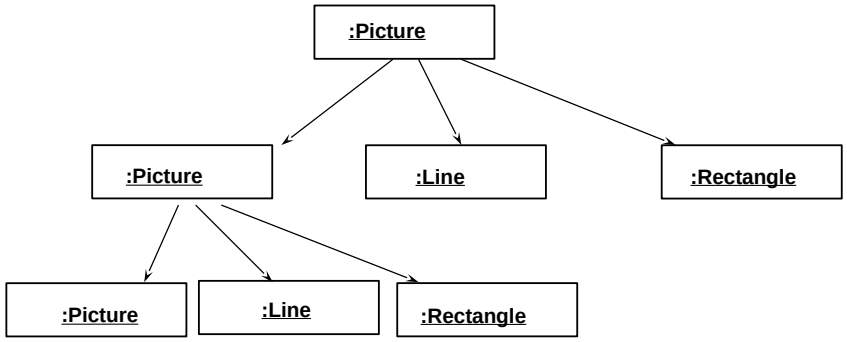
Technical objects can have thousands of parts, and Composite can manage all parts under a common interface of the “Component” abstract class.

Examples:

- Any product produced by a factory
- Any business object in a business software (ERP software): Bestellungen, Formulare, Rechnungen, Kataloge, …

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()