41. Composition Filters - A Filter-Based Grey-Box Component Model

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1. Inheritance Anomaly
2. Design Pattern Decorator
3. Composition Filters
4. Implementations of the Filter Concept in Standard Languages
5. Composition Filters and Role-Object Pattern
6. Evaluation

Literature (To Be Read)

- L. Bergmans, M. Aksit, K. Wakita, A. Yonezawa. An Object-Oriented Model for Extensible Concurrent Systems: The Composition-Filters Approach. Technical Report, University of Twente.
- http://trese.cs.utwente.nl
- Compose* is the current tool for Composition Filters. It is an extension of Java
  - http://composestar.sf.net/

Other Literature

- Mehmet Aksit and Lodewijk Bergmans. Obstacles in object-oriented software development. ACM Proceedings OOPSLA '92, SIGPLAN Notices, 27(10):341--358, October 1992.
- L. Bergmans. Composition filters. PhD thesis, Twente University, Enschede, Holland, 1994.
- Mehmet Aksit, Ken Wakita, Jan Bosch, Lodewijk Bergmans, and Akinori Yonezawa. Abstracting object interactions using composition filters. In O. Nierstrasz, R. Guerraoui, and M. Riveill, editors, Proceedings of the ECOOP'93 Workshop on Object-Based Distributed Programming, LNCS 79, pages 152--184. Springer, 1994.
- Mehmet Aksit and Lodewijk Bergmans. Composing crosscutting concerns using composition filters. Communications of the ACM, 44(10):51--57, October 2001.

- On the TRESE home page, there are many papers available for CF http://trese.cs.utwente.nl/

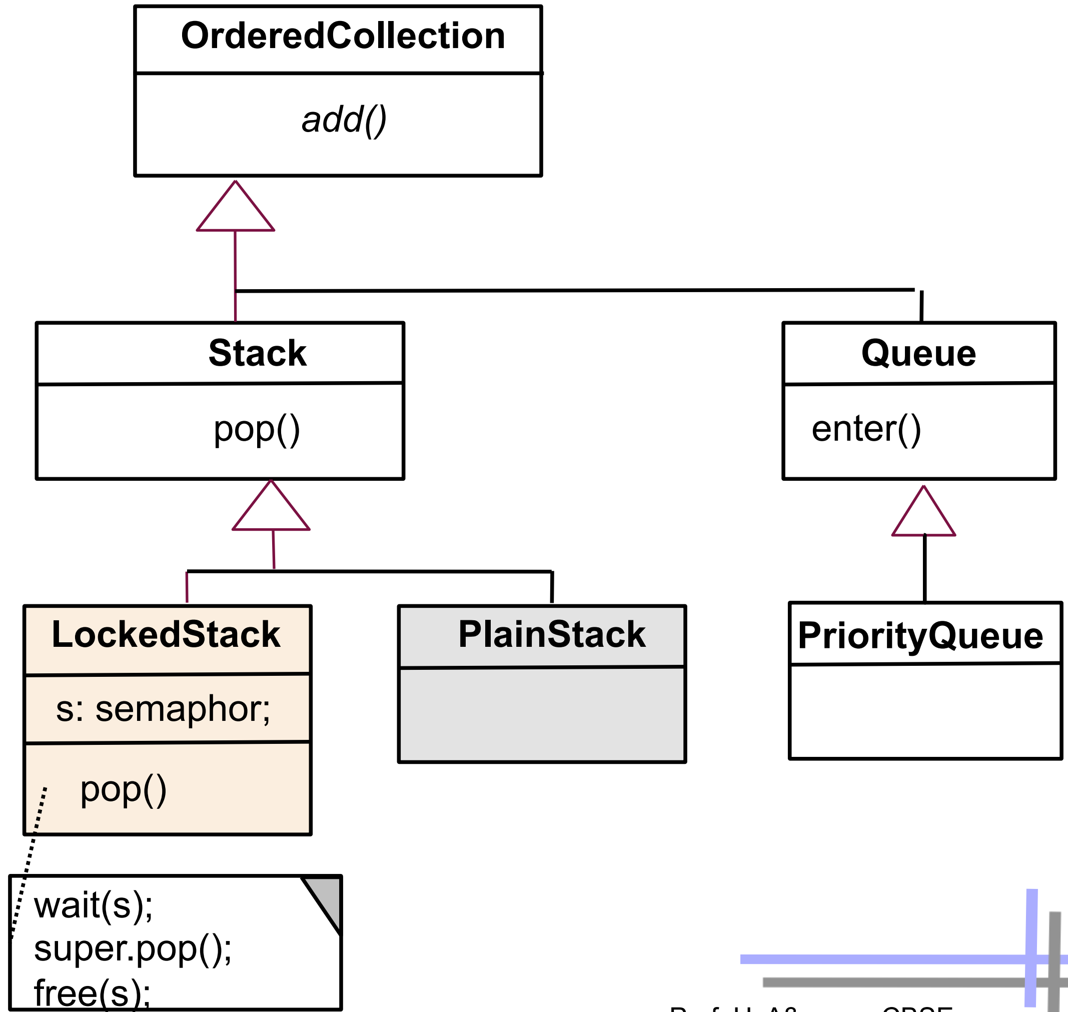
Goal

- Composition Filters (CF) are a solution to many composition problems
- The first approach to grey-box components
- Understand the similarty to decorator/adapter-based component models, and why grey-box provides an advantage

41.1. The Inheritance Anomaly

Inheritance Anomaly – Why Dimensional Software Composition Is Necessary

- In a parallel program, where should synchronization code be inserted?
  - Stack?
  - Queue?
  - OrderedCollection?
  - Collection?
  - Object?

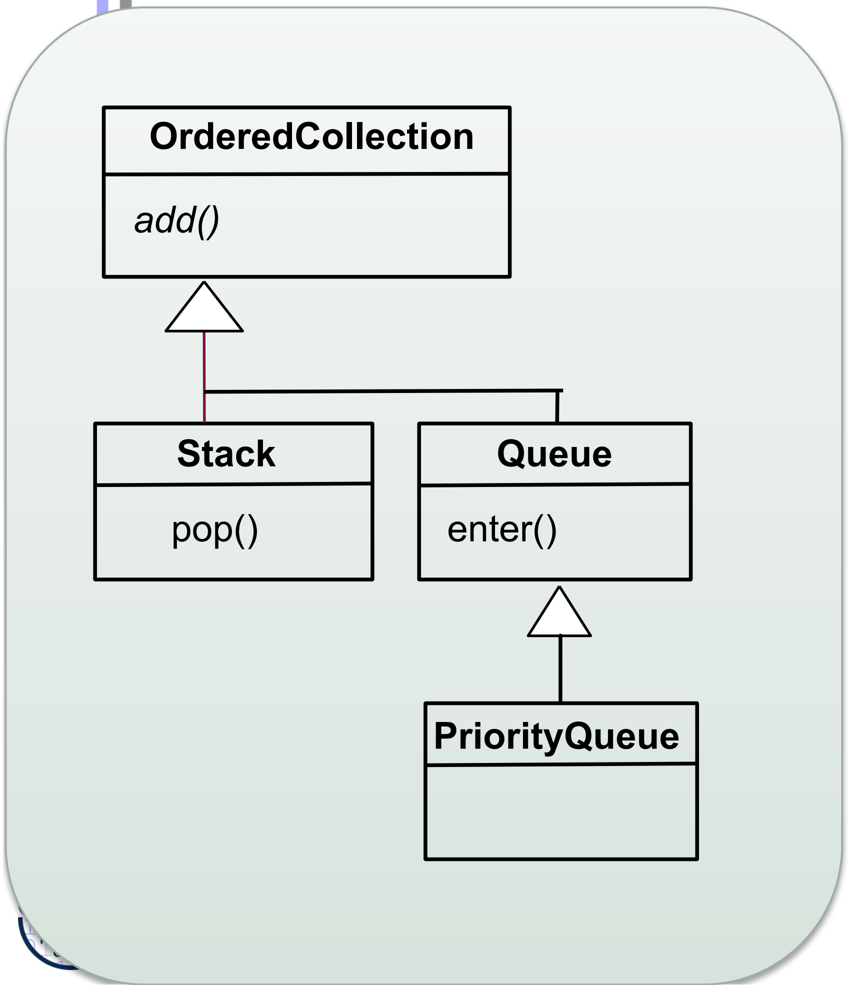


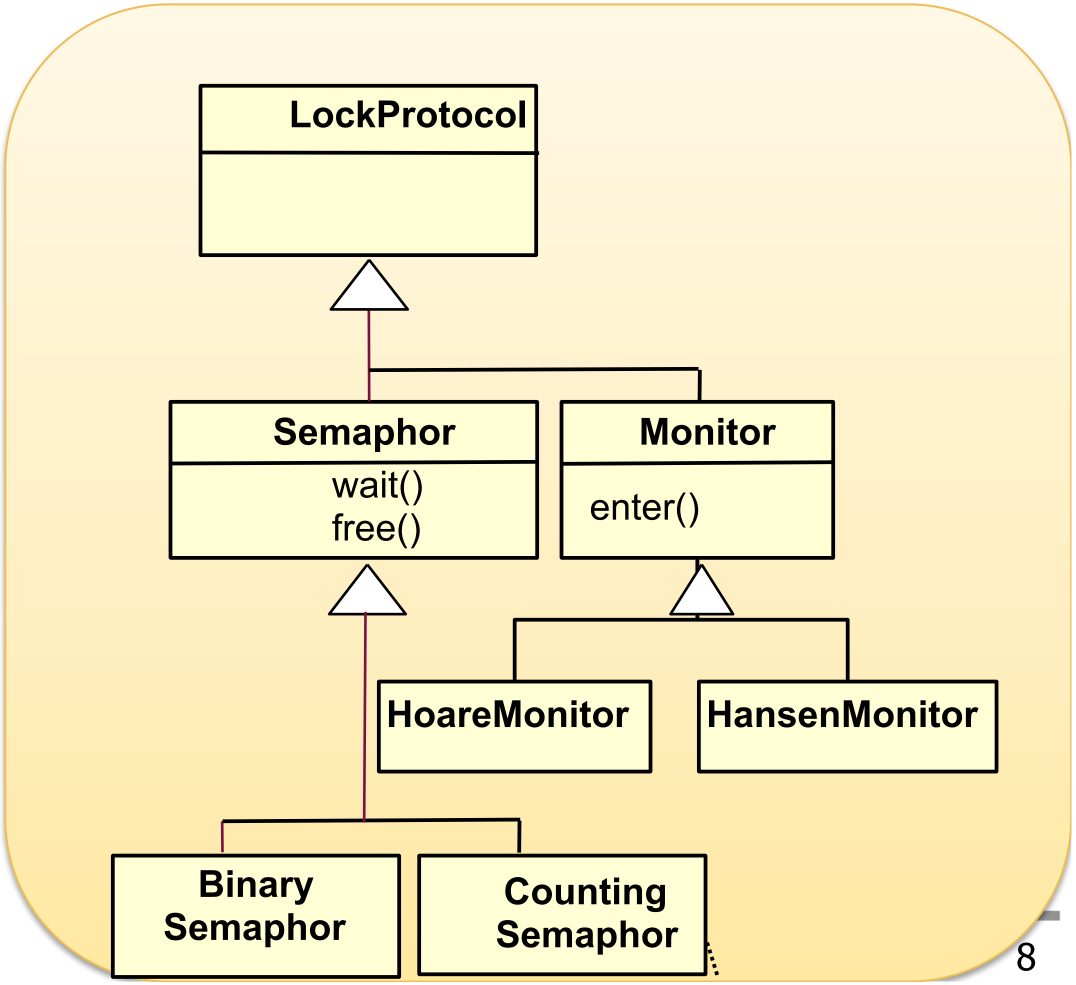
Inheritance Anomaly

- At the beginning of the 90s, parallel object-oriented languages failed, due to the inheritance anomaly problem
- **Inheritance anomaly**: In inheritance hierarchies, synchronization code is *tangled (interwoven)* with the algorithm,
  - and cannot be easily exchanged
  - when the inheritance hierarchy should be extended
  - Ideally, one would like to specify algorithm and function independently

Algorithm and Synchronization are Almost Facets

- But they depend on each other
- How to mix them appropriately?

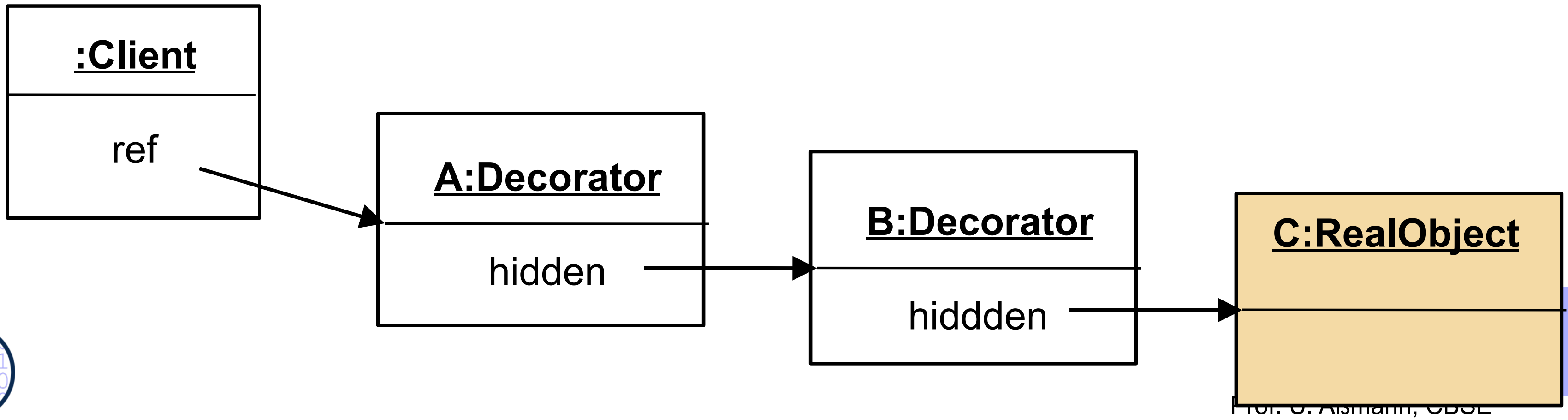




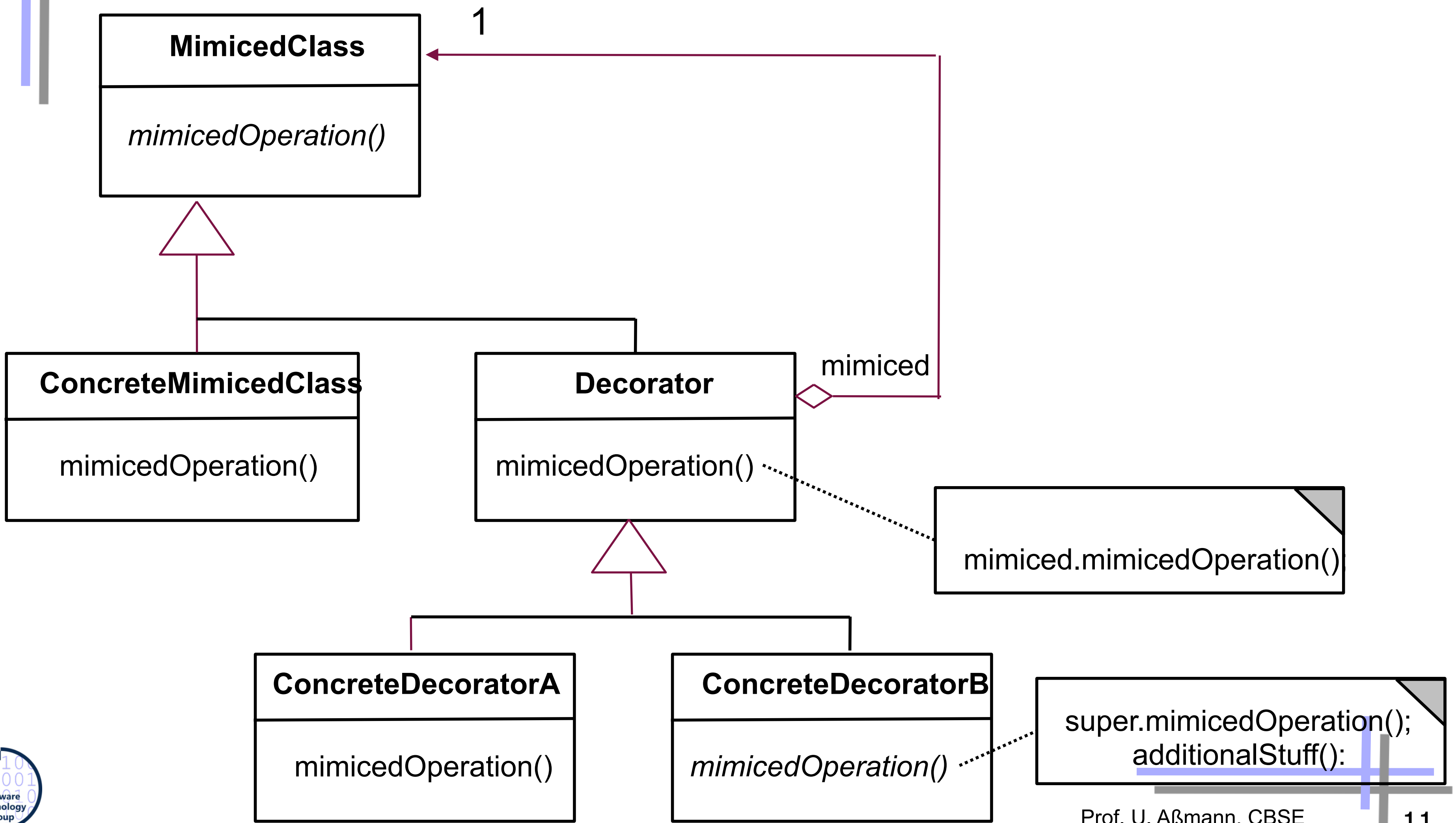
41.2 The Decorator Design Pattern (Rpt.)

Decorator Pattern

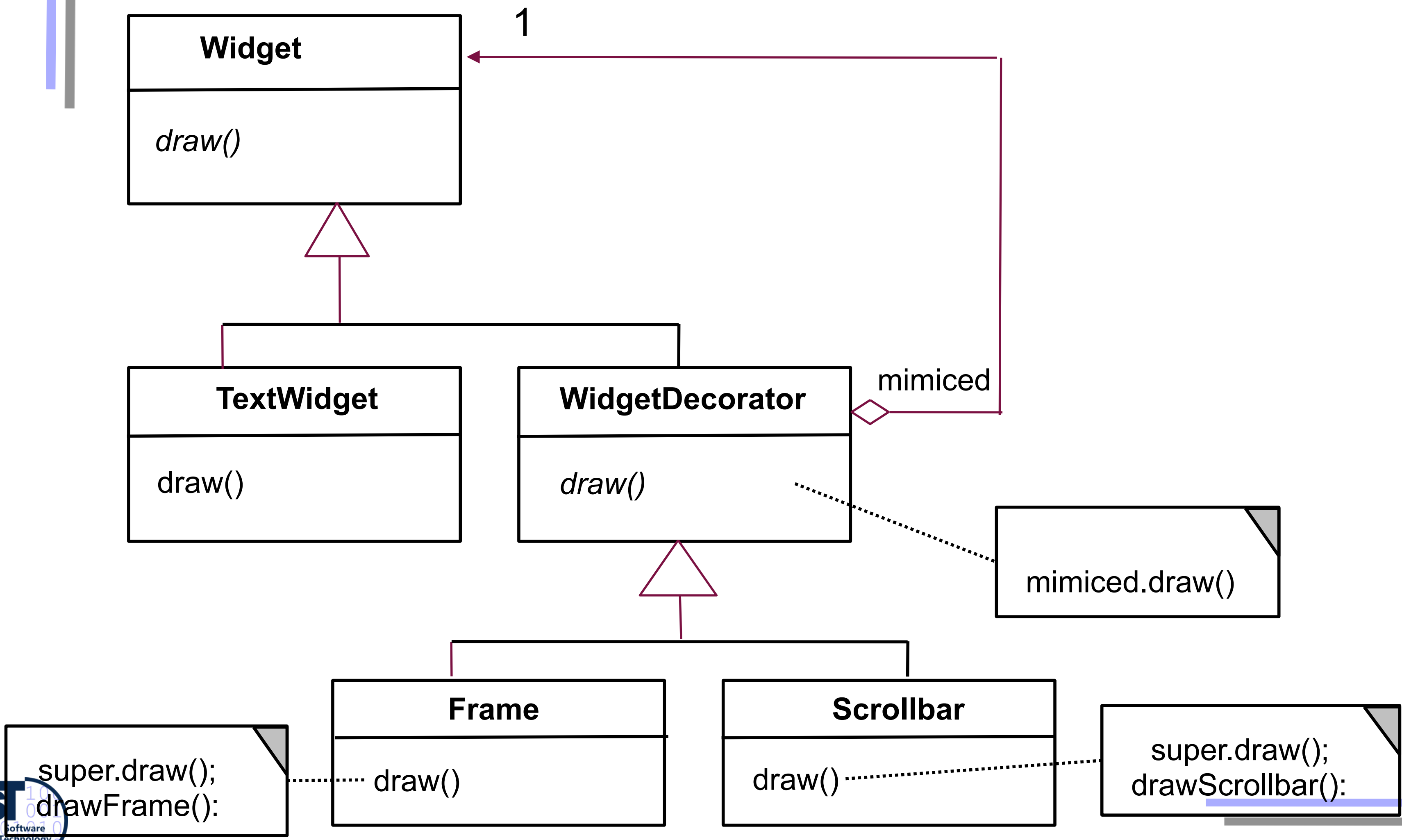
- A Decorator is a *skin* of another object
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
- Combines inheritance with aggregation
  - Inheritance from an abstract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



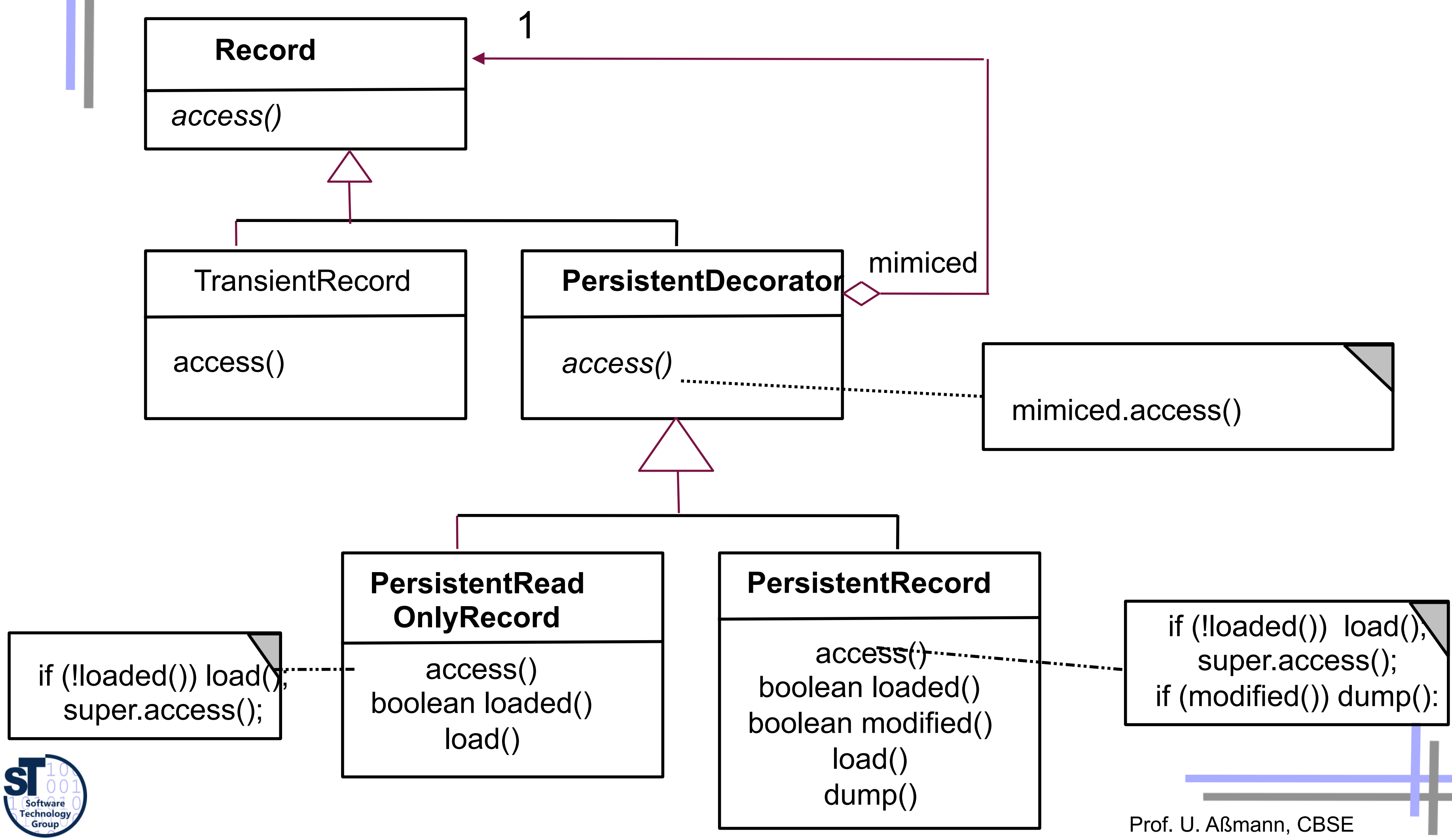
Decorator – Structure Diagram



Decorator for Widgets

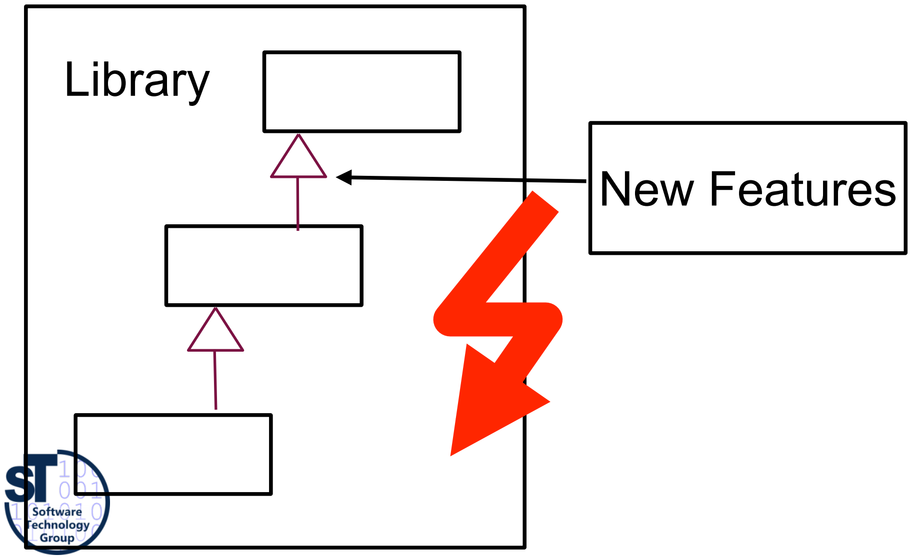


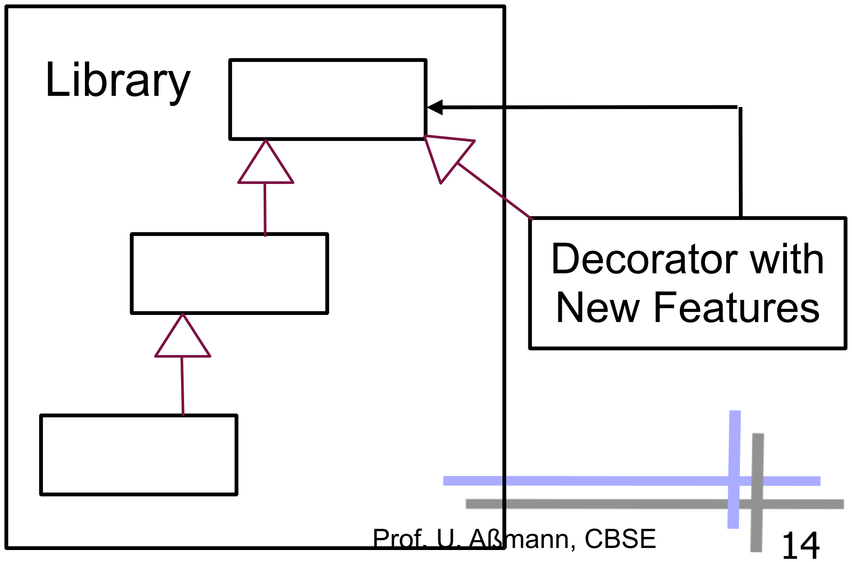
Decorator for Persistent Objects



Purpose Decorator

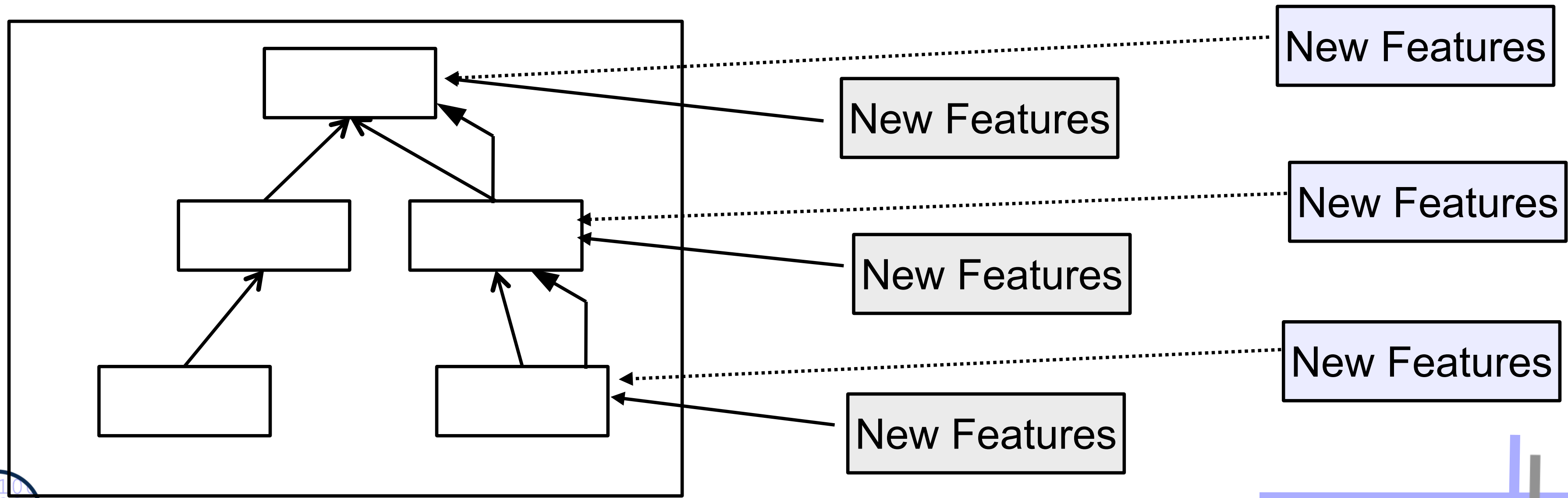
- For extensible objects (i.e., decorating objects)
  - Extension of new features at runtime
  - Removal possible
- Instead of putting the extension into the inheritance hierarchy
  - If that would become too complex
  - If that is not possible since it is hidden in a library





Variants of Decorators

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



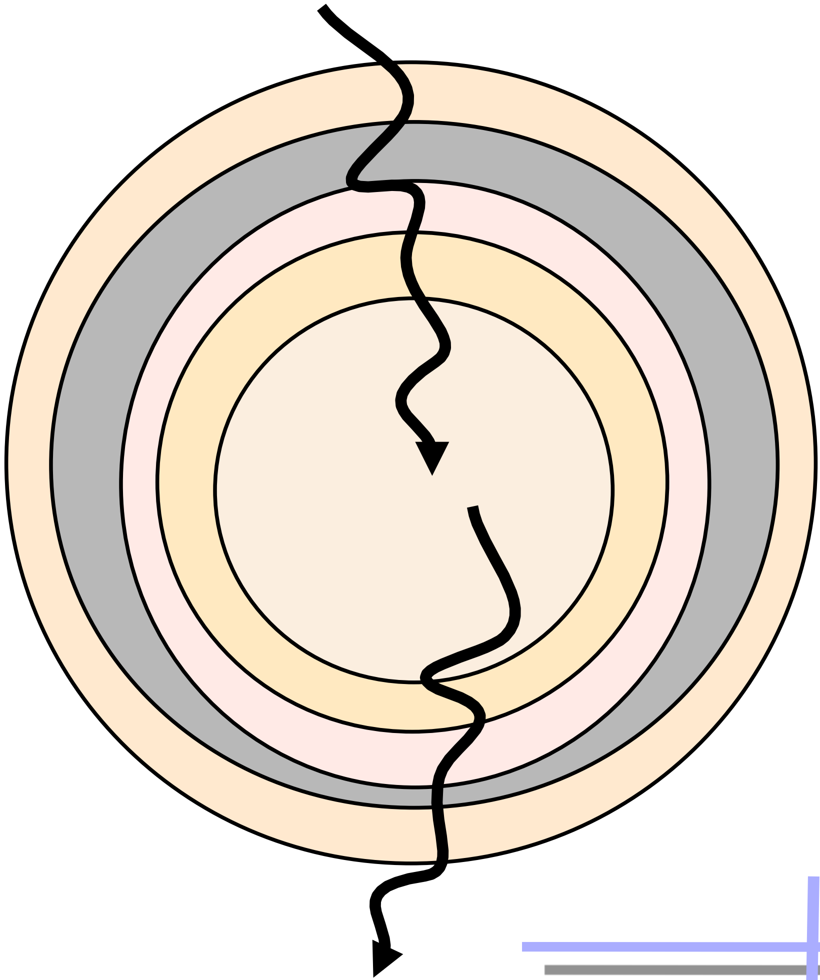
Decorator Relations

- Decorators can be chained to each other
- Dynamically, arbitrarily many new features can be added
- A decorator is a special ChainOfResponsibility with
  - The decorator(s) come first
  - Last, the mimiced object

41.3 Composition Filters

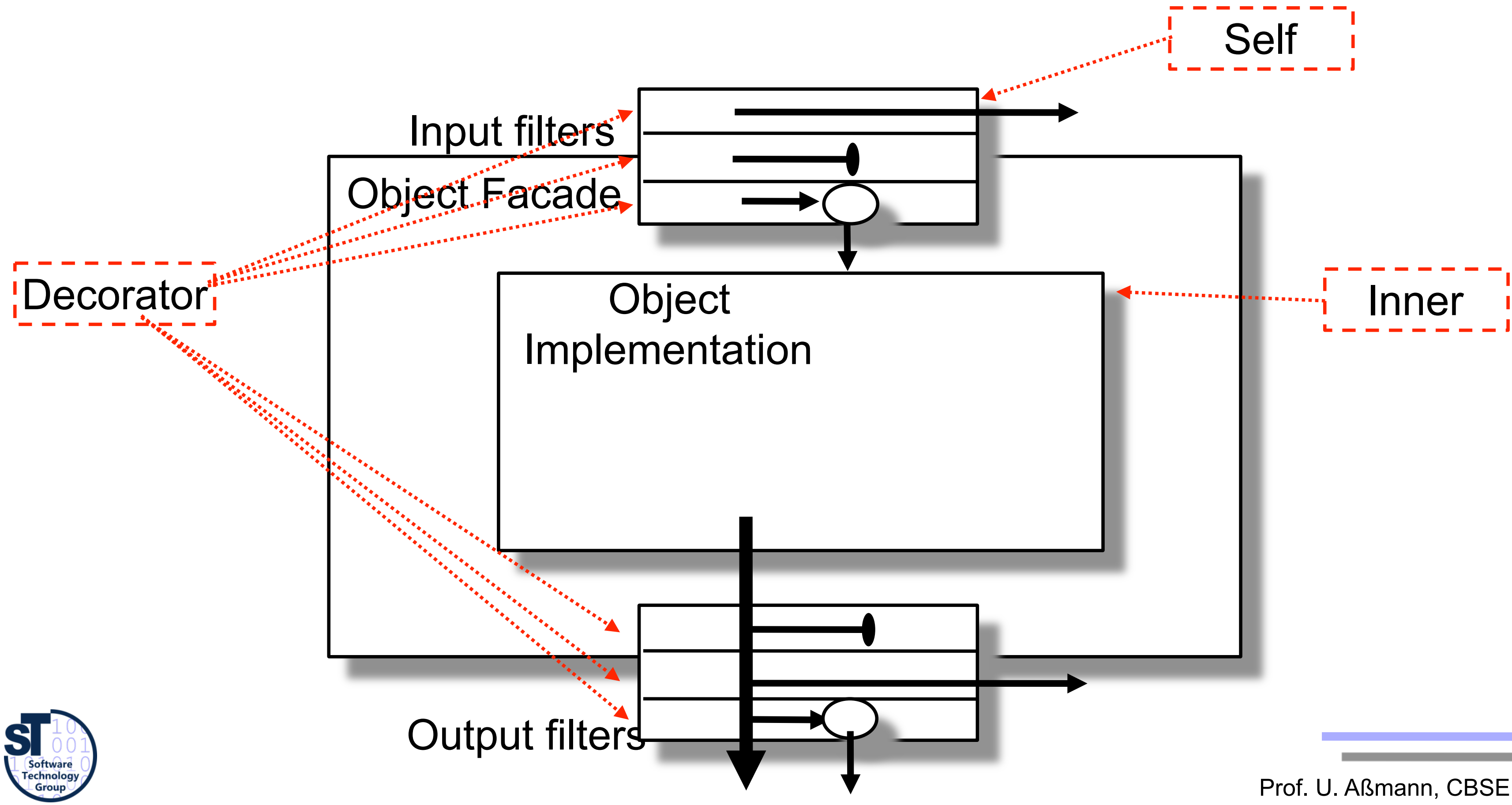
Filters are Layers

- Composition Filters (CF) wraps objects with *filters*
- A **filter** is a input or output *interceptor* of an object *being part of the object*
- Messages flow through the filters
  - are accepted or rejected
  - are modified by them
  - Wait on other objects
  - Notify other objects



Filters are Special Decorators

- Filters are decorators that do not suffer from object schizophrenia
- “inner” is the core of the object
- “self” comprises all filters and inner



Filter Types

- Filters are Event-Condition-Action rules
- ***Error***. An error filter tests whether a method exists.
  - If not, it stops filtering and execution.
  - In statically typed languages, error filters can be replaced by the compiler
- ***Wait***. A wait filter accepts methods only if a condition is true, otherwise it waits until the condition becomes true.
  - The condition may refer to a semaphore that is shared by all objects of the class
  - In case the semaphore is not free, the wait filter blocks execution
- ***Dispatch***. A dispatch filter dispatches the message
  - to the internal implementation, the “inner”
  - to other external objects, to a superclass,
  - or to sequences of objects.
- ***Meta***. A meta filter converts the message to an instance of class Message and passes it on to the continuation method. Then, the method can evaluate the new message.
- ***RealTime***. Specify a real-time constraint.

Filters in the special Composition Filters Language SINA

- **Grammar:**

```
InputFilters ::= ‘inputfilters‘ '<' Filter* '>'.
OutputFilters ::= ‘outputfilters’ '<' Filter* '>'.
Filter ::= Name ':' Type '=' '{'  FilterElement // ',' '}’.
FilterElement ::=
   GuardCondition '=>' Match     -- All matching messages are accepted
   | GuardCondition '~>' Match  -- All matching messages are rejected
   | GuardCondition '=>'         -- All matching messages are resent
             '[' Match ']' Match .  -- optional match
GuardCondition ::= BooleanFunctionCall.
Match ::= TargetObject '.' MethodName | MethodName .
TargetObject ::= 'self' | 'inner' | '*' .
MethodName ::= Name | '*' .
```

Filters in SINA

- **Sync Filter example:**

```
sync:Wait = { NonEmpty => pop,
              True => * }
```

Guard (Condition)

Action: Call 'pop'

Action: Pass on

- Meaning:

```
if (sync.Semaphore free) {
    if (NonEmpty())
        if (function.name == "pop") inner.pop
    else if (True)
        if (function.name == X) inner.X
}
```

Wrapping Methods with Calls

- Meta-filter example:
  - `Full => [put] bufferDistribute.Distribute;`
  - `Empty => [get] bufferDistribute.Distribute;`
- Wrapping Methods with Calls with the Meta filter:

```
counterWrapper: Meta {
    isCounting => [put] Counter.increaseCount;
    True => [*] inner.*;
}
```

Guard (Condition)

Match (name of incoming message)

Action

A Larger Example

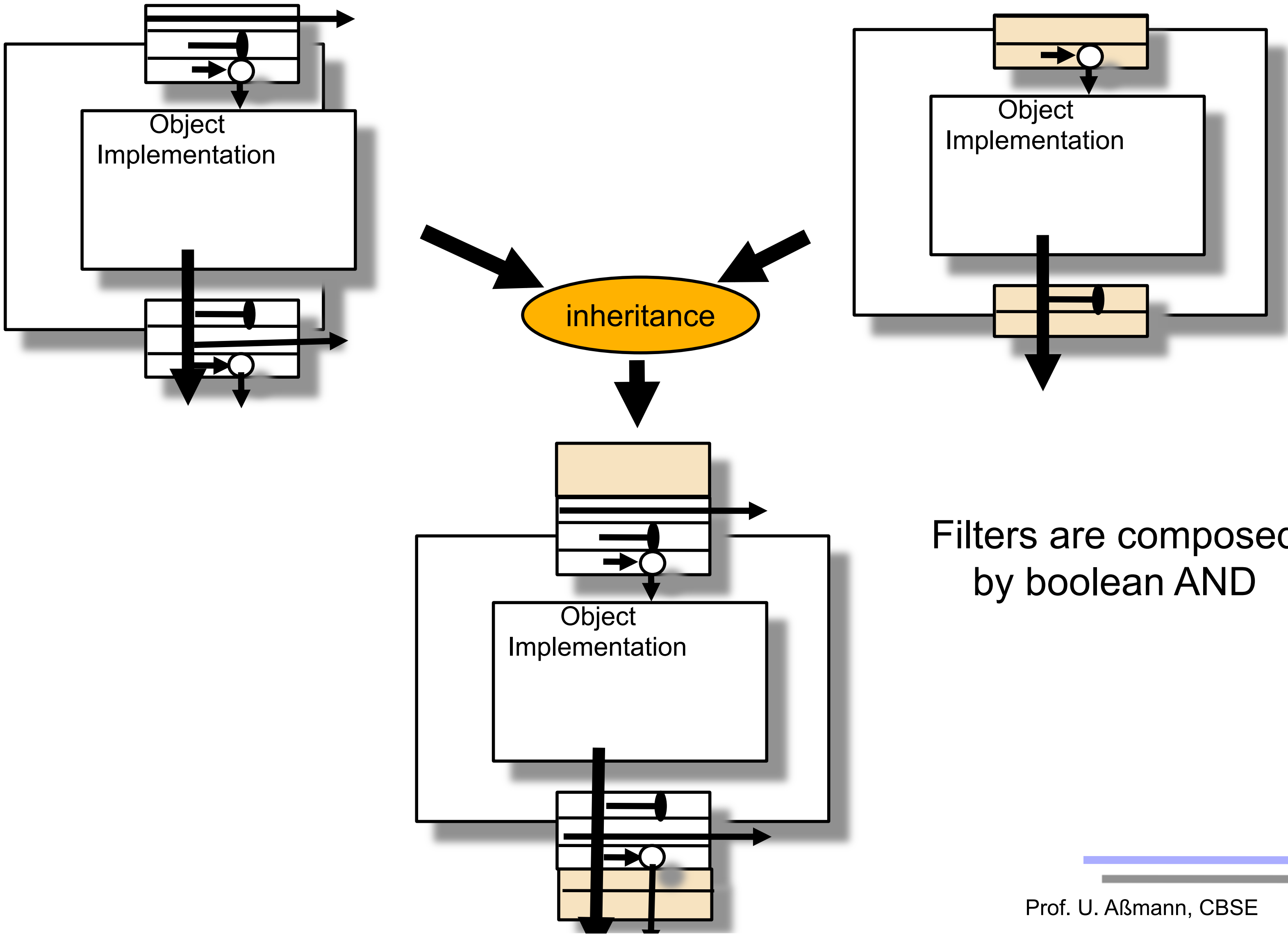
```
class PressOrAnimatedPress interface
  internals:
    visualize;
    doIt;
  externals:
    animatedDevice:AnimatedDevice;
  conditions:
    isAnimating;
    isInTracingMode;
    noOneElseIsAnimating;
  methods:
    inputTraceMethod;
    outputTraceMethod;
  inputfilters:
    tracing: Meta = {
      isInTractingMode => [*] inputTraceMethod }
    lockingDisplay: Wait = {
      noOneElseIsAnimating => *; }
    dispatch: Dispatch = {
      isAnimating => [*.*] animatedDevice.*;
      True => [*] inner.*; }
  outputfilters:
    tracing: Meta = {
      isInTracingMode => [*] outputTraceMethod }
end
```

- A press is modeled, either with or without animation.
- There are two Meta filters that call tracing methods when the press is in animation mode (precondition *isAnimating*).
  - The filters match all messages (pattern [*]) and call tracing methods.
  - Then, they pass on control to the next filter.
- As an input filter, a *Wait* filter is executed.
  - It collaborates with other animated devices and guarantees with a semaphore that only one device at a time uses the display.
  - If another device is animating, the wait filter blocks execution until the display is free again.
- The *Dispatch* filter selects a method for the real implementation work.
  - It contains two filter elements.
  - If the press is in animation mode, it forwards every message from an arbitrary object (pattern [*.*]) to the animated device delegatee, otherwise calls its inner object.

Main Advantage of the Filter Concept

- Filters are *built into* an object, they are *grey-box decorators*
  - They avoid object-schizophrenia
- Filters are specified in the interface, not in the implementation
  - Implementations are free of synchronization code
  - Separation of concerns (SOC): synchronization and algorithm are separated
  - Filters and implementations can be varied independently
- Filters are specified statically, but can be activated or deactivated dynamically
- Filters are statically composed with multiple inheritance
  - One dimension from algorithm,
  - one from synchronization strategy
  - Filters can be overwritten during inheritance

Filters Can be Multiply Inherited

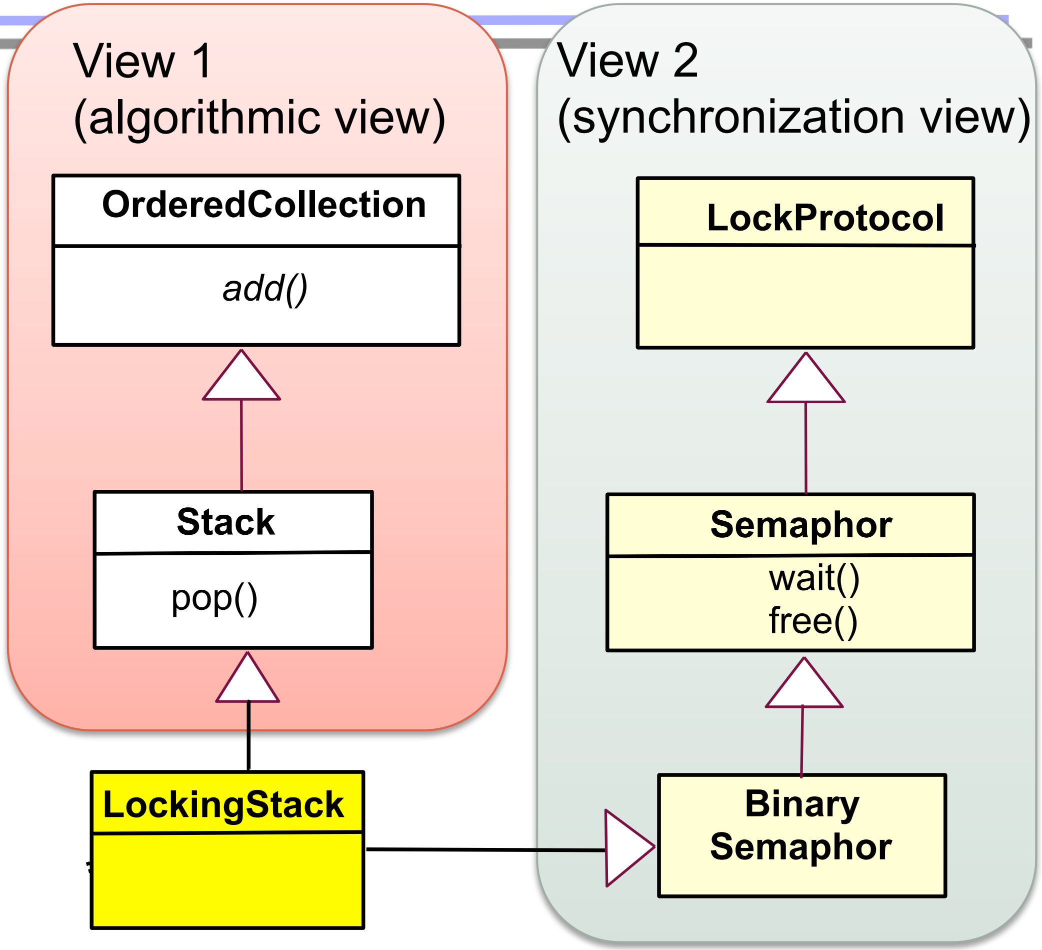


Filters are composed by boolean AND

Composing a Locking Stack by Composing Filters

- Filter composition can be specified by selecting filters from superclasses
- Compose* can superimpose filters also dynamically

```
class LockingState interface
internals
  -- superclasses
  superStack: Stack
  locker:BinarySemaphor
Inputfilters  <
    locker.locking;
    superStack.sync;
    disp:Dispatch= {
         superStack.*,
        locker.*};
  >
```



Sequential
AND Composition
of superclass filters

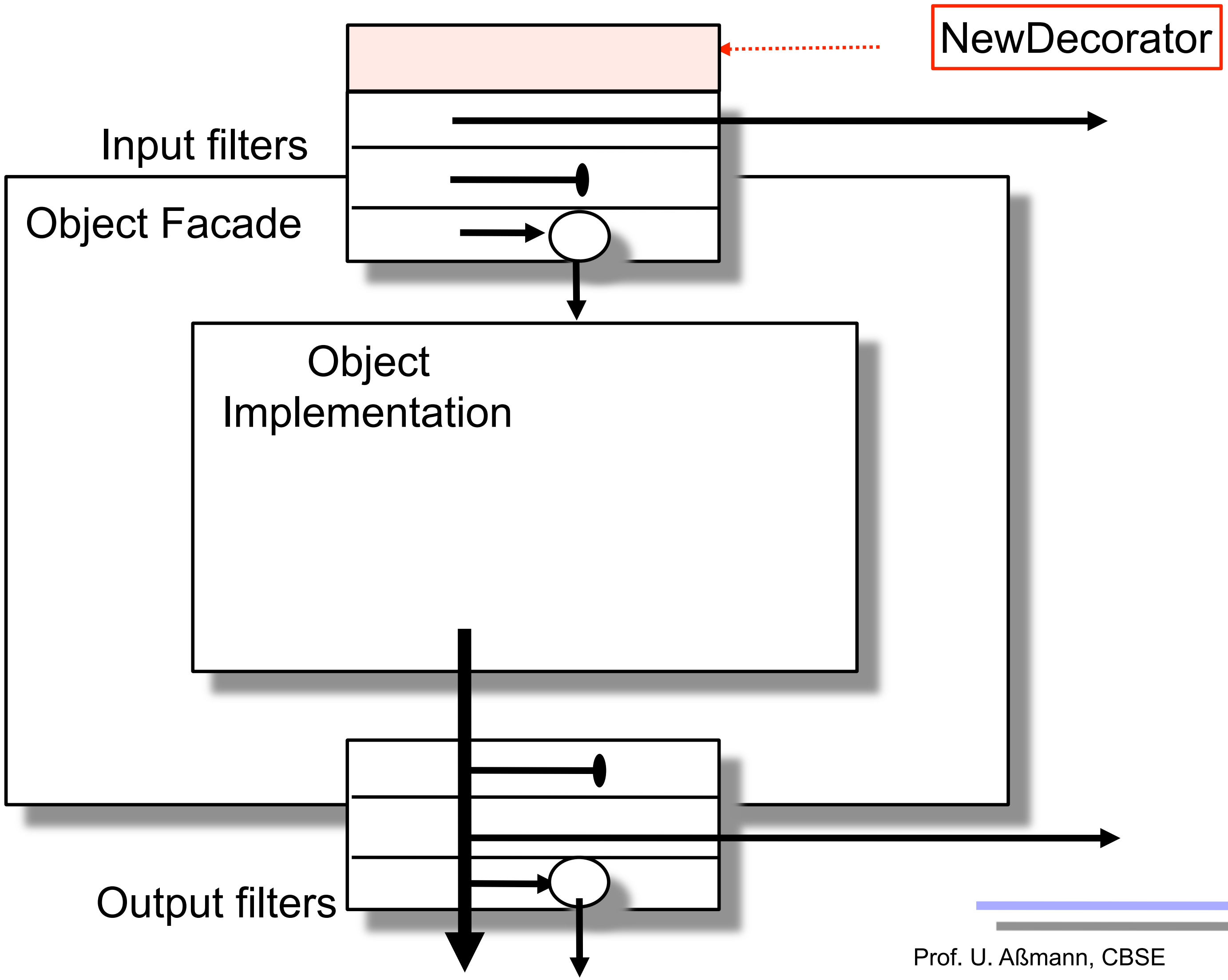
41.4 Implementations of the Filter Concept in Standard Languages

Implementation with Decorator

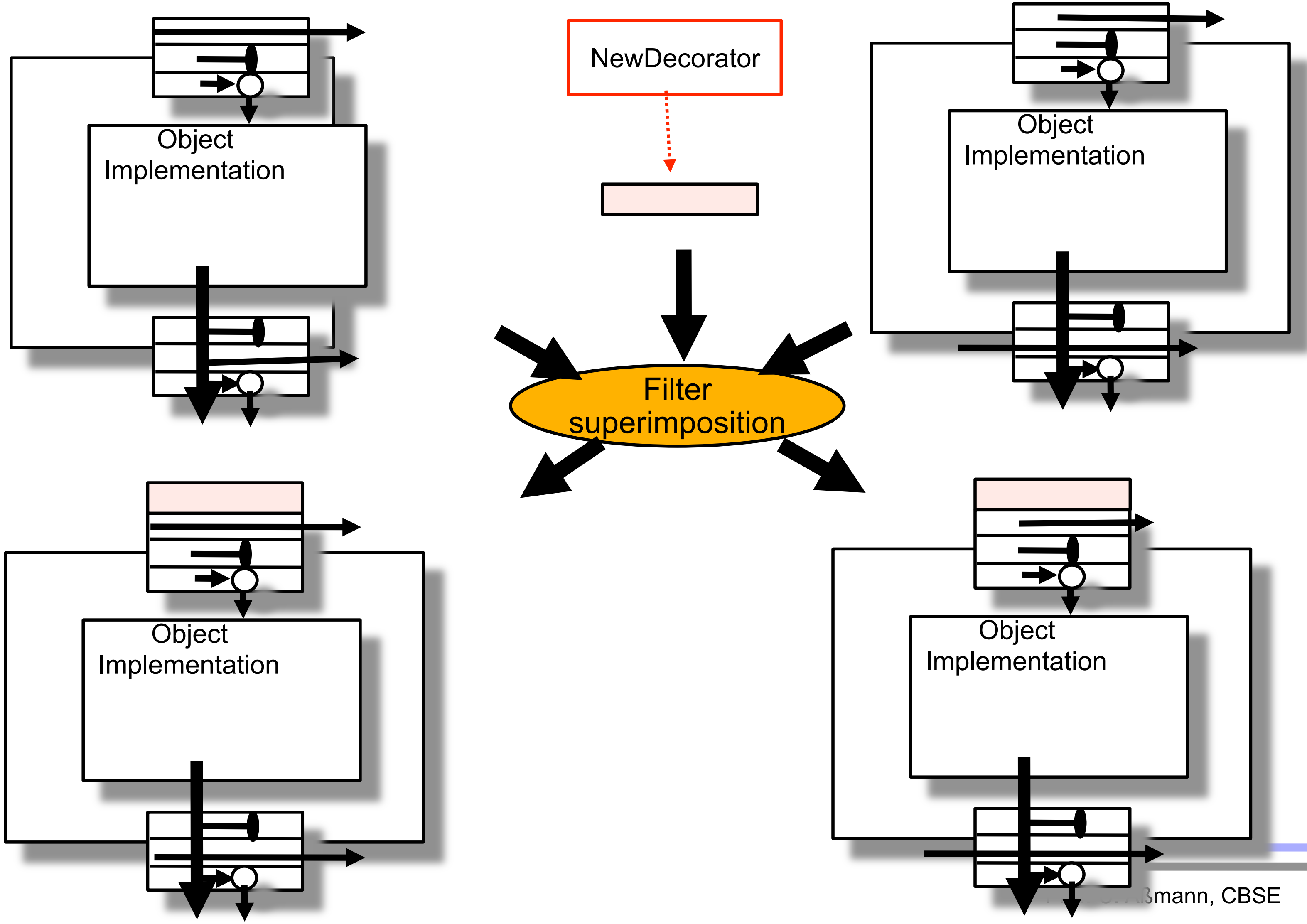
- The superclass of the Decorator pattern implements the object interface
  - The decorating classes are the filters
  - Problem: Decorators do not provide access to the “inner” object or the “self” object
- Filters also can be regarded as ChainOfResponsibility
  - However, there is a final element of the Chain, the object implementation

Filters Can be Composed From Outside

- Filter superimposition



Filters Can be Composed From Outside



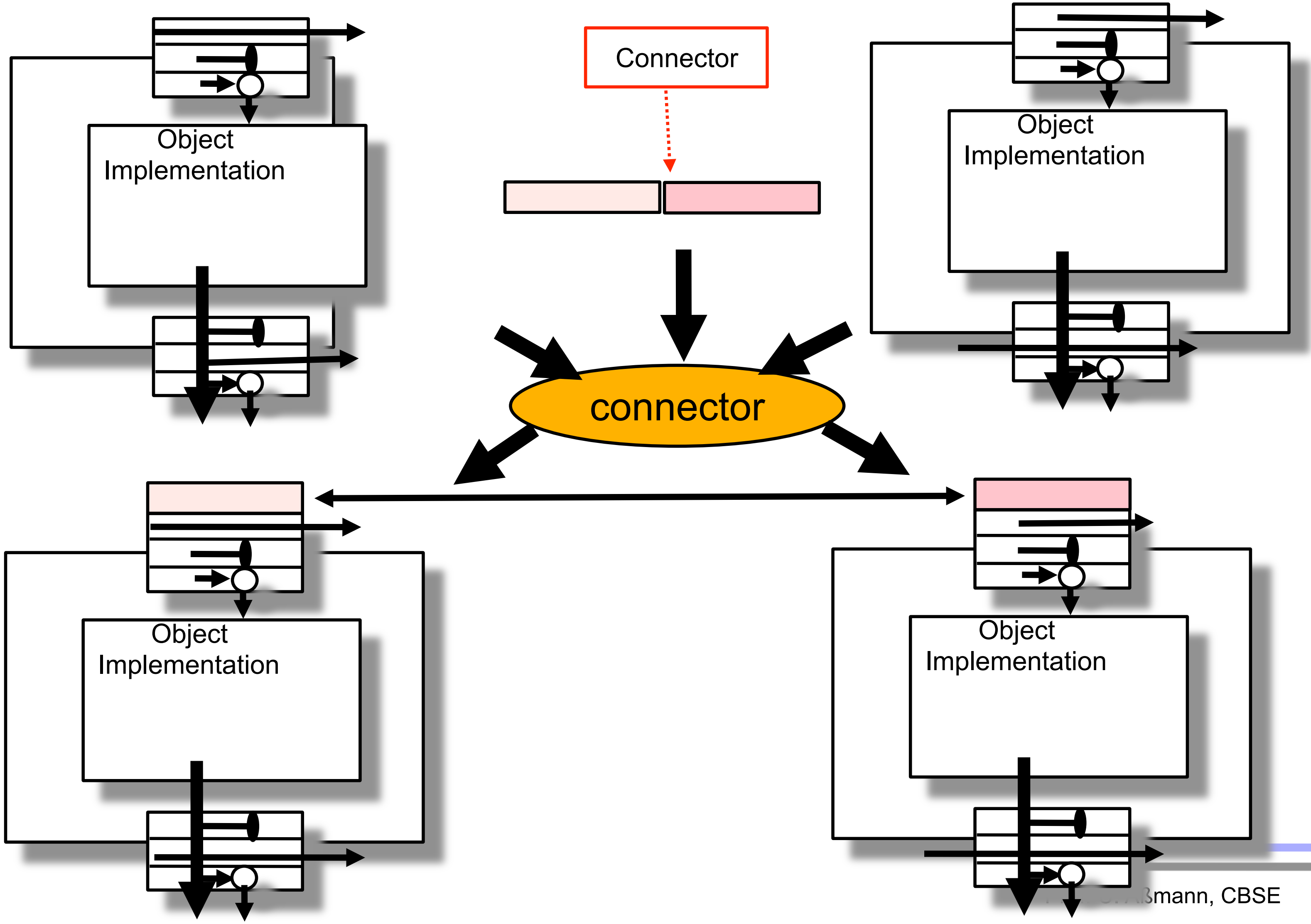
Superimposing a Decorator in Hand-Written Code

- Walk through the list of decorators
- Insert a new decorator where appropriate

- Example: superimposing synchronization:
  - Do for all objects involved:
    - Get the first decorator
    - Append a locking decorator, accessing a common semaphore
- Removing synchronization
  - Do for all objects involved:
    - Get the synchronizing decorator
    - Dequeue it

Superimposing Several Filters Produces Filter-Connector Pattern

- The Decorator-Connector Pattern can be realized with filters



Filters in MOP-Based Languages

- In languages with a MOP, a filter can be implemented as a specific object that is called during the functions
  - enterObject
  - accessAttribute
  - callMethod

A MOP-based Implementation of Filters

```
class Filter {
  // Test whether the filter can be applied to a method.
  public boolean matches(Method method) { .. }
  // Filter executes accept.  Also, it substitutes a continuation.
  public Object acceptAction(Method method) {
     ..
     return substitute(method);
  }
  // Filter executes reject.  Also, it substitutes a continuation.
  public Object rejectAction(Method method) {
     ..
     return substitute(method);
  }
  public Object substitute(Method method) {
    if (<<filtering should be stopped>>)
       return null;
    ..
    return <<continuationMethod>>;
  }
}
```

```
class FilteredClass extends Class {
  Filter[] inputFilters;
  public FilteredClass() { .. }
  public void enterMethod() {
    // First assign the called inner method to be the continuation
    Method continuation = thisMethod;
    // Run the input filters and calculate the real continuation
    for (int i = 0; i < inputFilters.size(); i ++) {
      if (filter.matches(continuation))
         continuation = filter.acceptAction(continuation);
      else
         continuation = filter.rejectAction(continuation);
      // If the filter returned null, stop here
      if (continuation == null)
         return;
      // Continue at next filter
      if (continuation == inputFilters.getNext())
         continue;
      // Otherwise, continue at continuation
      else
         continuation.execute();
    }
  }
  // Similar for output filters...
  Filter[] outputFilters;
  ...
```

A Specialized Filter

```
class TracingFilter extends Filter {
  public void matches(Method method) { return true; }
  public Object acceptAction(Method method) {
    trace();
    return substitute(method);
  }
  public Object substitute(Method method) {
    return method;
  }
  public void trace() {
    System.out.println("Here is the class "+getClass().getName());
  }
}
Class WorkPiece = new FilteredClass("WorkPiece",
                    new Filter[]{TracingFilter},
                    new Filter[]{});
```

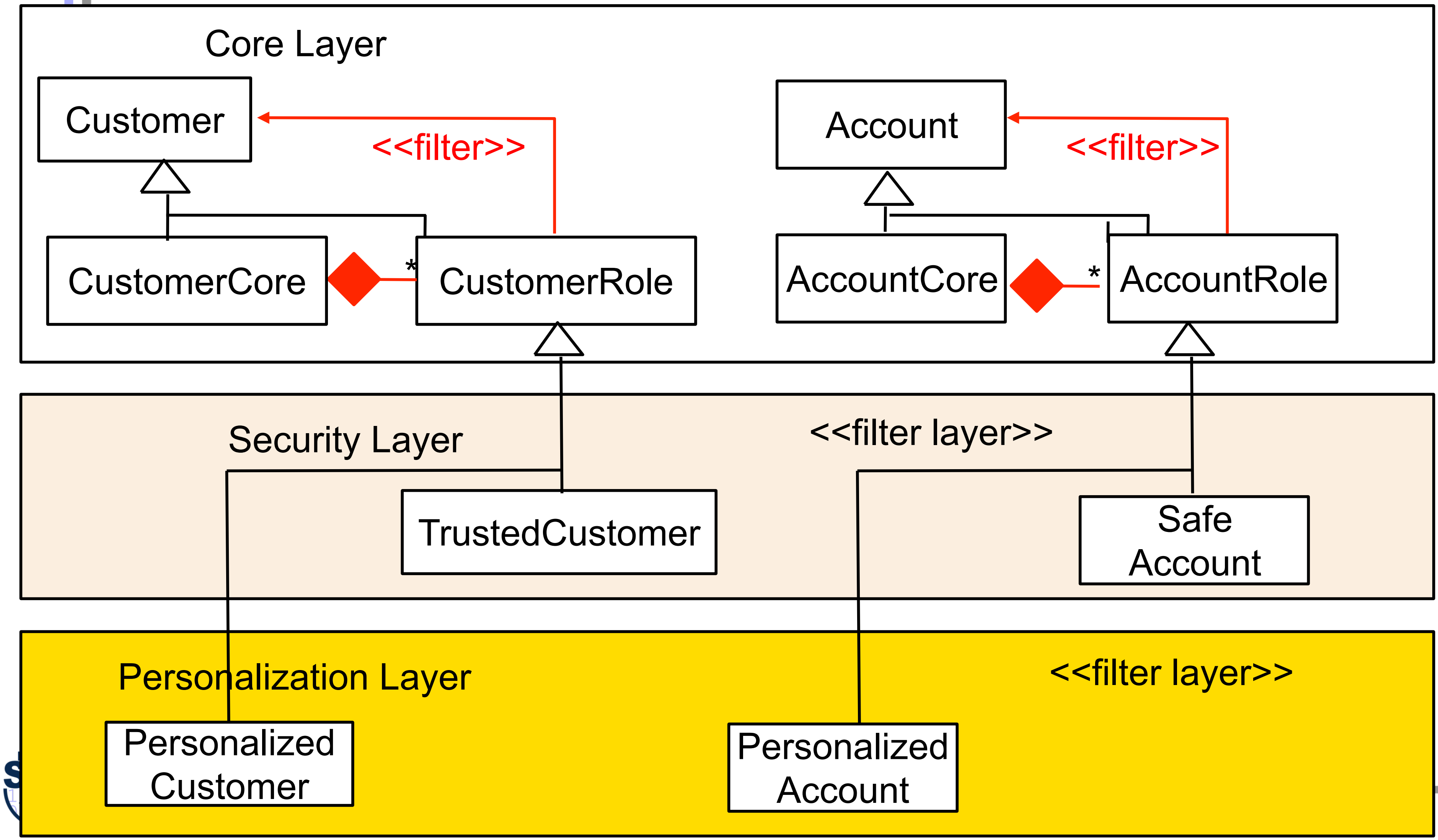
41.5 Composition Filters and The Role Object Pattern

Composition Filter Layers

- Instead of role objects, filter objects can be used
- Then, filters belong to layers
  - Layers are like slices through the application
  - We get a *layered object model*
- The filters are separate objects (role objects)
  - Which can be exchanged separately
  - Which can be superimposed appropriately

Aksit's Filter Pattern in Framework Layers

Role Object Pattern can implement roles as filters

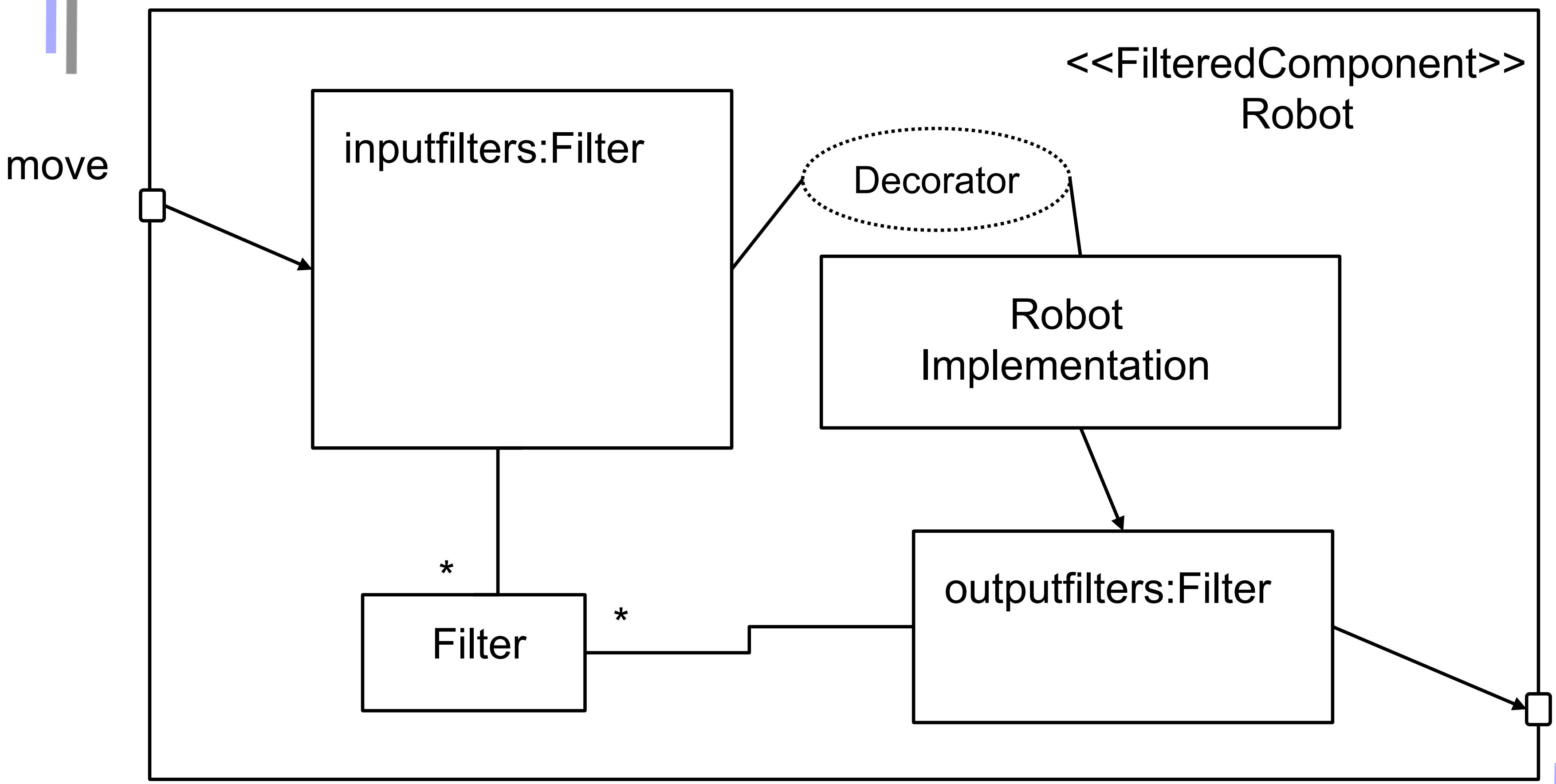


Using Composition Filters

- Filters can implement a supercall (upcall) in the inheritance hierarchy
  - Delegating to an object of the superclass
  - Also in languages without inheritance
- Filters can implement multiple and mixin inheritance in languages with single inheritance
- Filters are applicable to all types of components
  - Filters are appropriate to implement the DCOM/COM+ facade-based component model
    - The dispatch filter delegates to aggregated objects
  - or to UML components

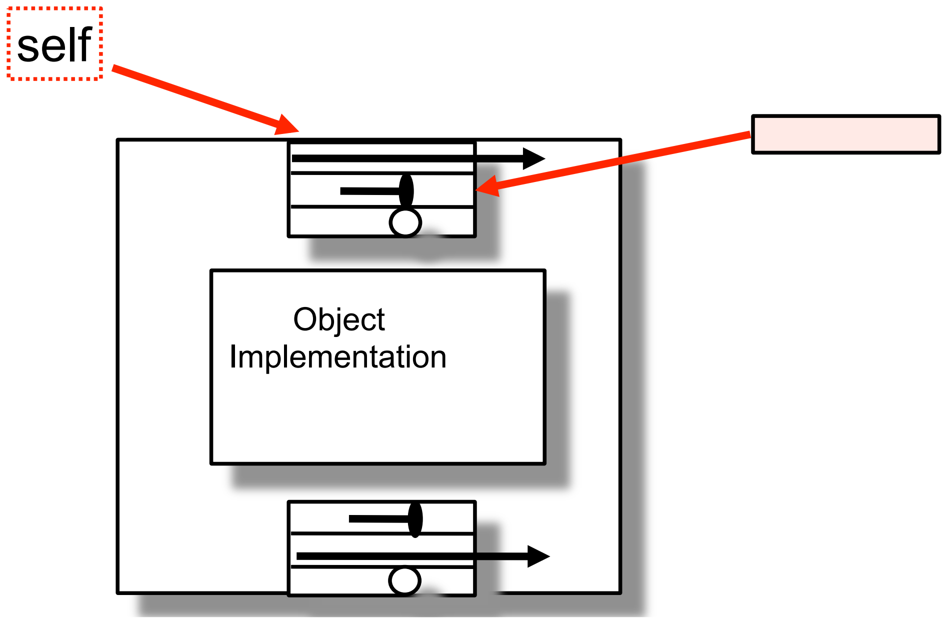
Filters In UML

- Realize as inner components



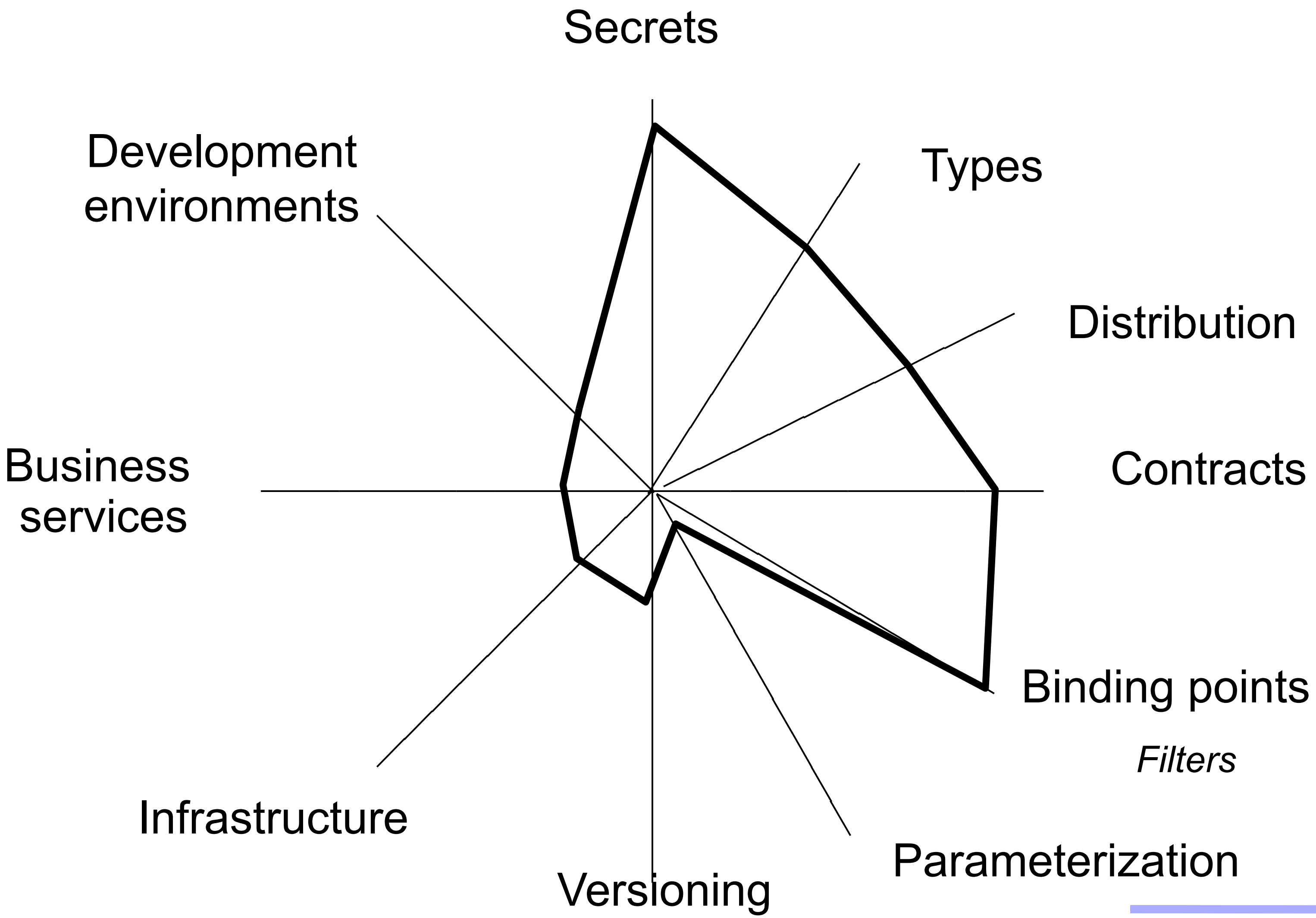
Insight: Greybox Composition Relies on Extensibility

- Composition Filters is a *greybox* composition technology
  - Because it inlines Decorators into objects
- Superimposition of filters can be used for greybox composition
  - Adding filters changes objects extensively, but the “self” identity does not change
  - Connectors can be made grey-box with the Filter-Connector pattern

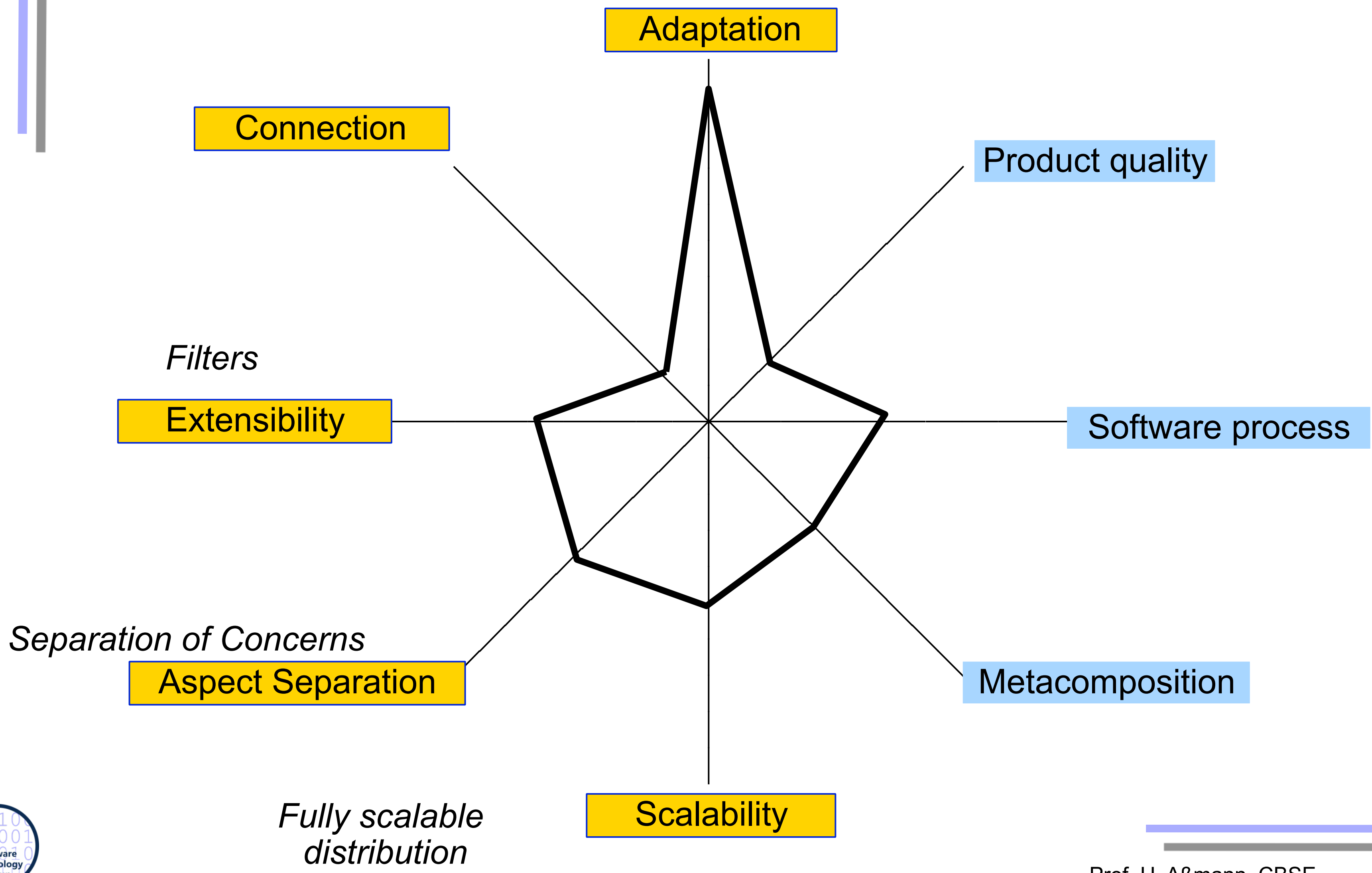


41.6 Evaluation as Composition System

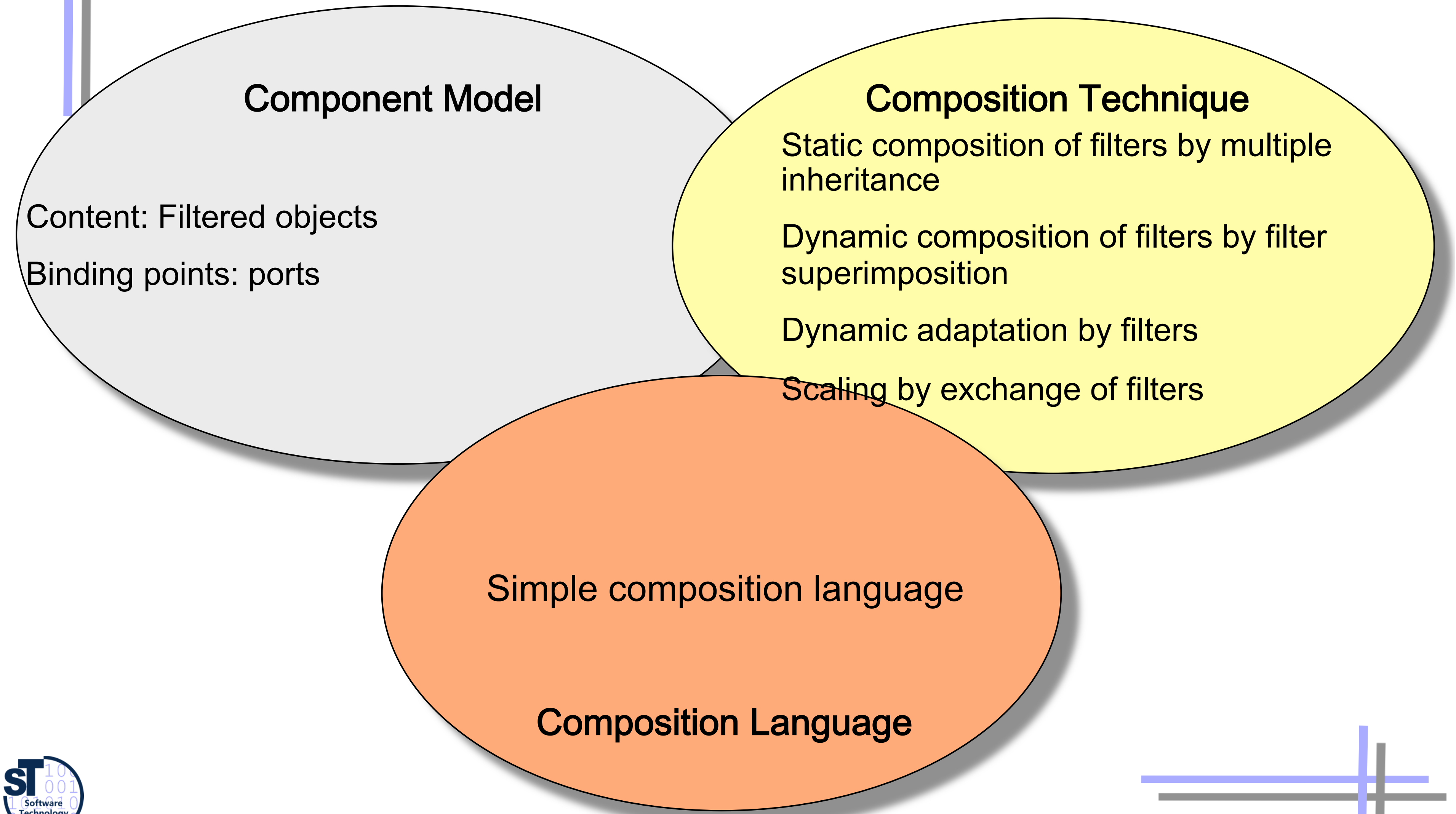
CF - Component Model



CF – Composition Technique and Language



CF as Composition System



What Have We Learned?

- CF extends the standard object model to a new component model *FilteredComponent*
  - The objects have filters and can be adapted easily
- Any component model that provides interceptors or decorators can be used as filtered component
- Filtered components support
  - Adaptation
  - Greybox composition

The End