

21) Composition Filters - A Filter-Based Grey-Box Component Model

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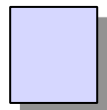
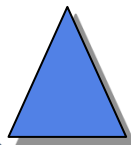
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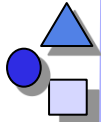
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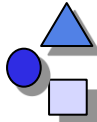
1. Inheritance Anomaly
2. Design Pattern Decorator
3. Composition Filters
4. Implementations of the Filter Concept in Standard Languages
5. Composition Filters and Role-Object Pattern
6. Evaluation





Literature (To Be Read)

- L. Bergmans, M. Aksit, K. Wakita, A. Yonezwa. An Object-Oriented Model for Extensible Concurrent Systems: The Composition-Filters Approach.
 - ▶ <http://trese.cs.utwente.nl>



Other Literature

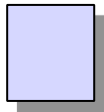
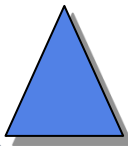
- ▶ L. Bergmans. Composition filters. PhD thesis, Twente University, Enschede, Holland, 1994.
- ▶ On the TRESE home page, there are many papers available for CF <http://trese.cs.utwente.nl/>



Goal

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

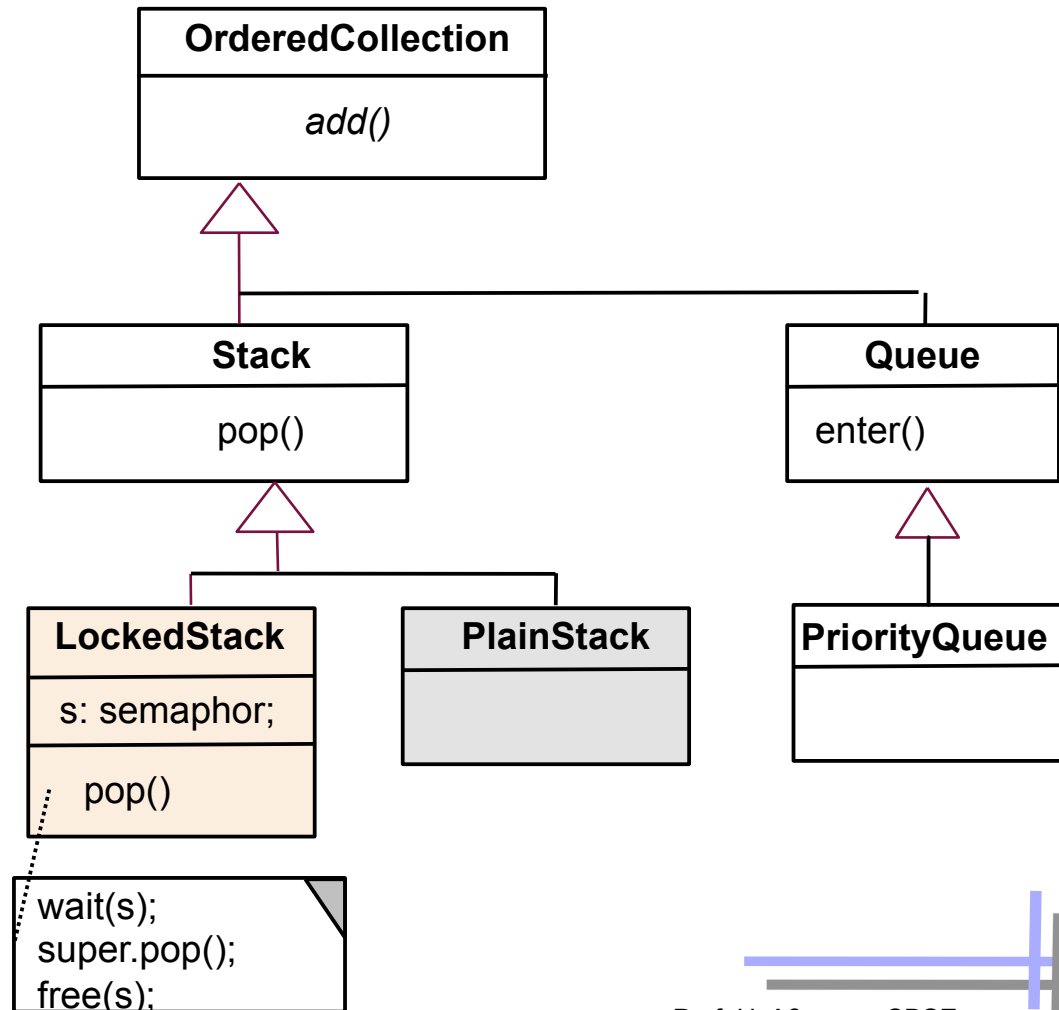
21.1- The Inheritance Anomaly



Inheritance Anomaly – Why Dimensional Software Composition Is Necessary

- ▶ In a parallel program, where should synchronization code be inserted?

- Stack?
- Queue?
- OrderedCollection?
- Collection?
- Object?



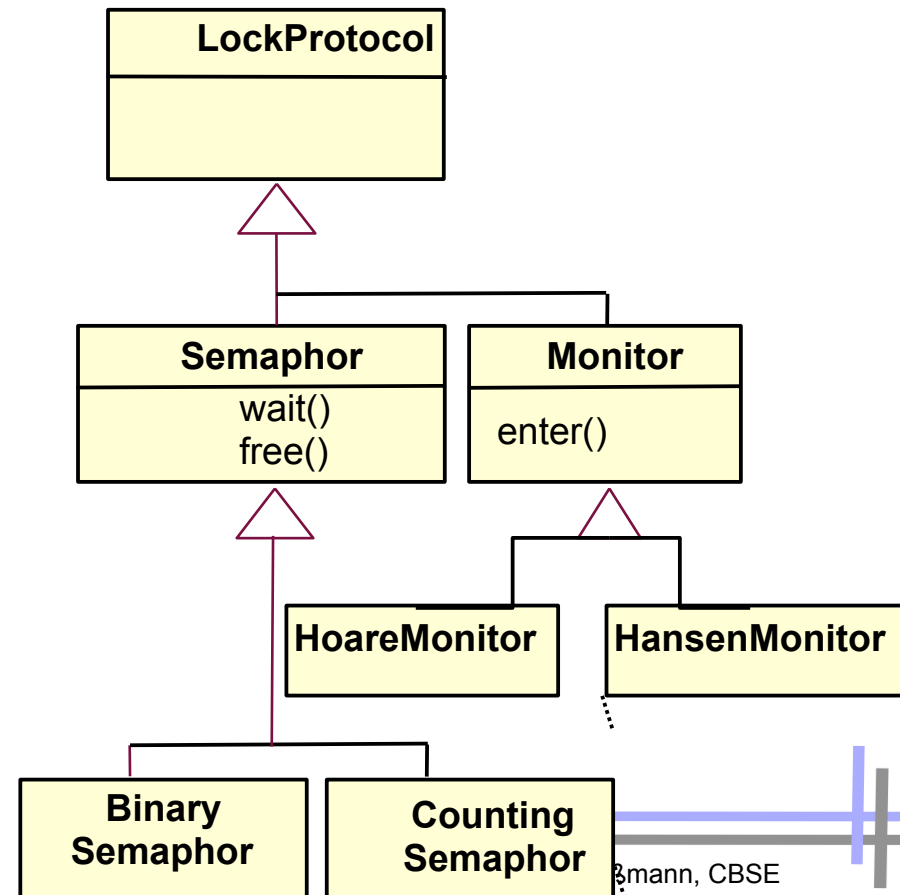
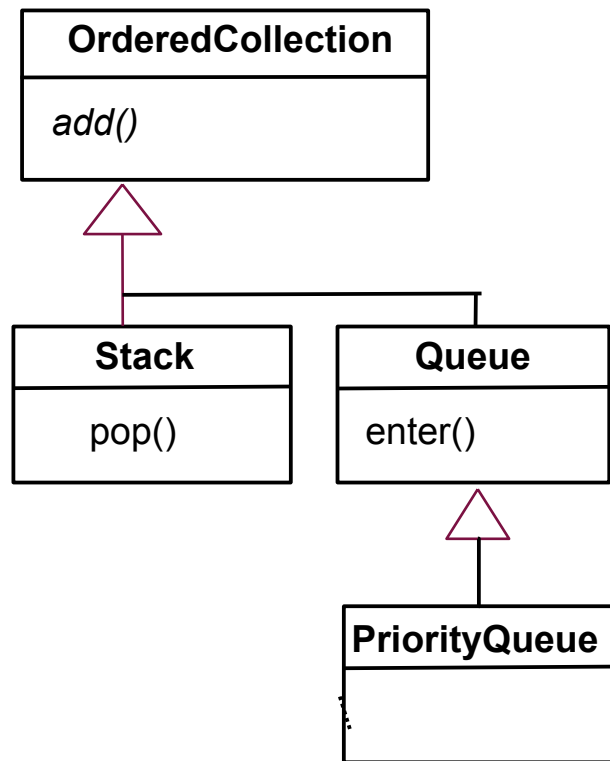


Inheritance Anomaly

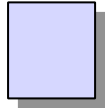
- ▶ At the beginning of the 90s, parallel object-oriented languages failed, due to the inheritance anomaly problem
- ▶ **Inheritance anomaly:** In inheritance hierarchies, synchronization code is *tangled (interwoven)* with the algorithm,
 - and cannot be easily exchanged
 - when the inheritance hierarchy 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?



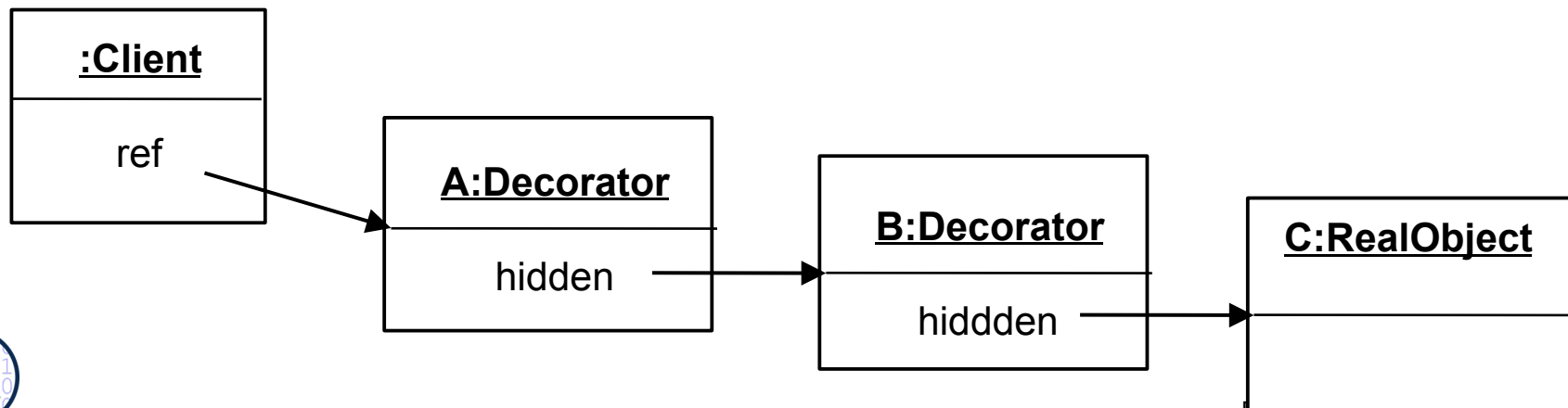
21.2 The Decorator Design Pattern (Rpt.)

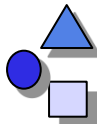




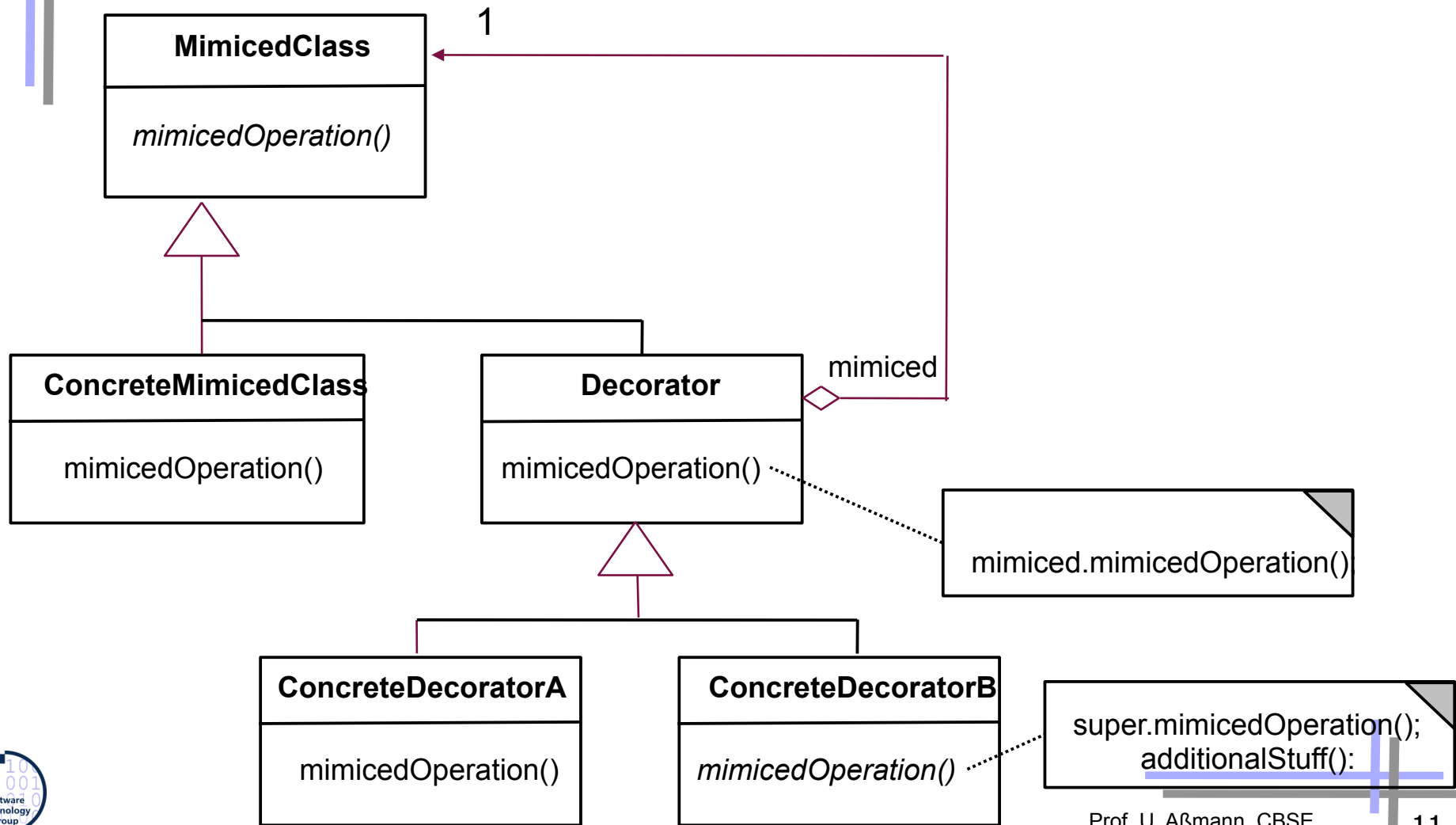
Decorator Pattern

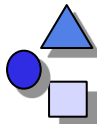
- ▶ A Decorator is a *skin* of another object
- ▶ It is a 1-ObjectRecursion (i.e., a restricted Composite):
 - A subclass of a class that contains an object of the class as child
 - However, only one composite (i.e., a delegatee)
- ▶ Combines inheritance with aggregation
 - Inheritance from an abstract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



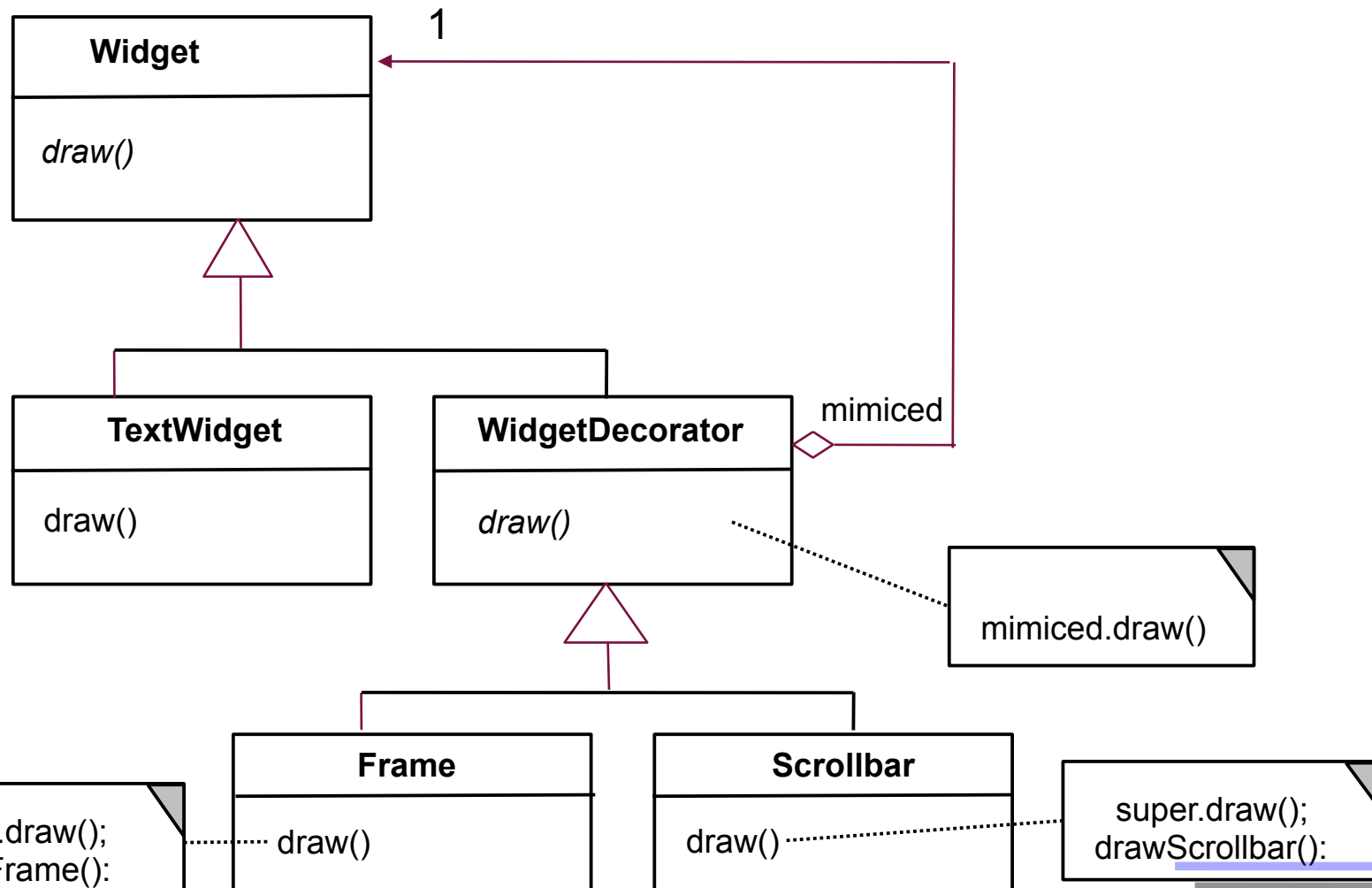


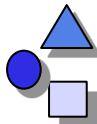
Decorator – Structure Diagram



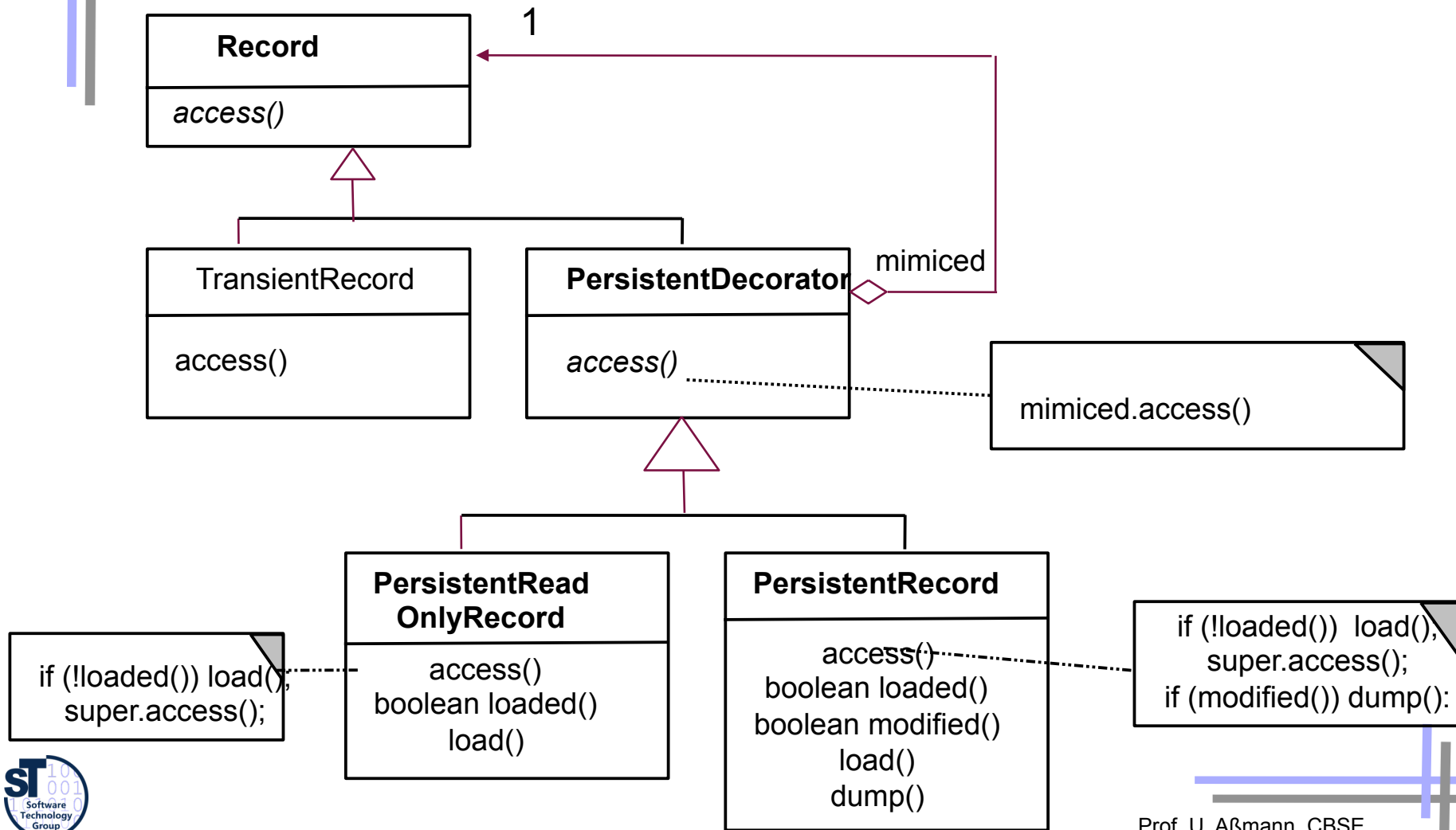


Decorator for Widgets





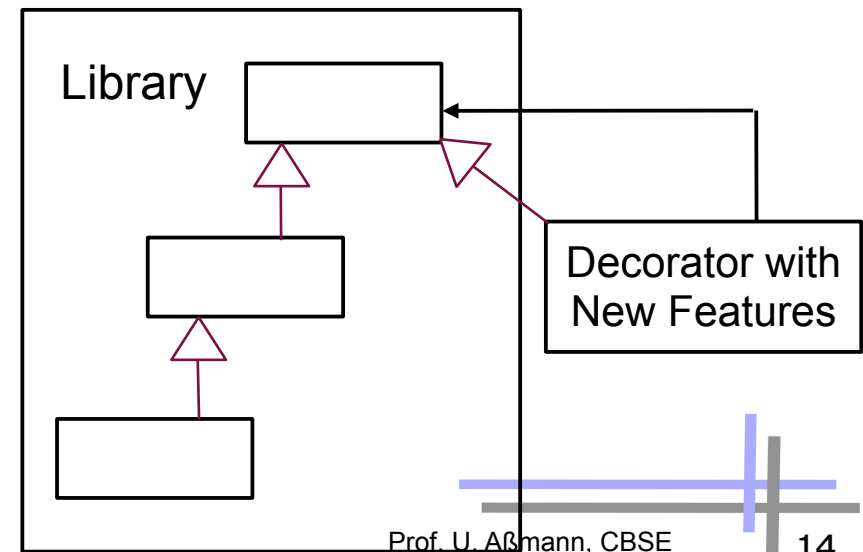
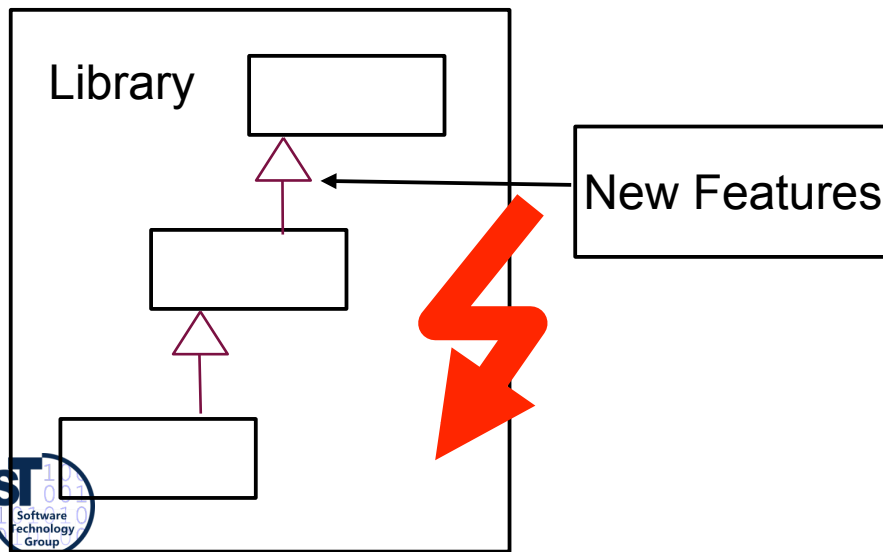
Decorator for Persistent Objects





Purpose Decorator

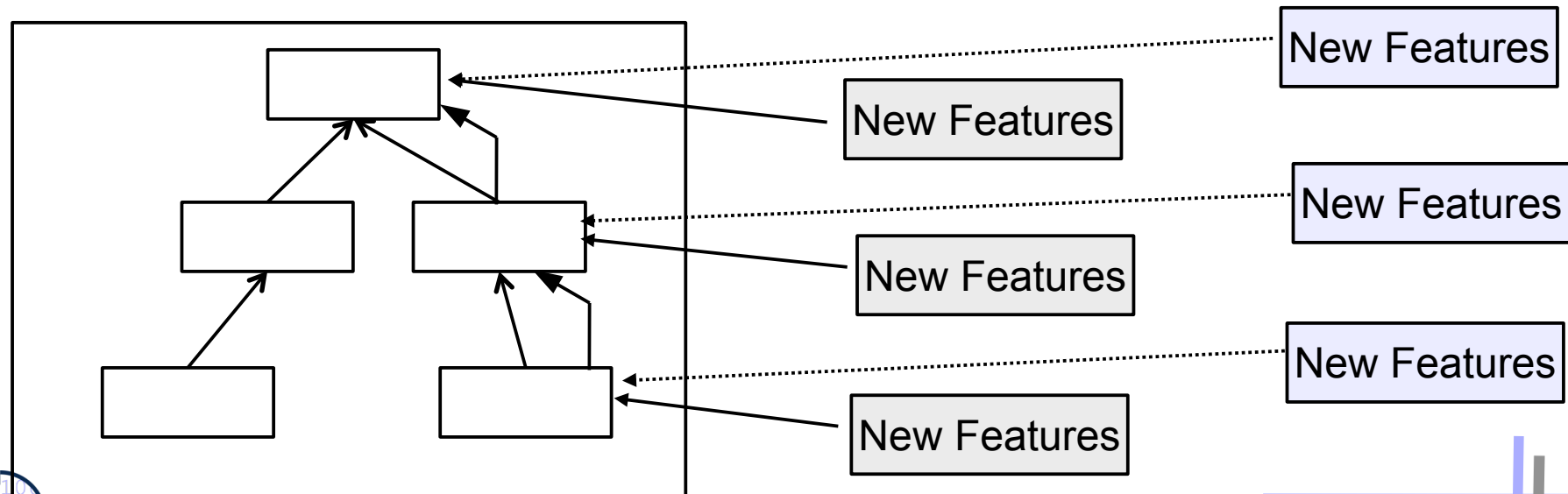
- ▶ For extensible objects (i.e., decorating objects)
 - Extension of new features at runtime
 - Removal possible
- ▶ Instead of putting the extension into the inheritance hierarchy
 - If that would become too complex
 - If that is not possible since it is hidden in a library

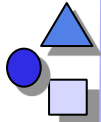




Variants of Decorators

- ▶ 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

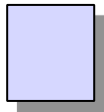
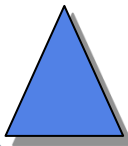




Decorator Relations

- ▶ 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

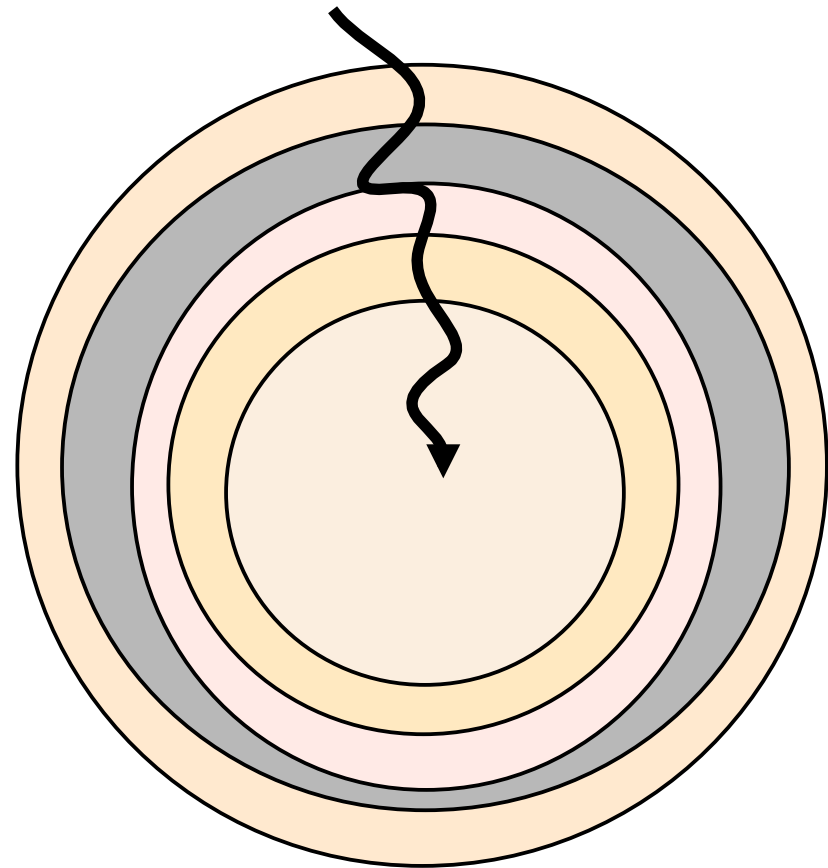
21.3 Composition Filters

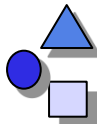




Filters are Layers

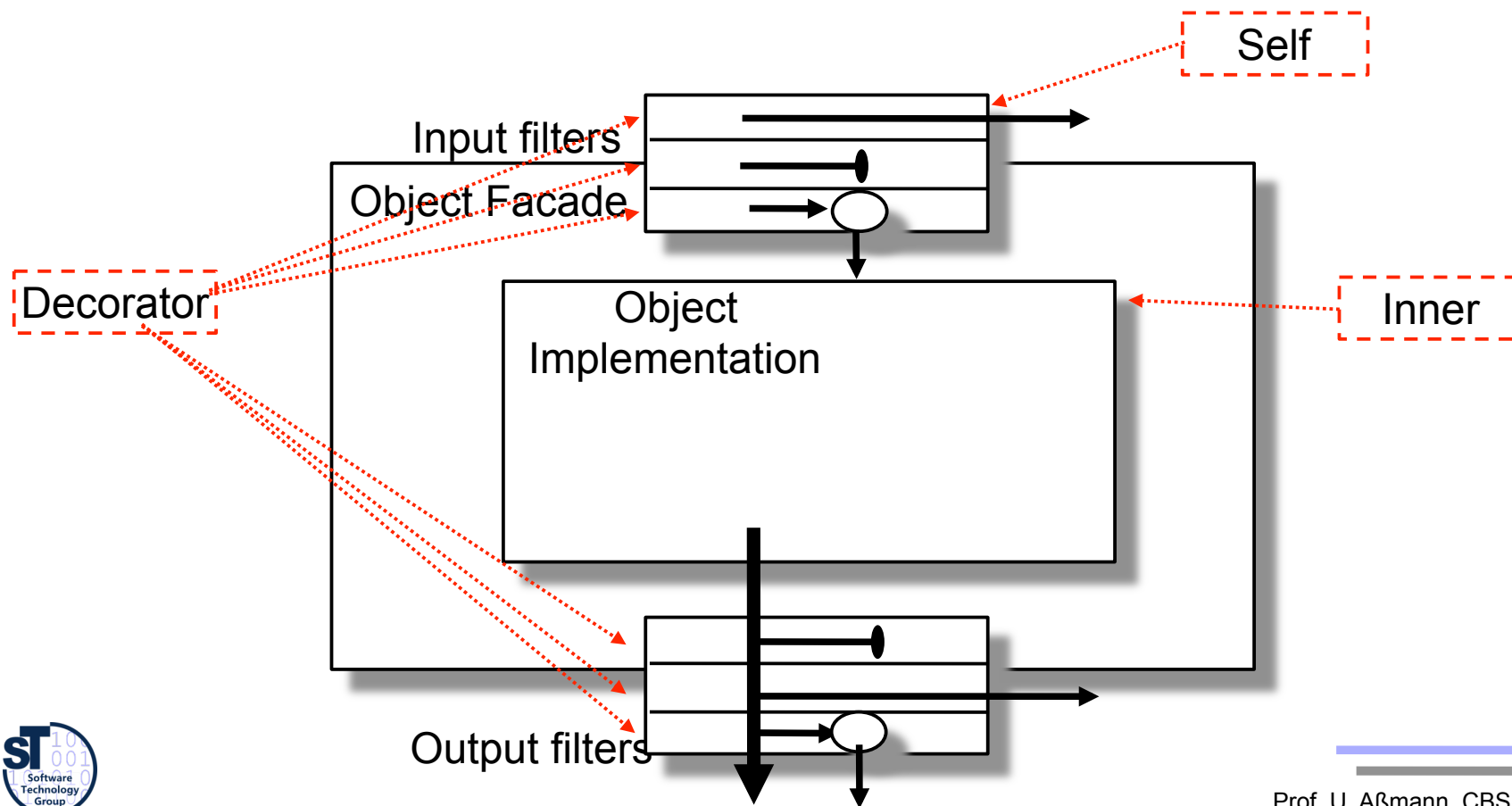
- ▶ Composition Filters (CF) wraps objects with *filters*
- ▶ Messages flow through the filters
 - are accepted or rejected
 - are modified by them
- ▶ A filter is an *interceptor* that is part of an object





Filters are Special Decorators

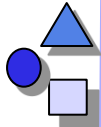
- ▶ Filters are decorators that do not suffer from object schizophrenia





Filter Types

- ▶ **Error.** An error filter tests whether a message is available.
 - If not, it stops filtering and execution.
- ▶ **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 ::=

- Guard '=>' Match -- All matching messages are accepted
- | Guard '~>' Match -- All matching messages are rejected
- | Guard '=>' '[' Match ']' Match . – optional match

Guard ::= BooleanFunctionCall.

Match ::= TargetObject '.' MethodName | MethodName .

TargetObject ::= 'self' | 'inner' | '*' .

MethodName ::= Name | '*' .



Filters in SINA

Guard
(Condition)

Action

▶ Sync Filter example:

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

▶ Meaning:

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



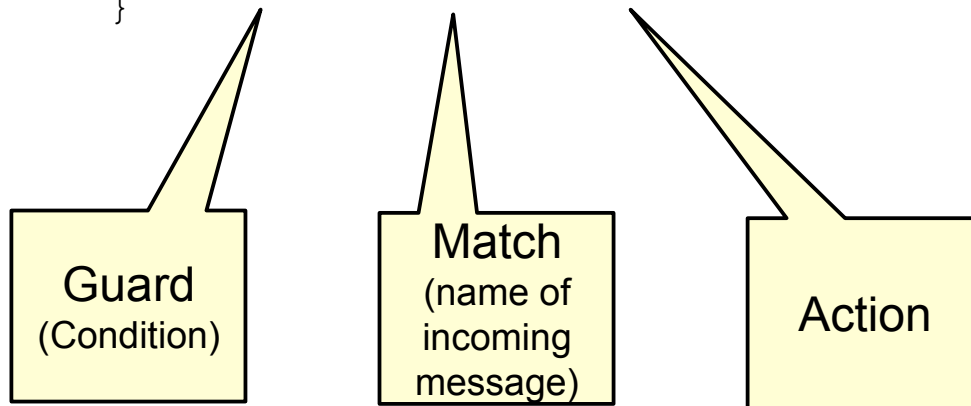
Wrapping Methods with Calls

▶ **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.*;  
}
```

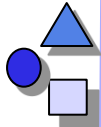




A Larger Example

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

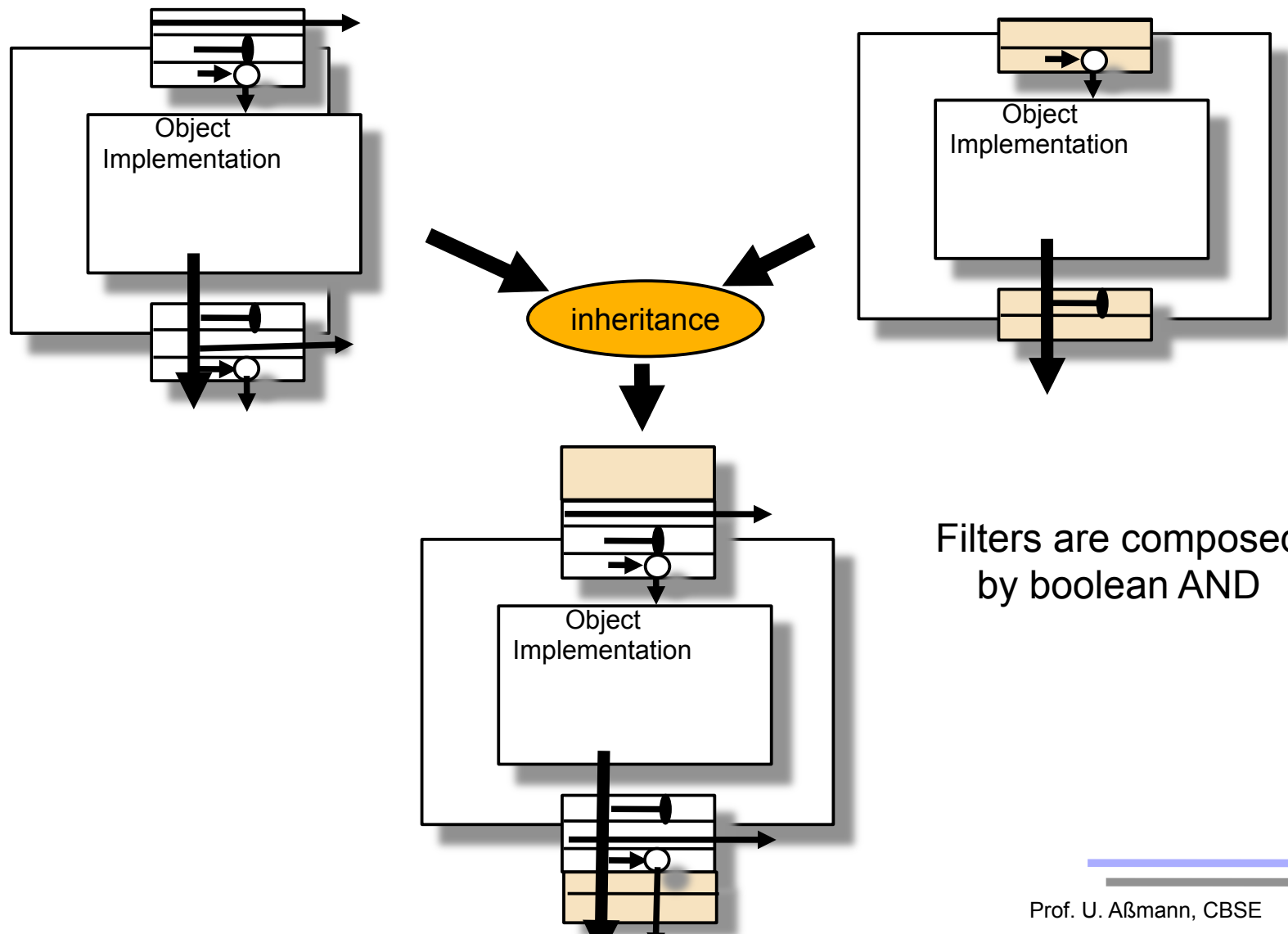
- A press is modeled, either with or without animation.
- There are two Meta filters that call tracing methods when the press is in animation mode (precondition *isAnimating*).
 - The filters match all messages (pattern [*]) and call tracing methods.
 - Then, they pass on control to the next filter.
- 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.

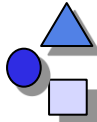


Main Advantage of the Filter Concept

- ▶ 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





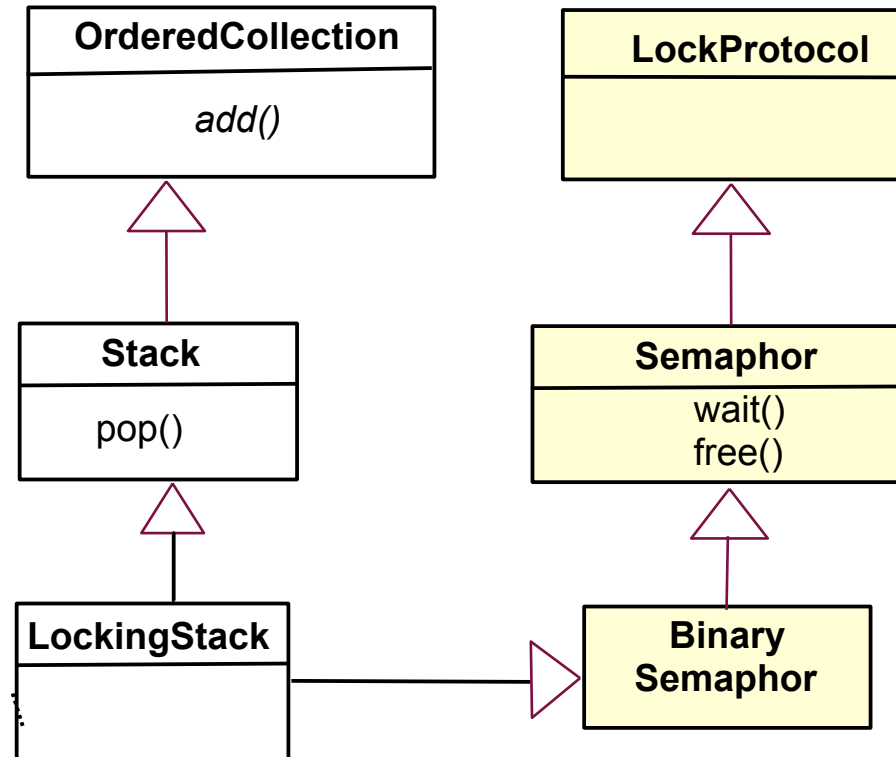
Composing a Locking Stack

- ▶ Additionally, filter composition has to be specified:

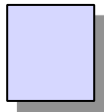
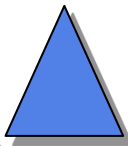
```
class LockingState interface
internals
  superStack: Stack
  locker: BinarySemaphor
inputfilters
  <locker.locking;
  superStack.sync;
  disp: Dispatch={superStack.*,
                  locker.*};
>
```

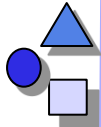
superclasses

sequential
AND
composition



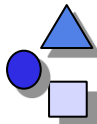
21.4 Implementations of the Filter Concept in Standard Languages





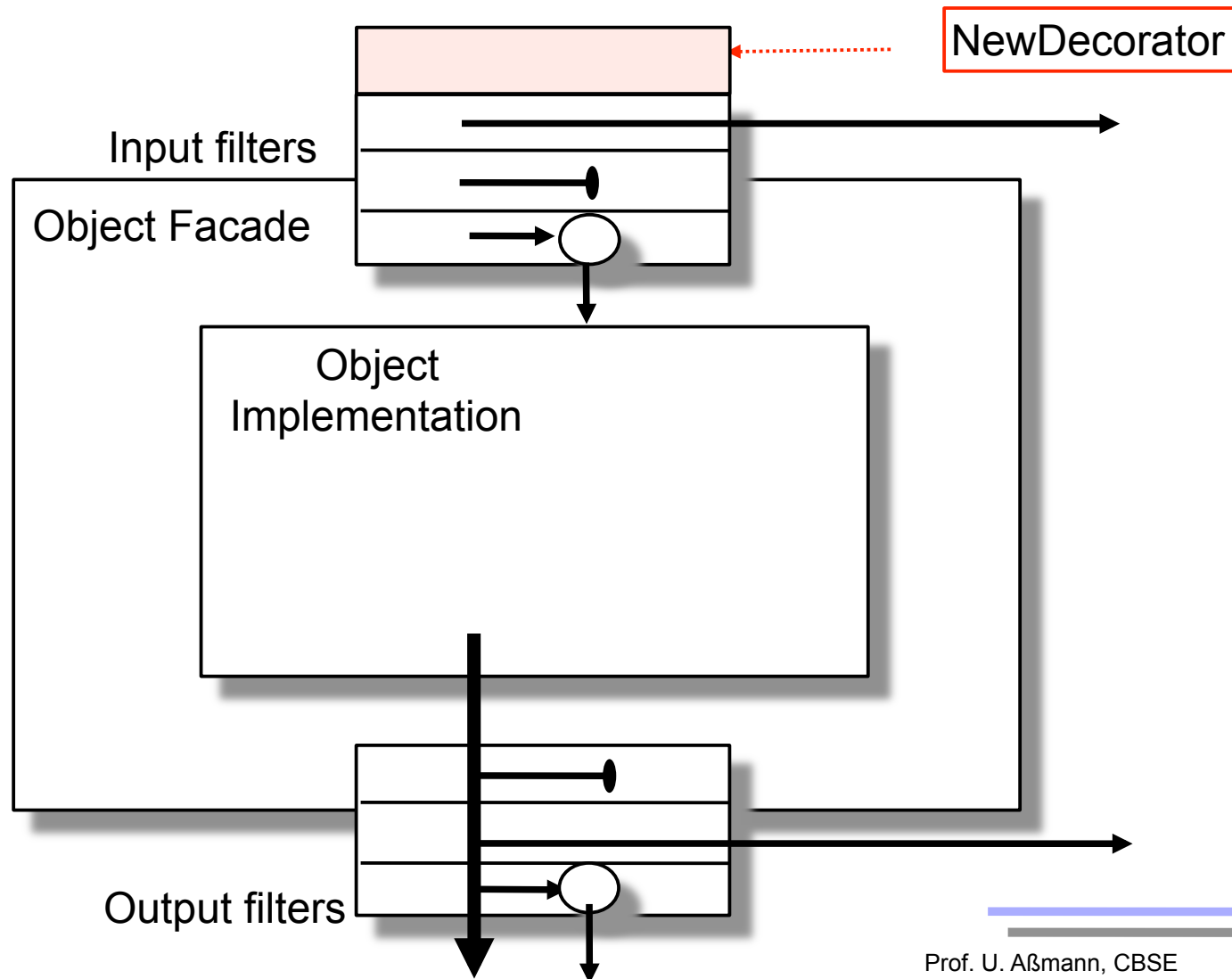
Implementation with Decorator

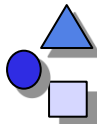
- ▶ The superclass of the Decorator pattern implements the object interface
 - The decorating classes are the filters
 - Problem: Decorators do not provide access to the “inner” object or the “self” object
- ▶ Filters also can be regarded as ChainOfResponsibility
 - However, there is a final element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



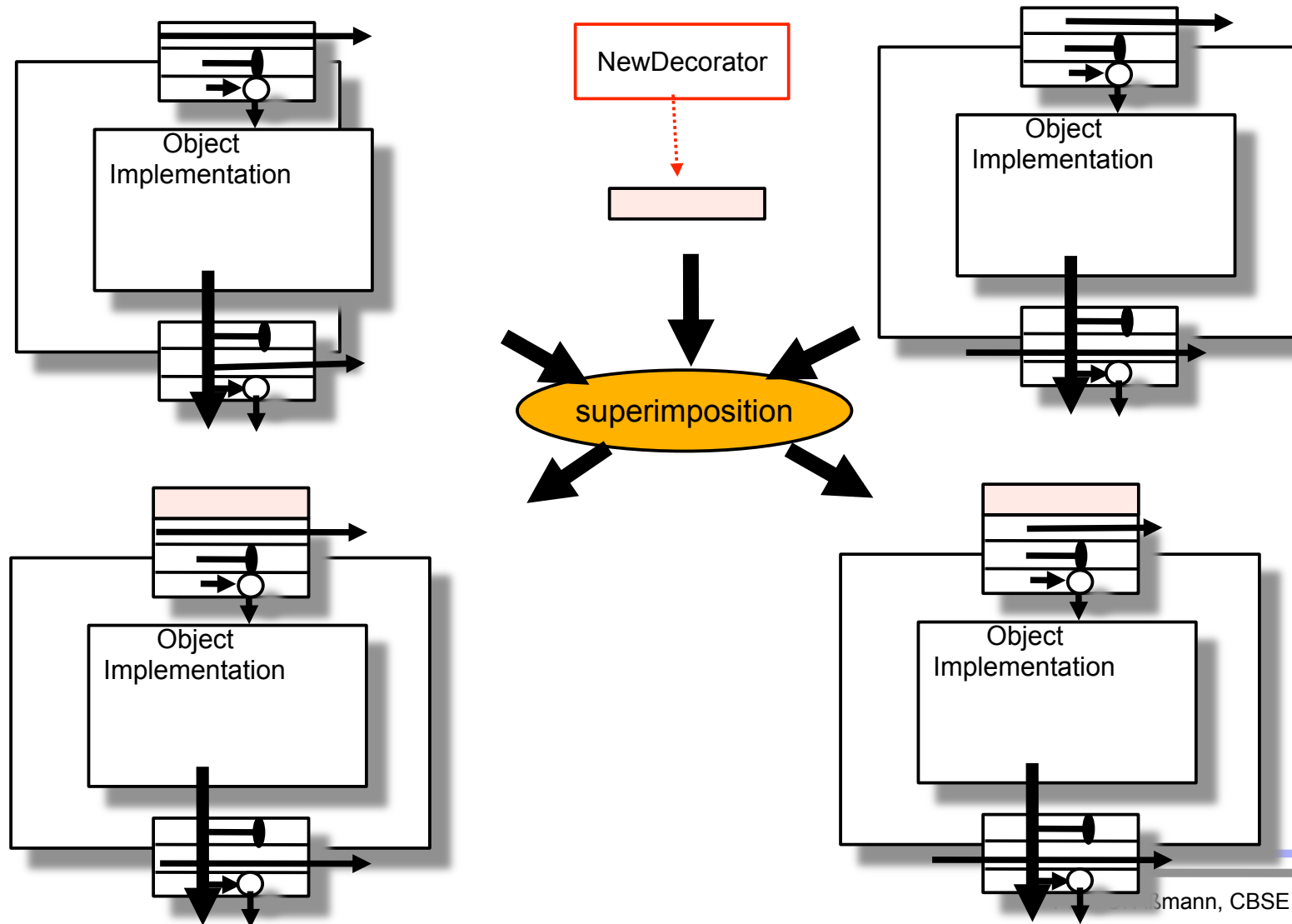
Filters Can be Composed From Outside

- ▶ Filter superimposition





Filters Can be Composed From Outside





Superimposing a Decorator in Hand-Written Code

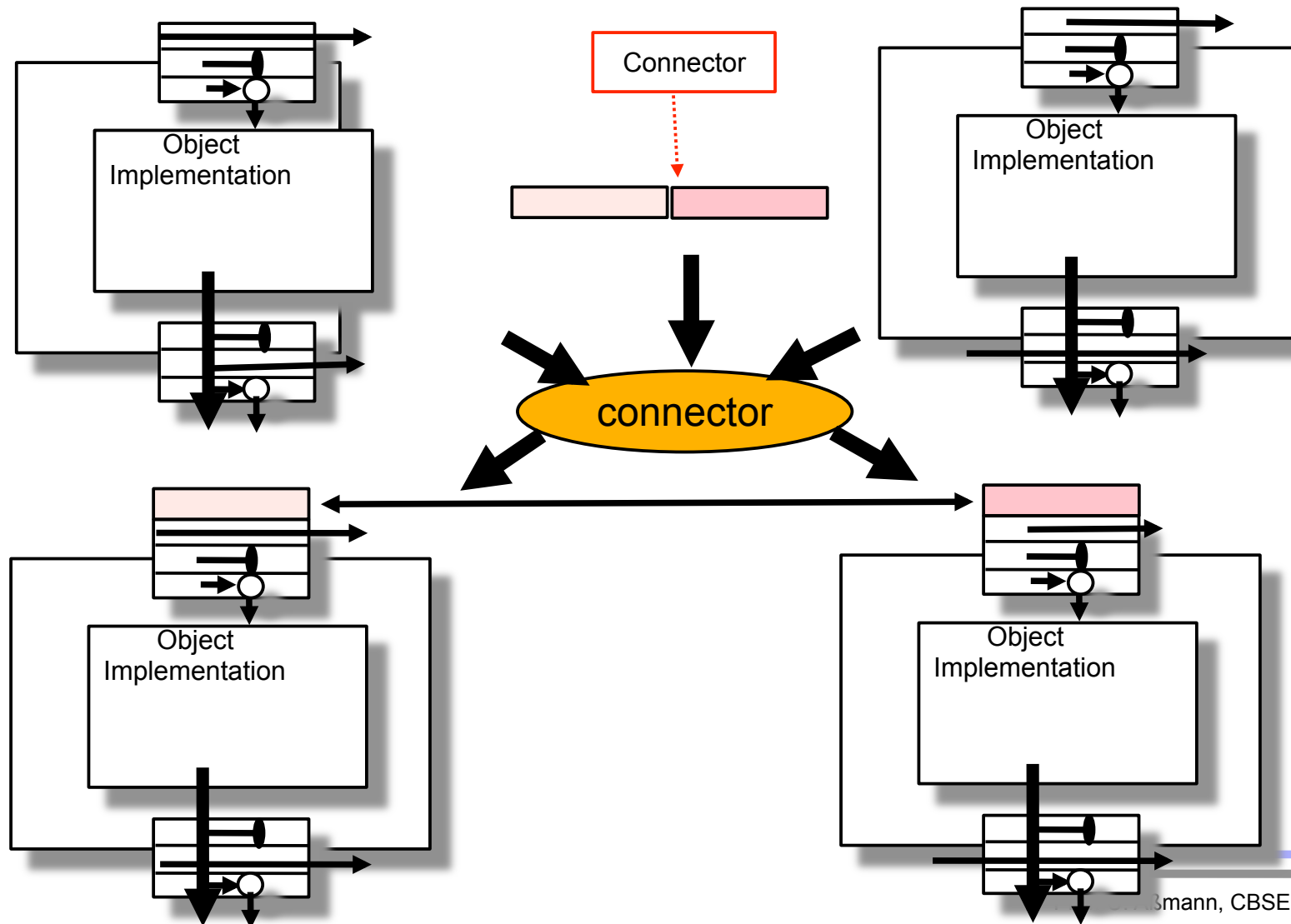
- ▶ Walk through the list of decorators
- ▶ Insert a new decorator where appropriate

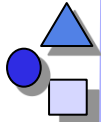
- ▶ Example: superimposing synchronization:
 - Do for all objects involved:
 - . Get the first decorator
 - . Append a locking decorator, accessing a common semaphore

- ▶ Removing synchronization
 - Do for all objects involved:
 - . Get the synchronizing decorator
 - . Dequeue it

Superimposing Several Filters Produces Filter-Connector Pattern

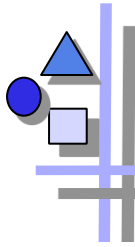
- ▶ The Decorator-Connector Pattern can be realized with filters





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>>;
    }
}
```

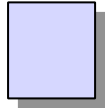
```
class FilteredClass extends Class {
    Filter[] inputFilters;
    public FilteredClass() { .. }
    public void enterMethod() {
        // First assign the called inner method to be the continuation
        Method continuation = thisMethod;
        // Run the input filters and calculate the real 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[]{});
```

21.5 Composition Filters and The Role Object Pattern



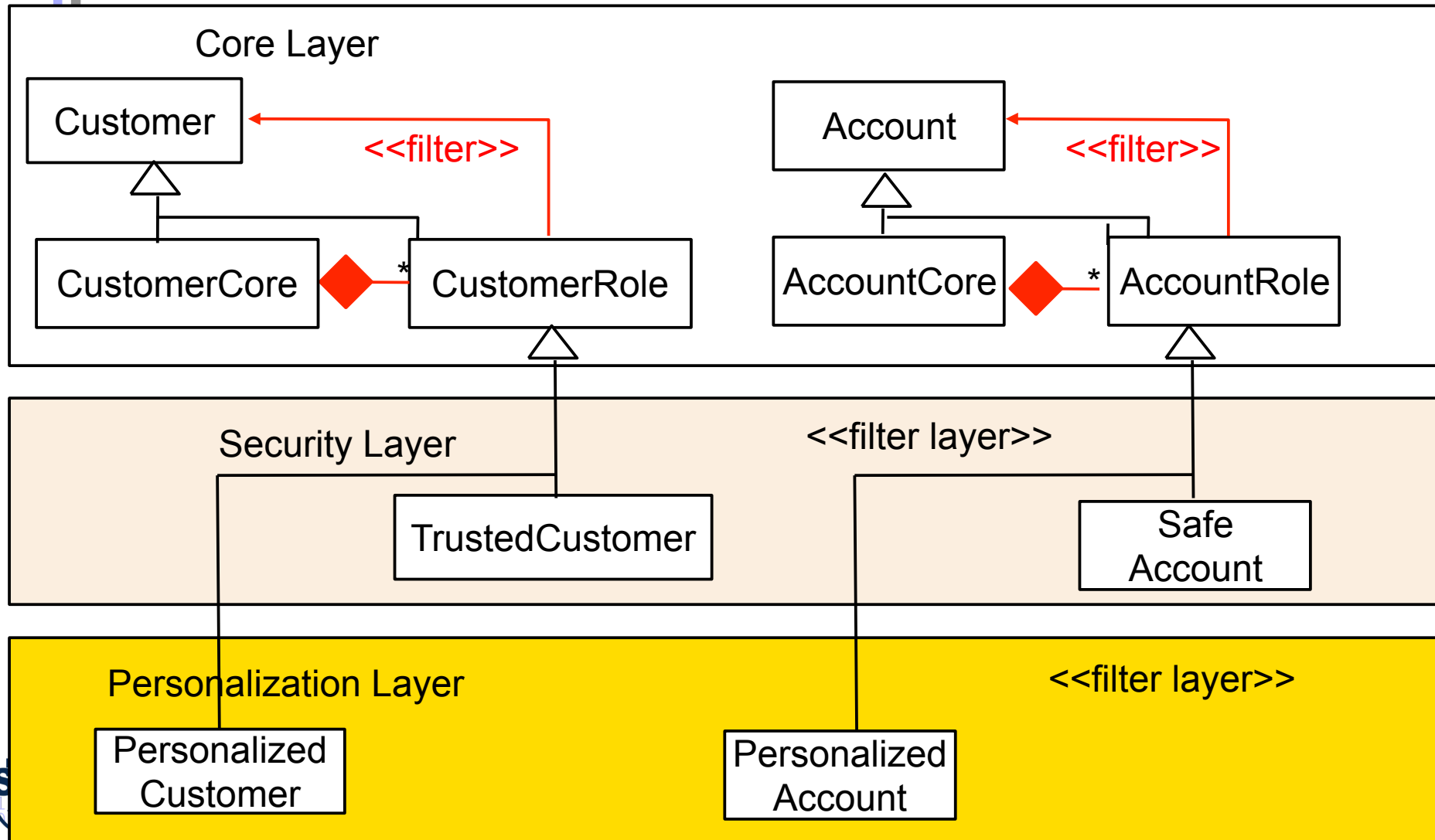


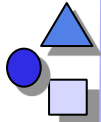
Composition Filter Layers

- ▶ 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

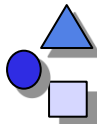
Role Object Pattern can implement roles as filters





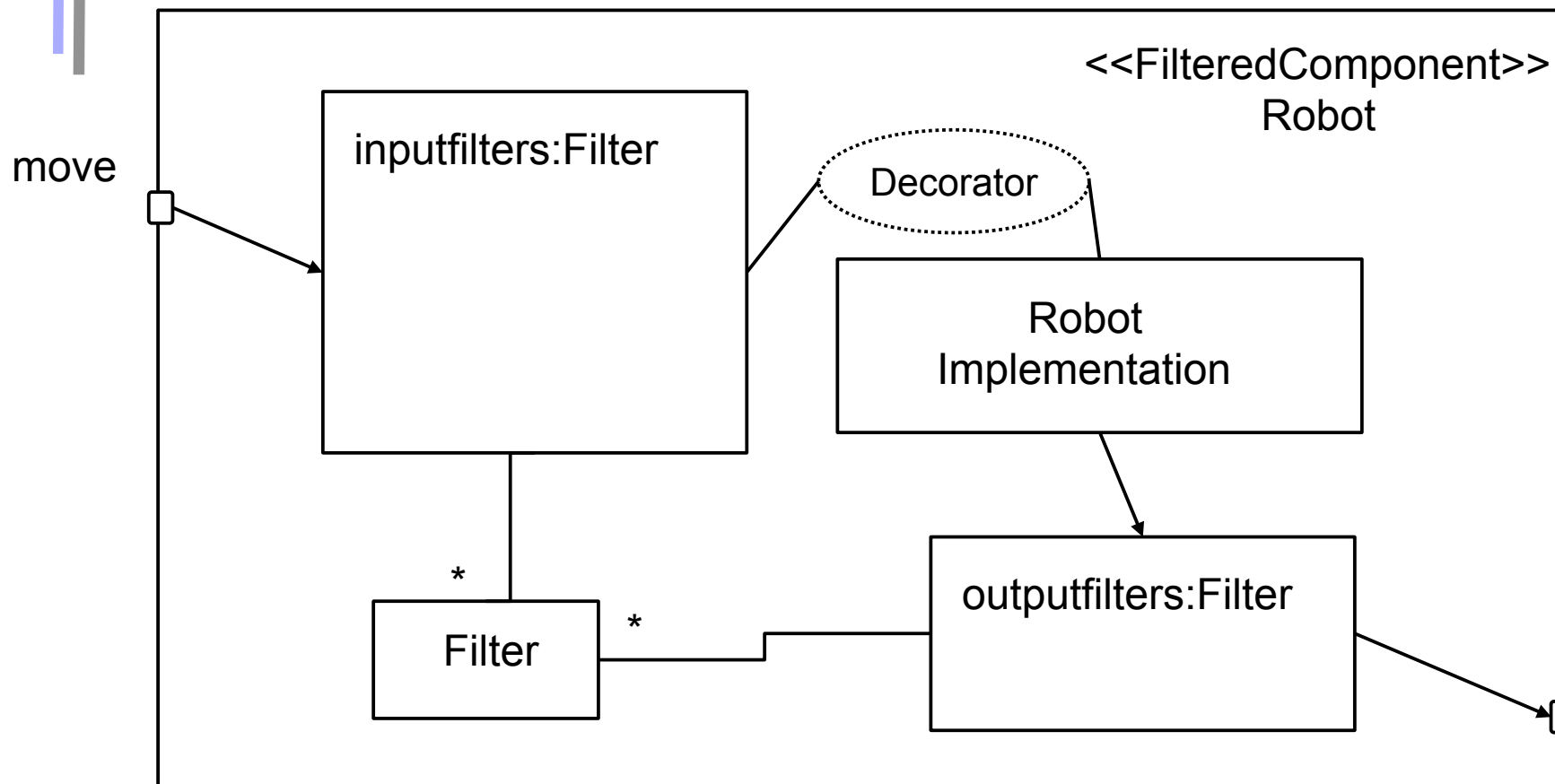
Using Composition Filters

- ▶ 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



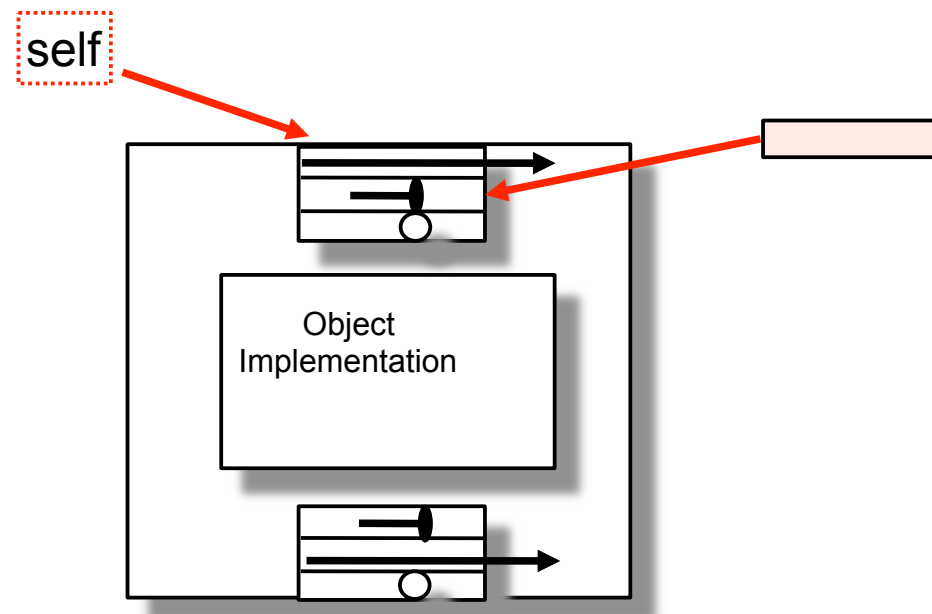
Filters In UML

- ▶ Realize as inner components

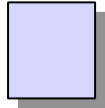


Insight: Greybox Composition Relies on Extensibility

- ▶ 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

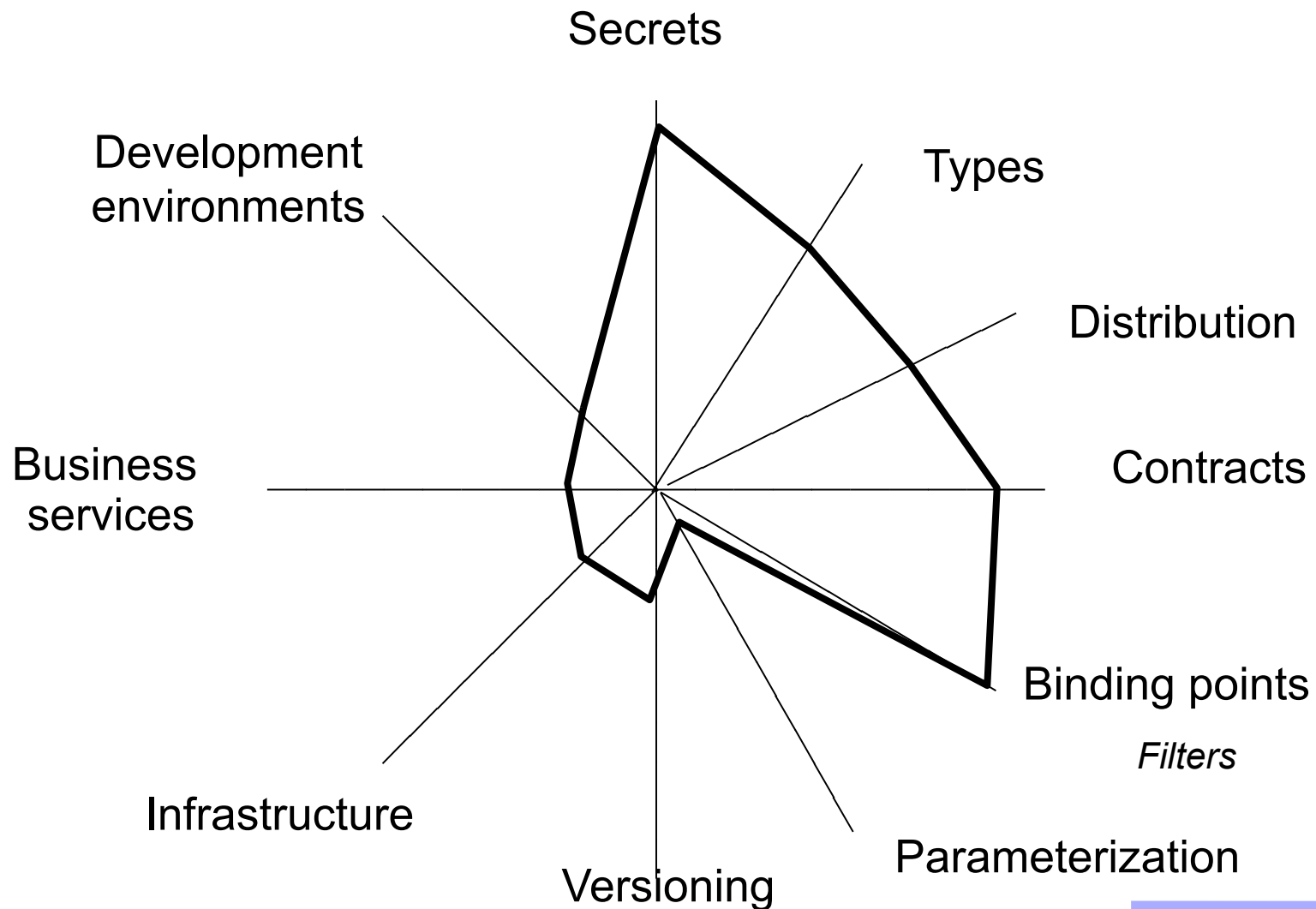


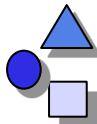
21.6 Evaluation as Composition System



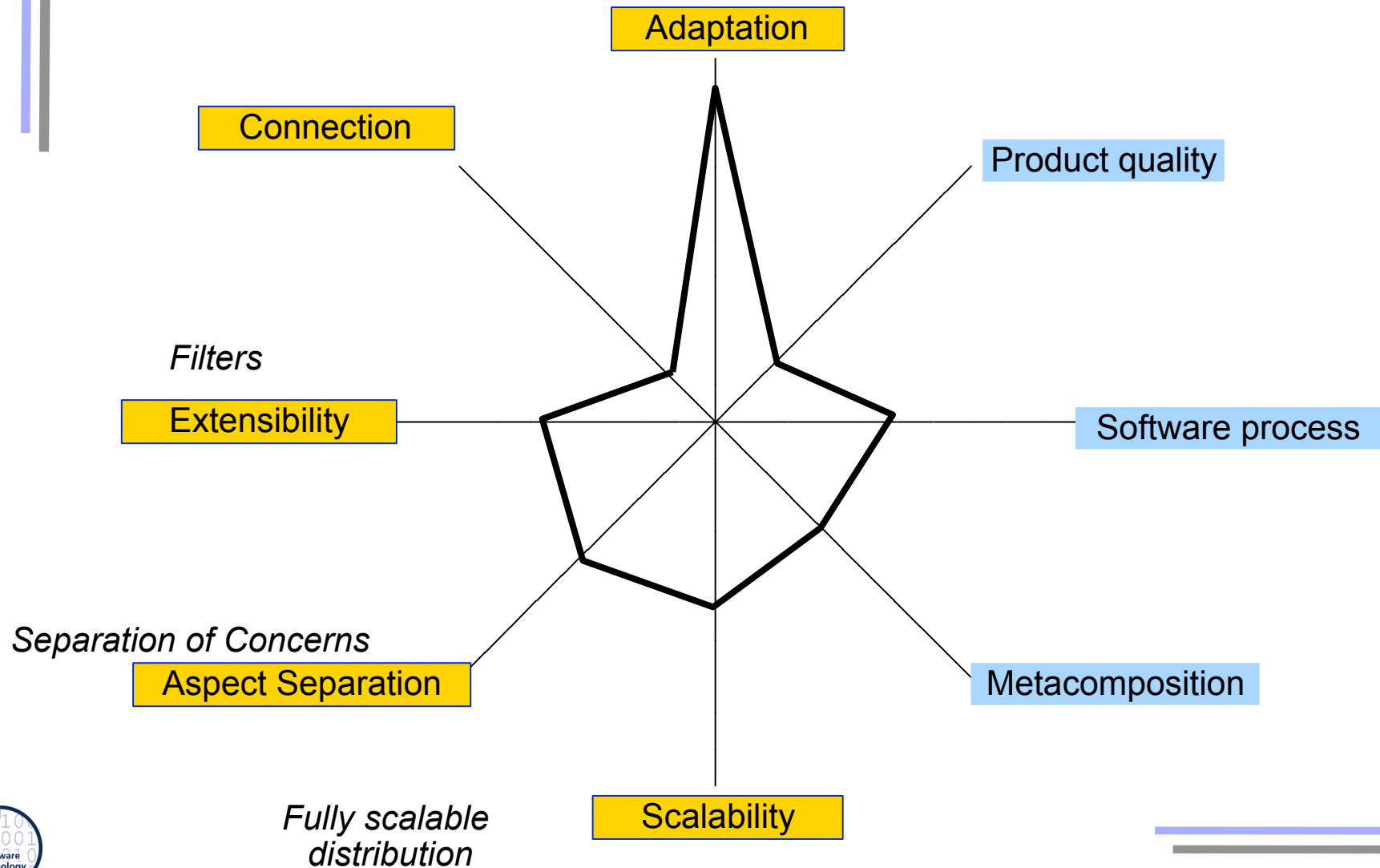


CF - Component Model



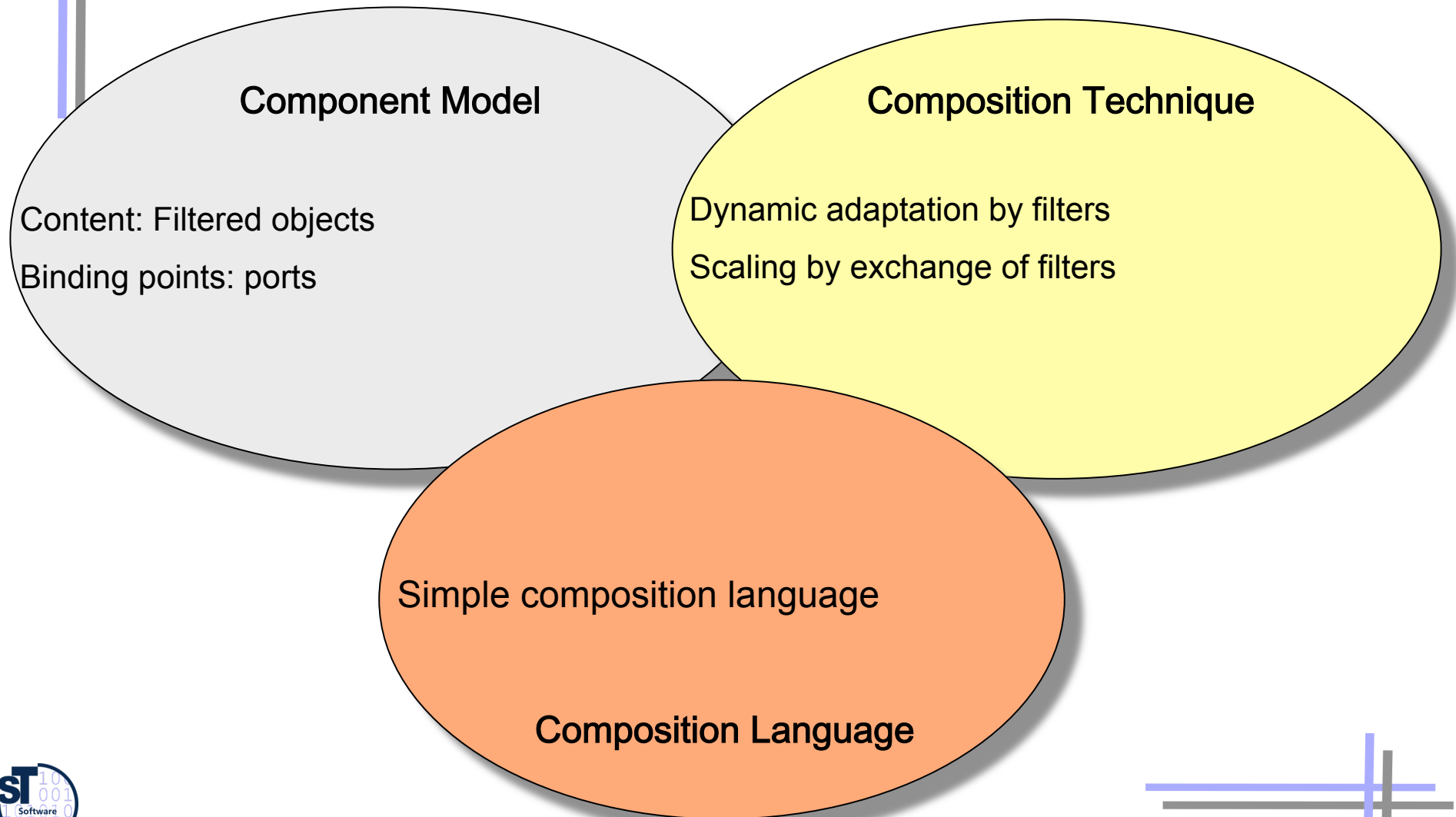


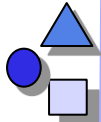
CF – Composition Technique and Language





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