21) 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. 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/

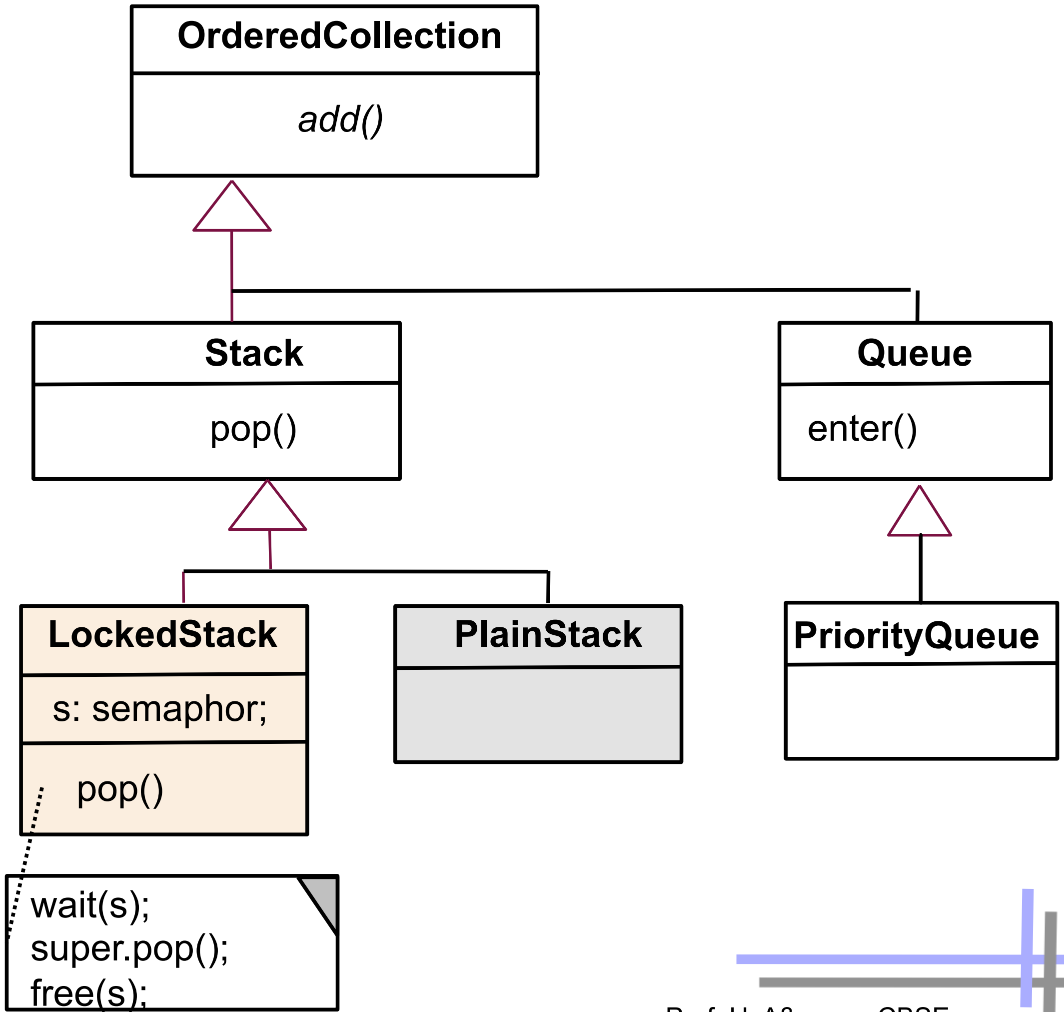
Goal

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

21.1) Inheritance Anomaly

Inheritance Anomaly - Why Software Composition Is Necessary

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

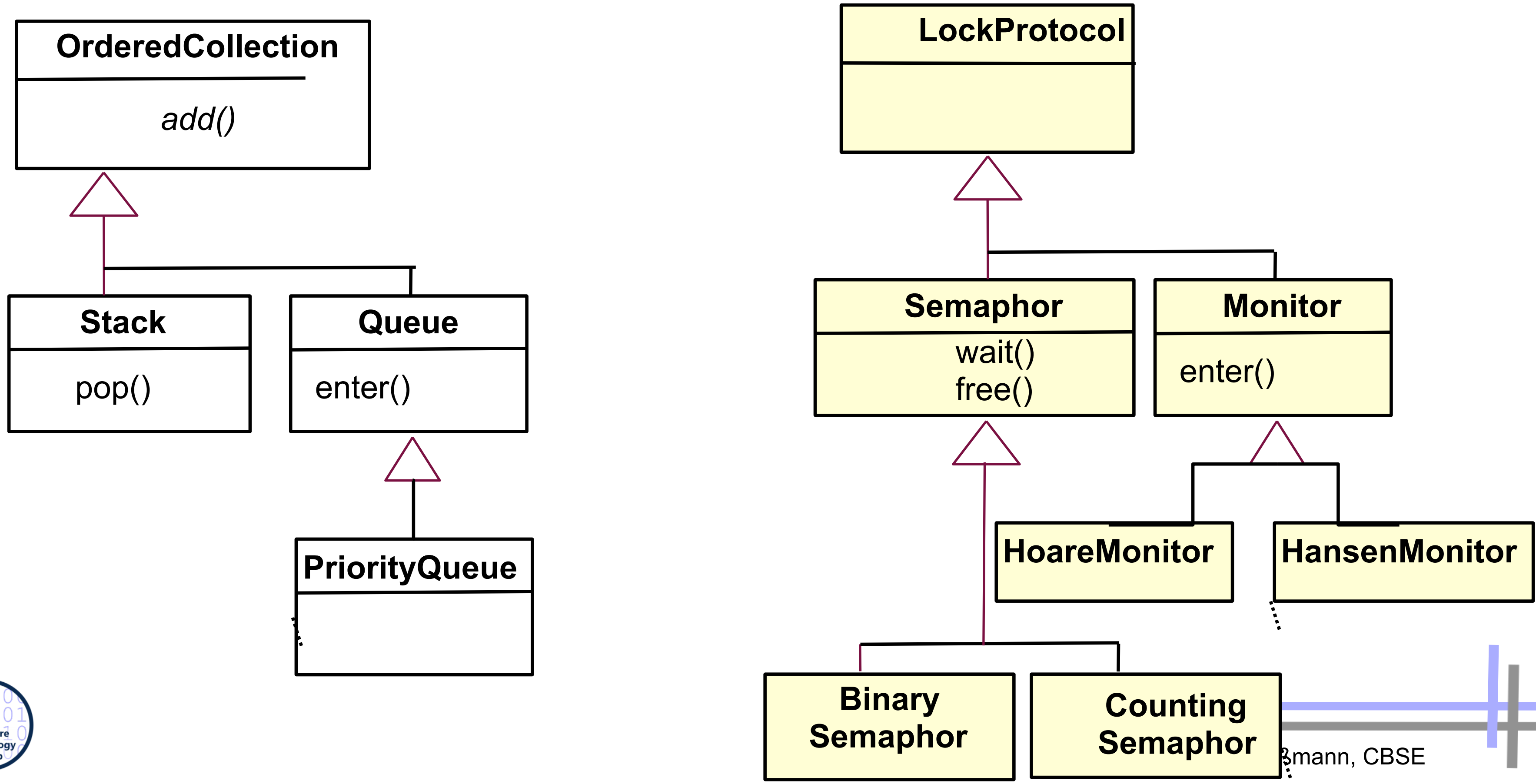


Inheritance Anomaly

- 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

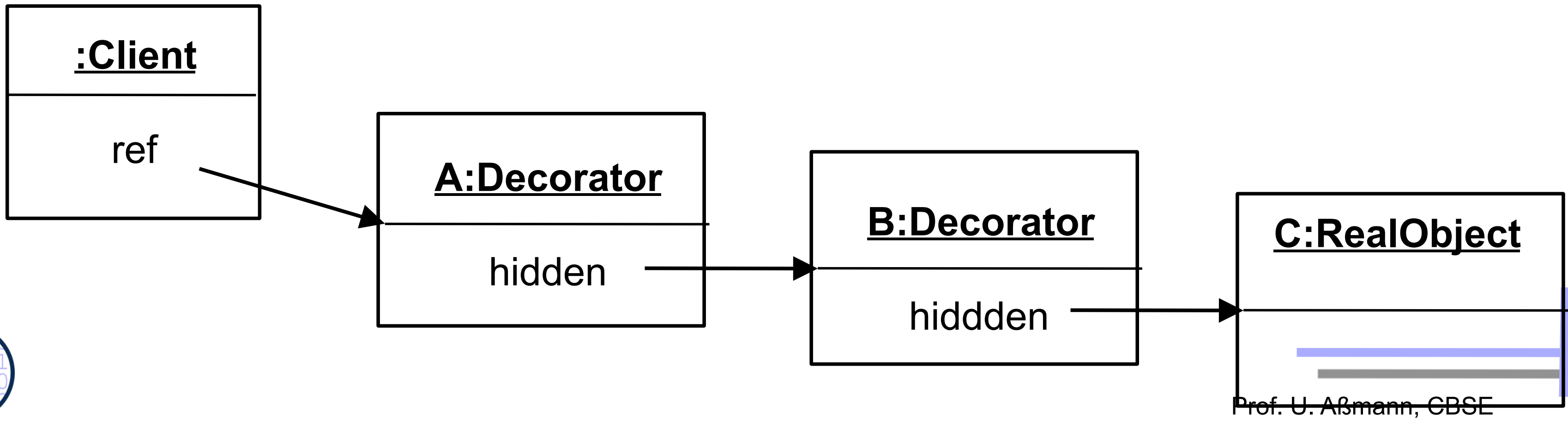
- But they depend on each other
- How to mix them appropriately?



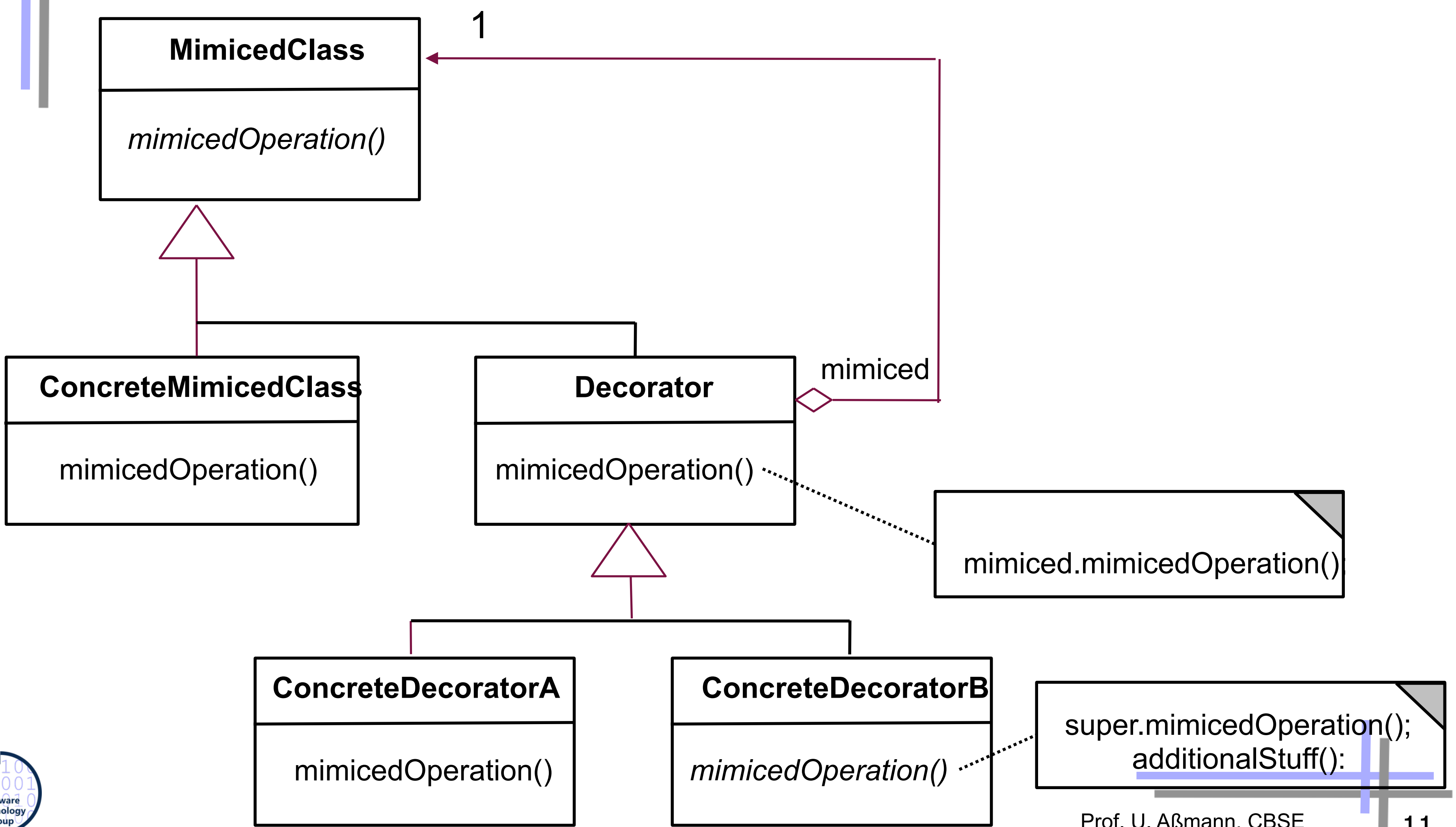
21.2 The Decorator Design Pattern (Rpt.)

Decorator Pattern

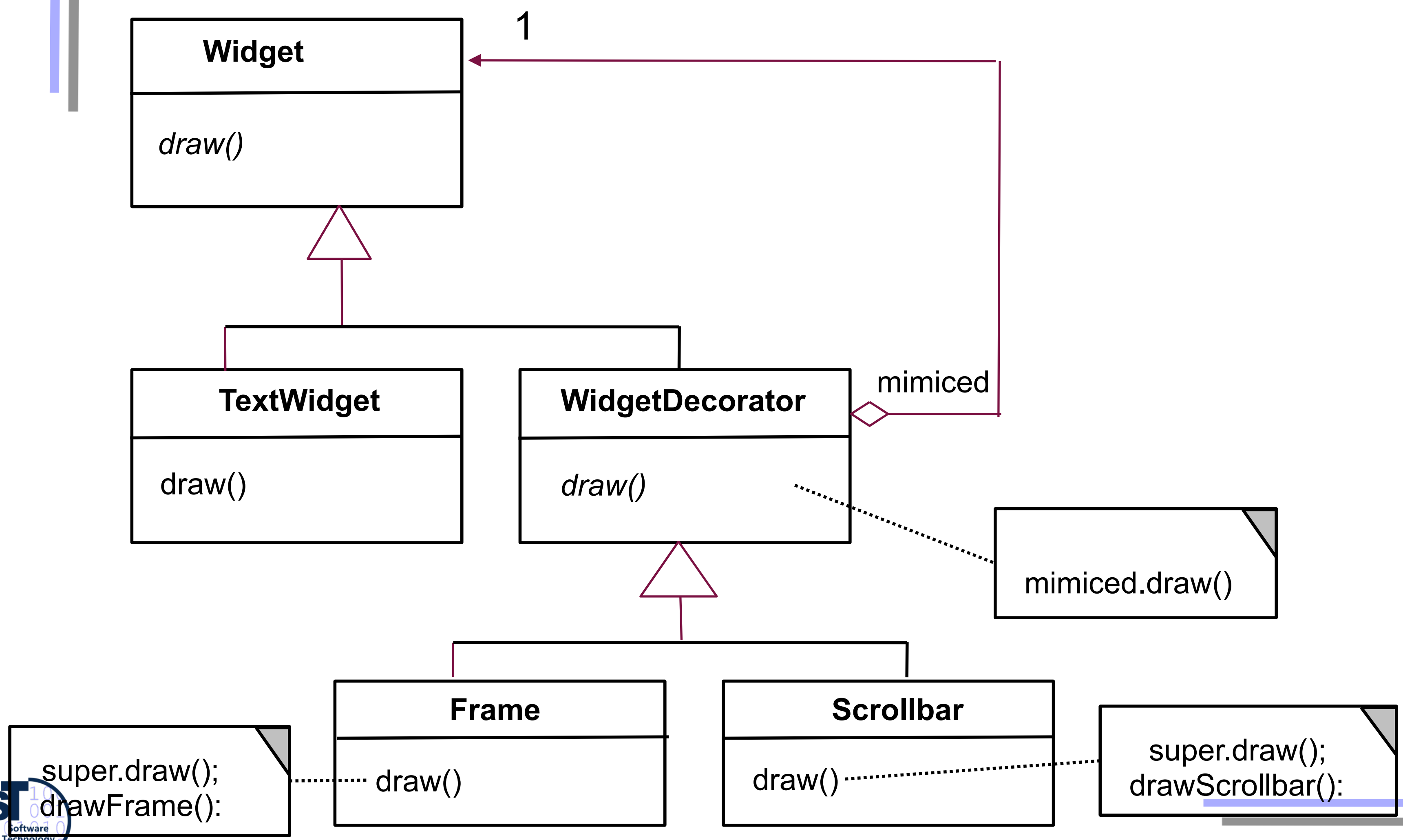
- A Decorator is a *skin* of another object
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
- Combines inheritance with aggregation
  - Inheritance from an abstract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



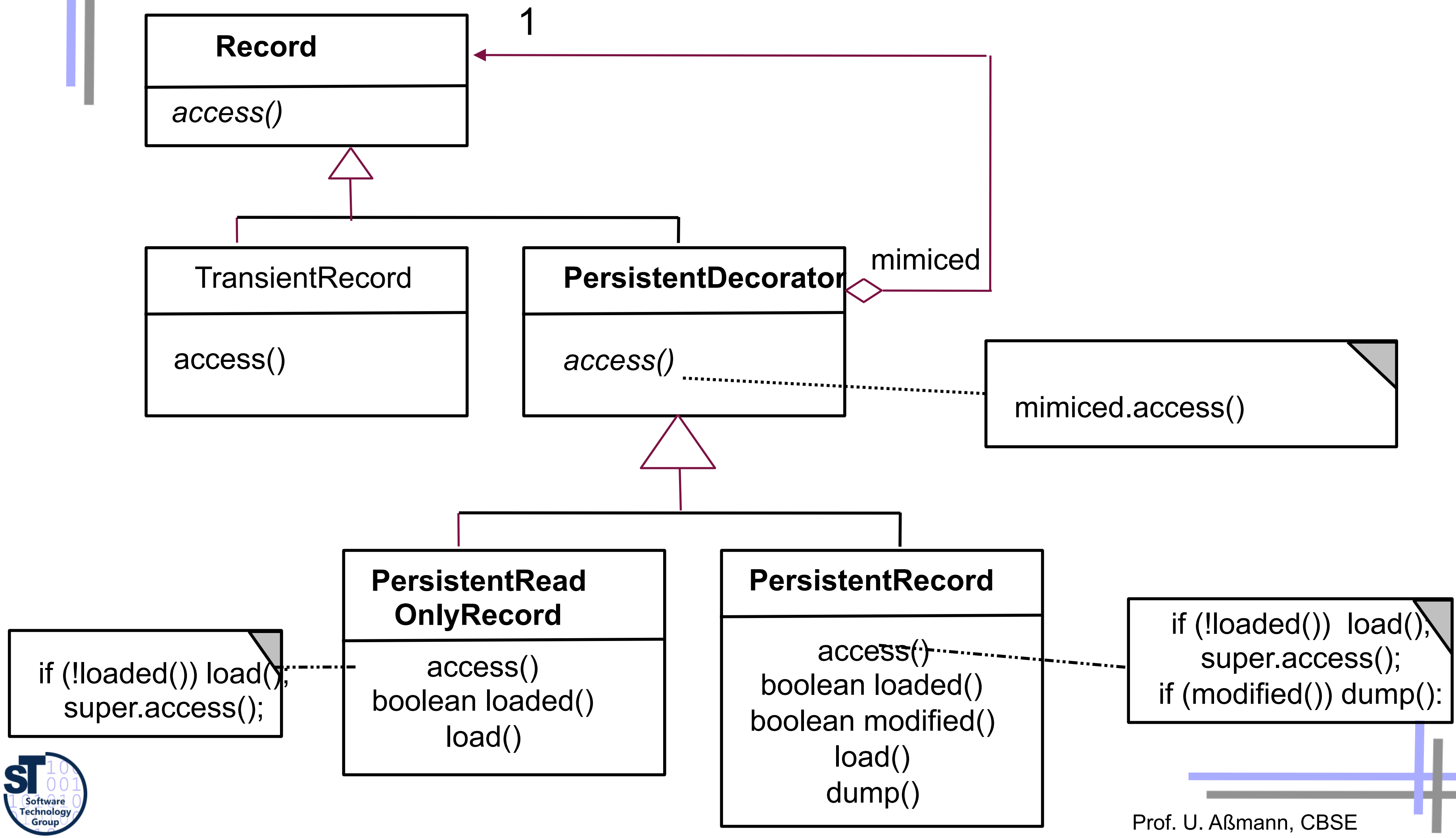
Decorator – Structure Diagram



Decorator for Widgets

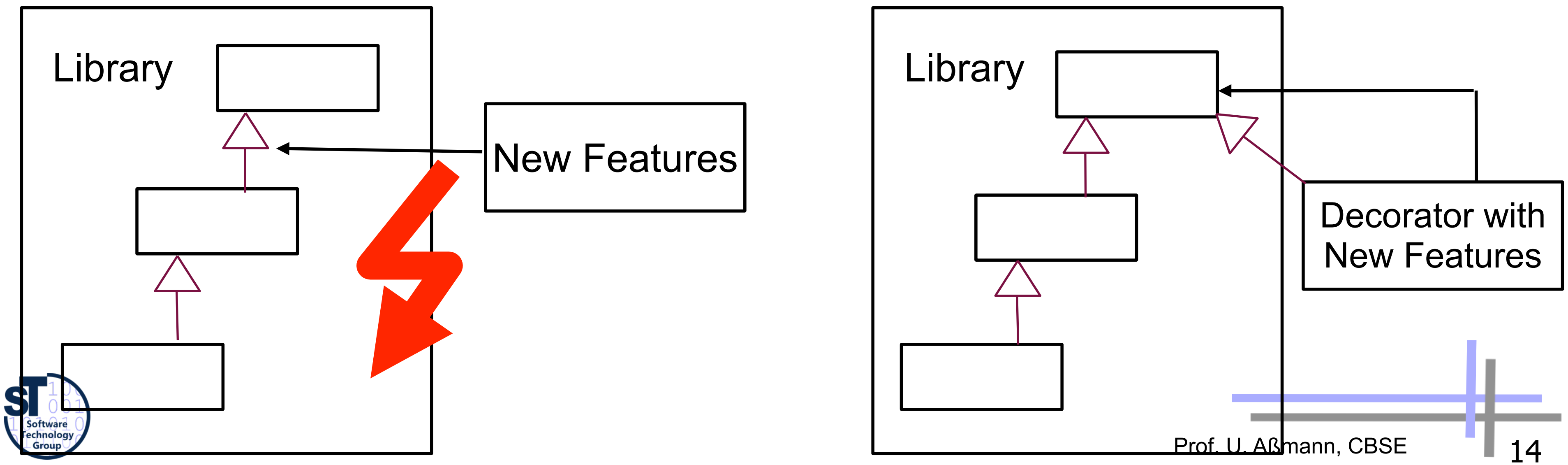


Decorator for Persistent Objects



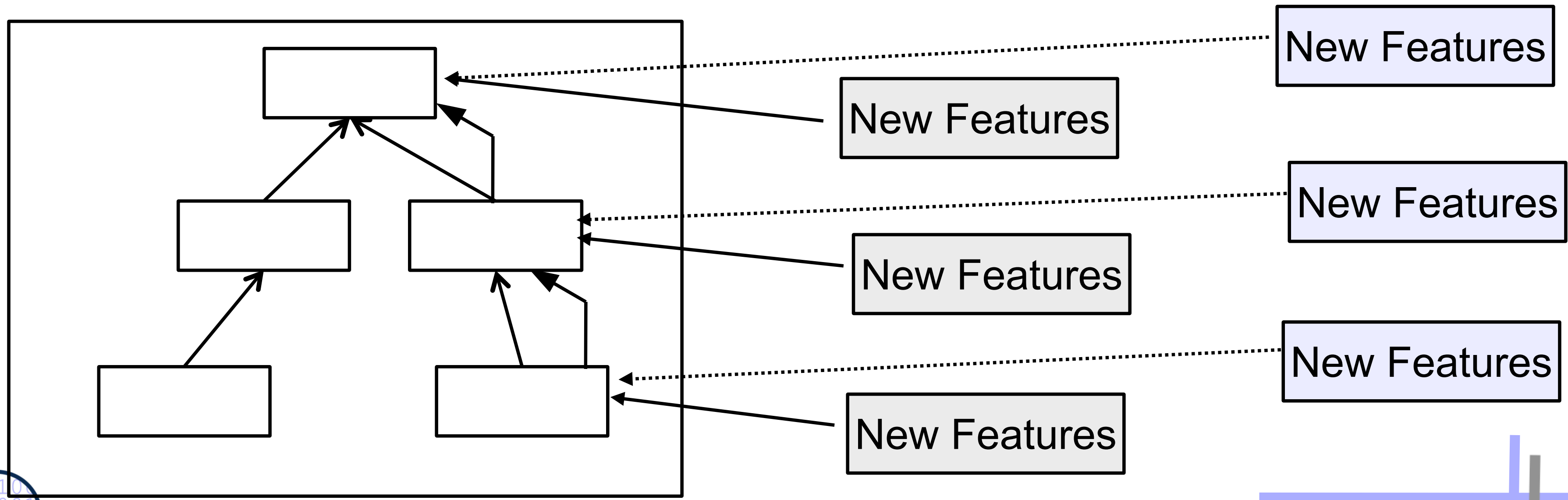
Purpose Decorator

- 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



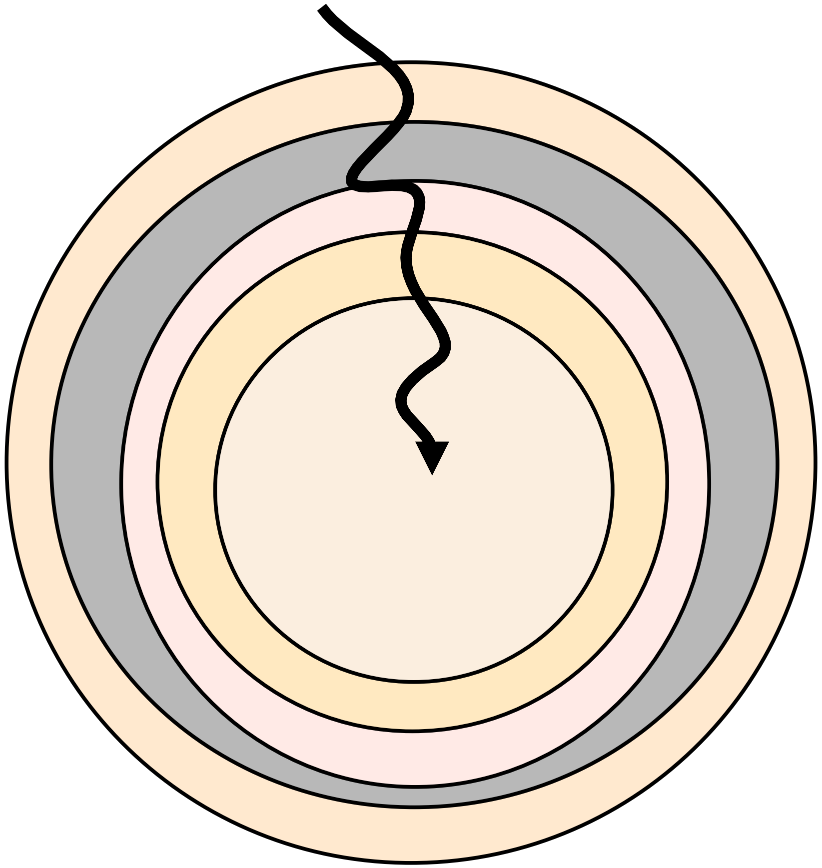
Decorator Relations

- 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

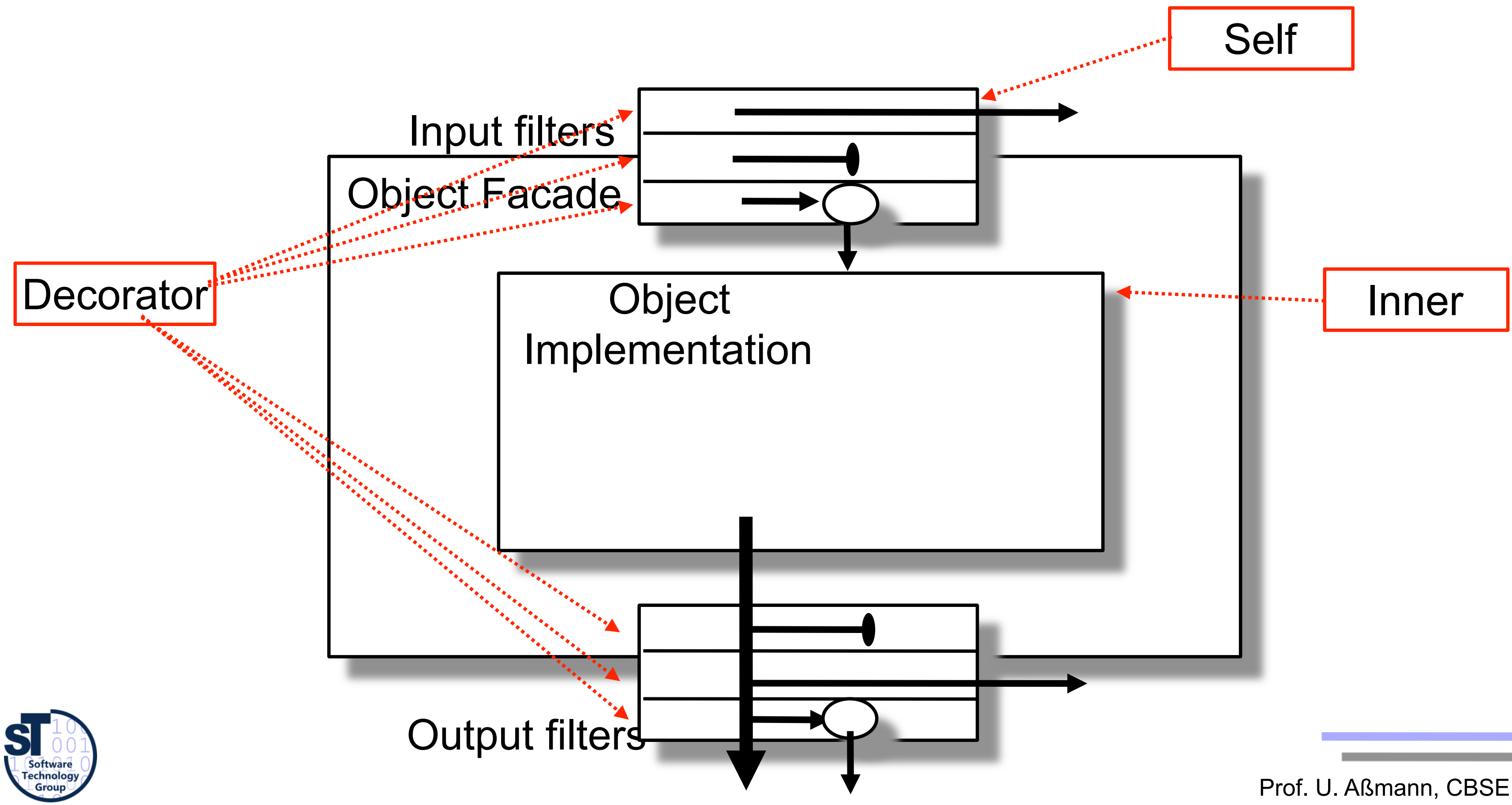
Filters are Layers

- 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,
  - 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 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
        | Replacement               -- All matching messages are resent
Replacement ::= Guard '=>'  '[' Match ']' 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.*;
}
```

Guard (Condition)

Match (name of incoming message)

Action

A Larger Example

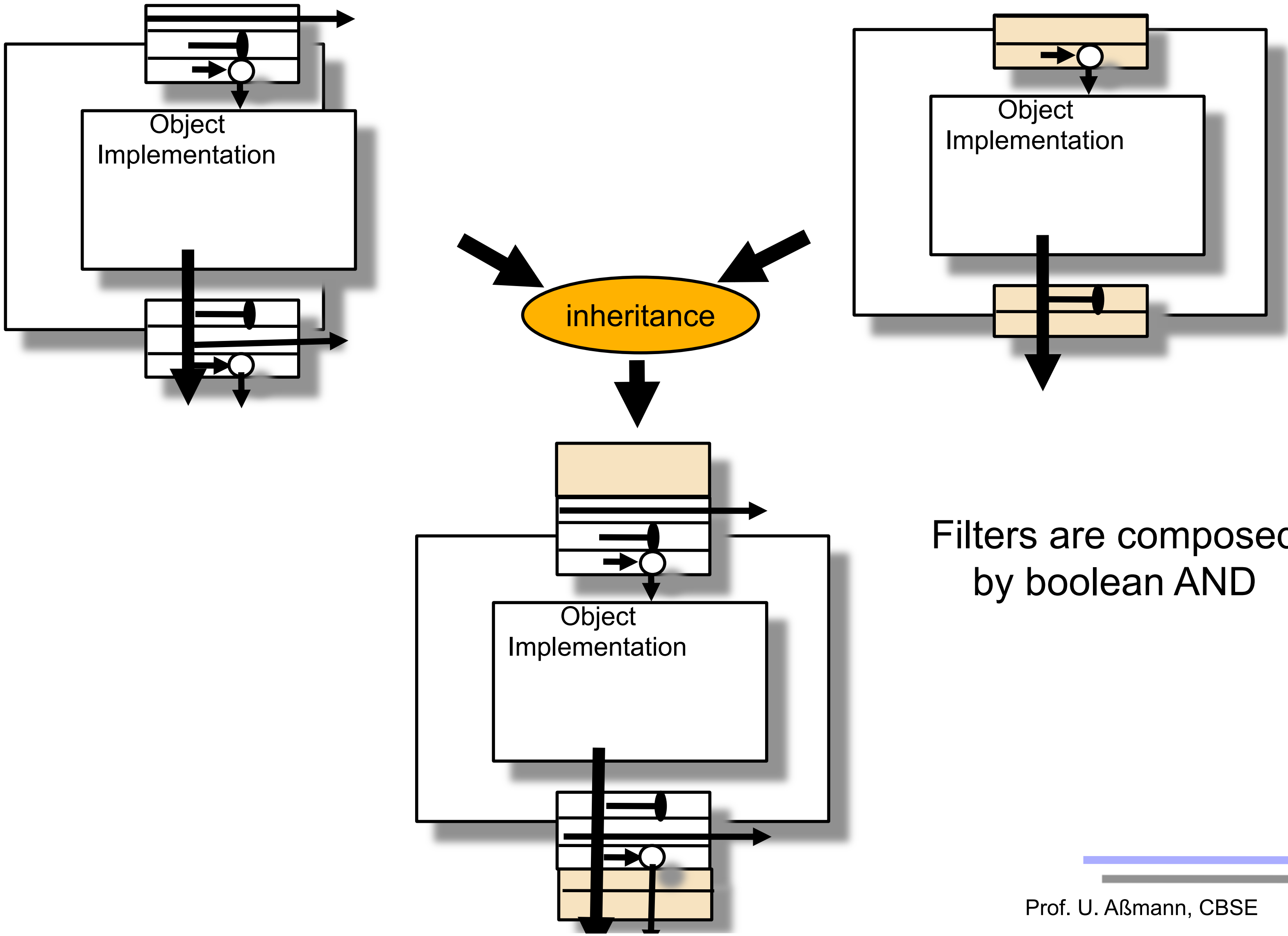
```
class PressOrAnimatedPress interface
  internals:
    visualize;
    doIt;
  externals:
    animatedDevice:AnimatedDevice;
  conditions:
    isAnimating;
    isInTracingMode;
    noOneElseIsAnimating;
  methods:
    inputTraceMethod;
    outputTraceMethod;
  inputfilters:
    tracing: Meta = {
      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*
- 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

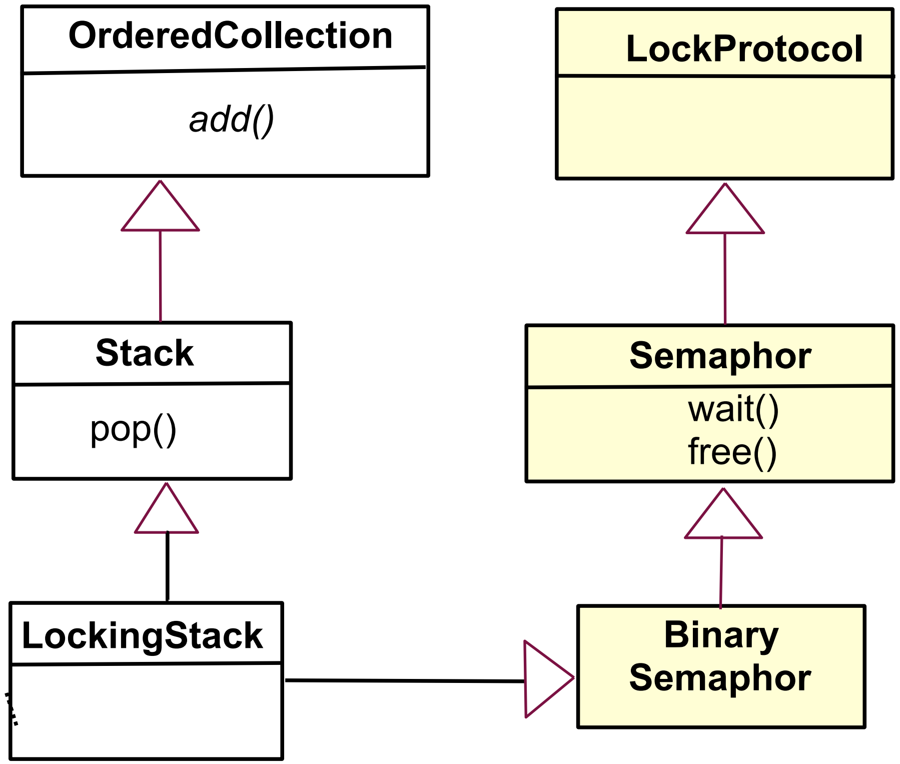
Composing a Locking Stack

- 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



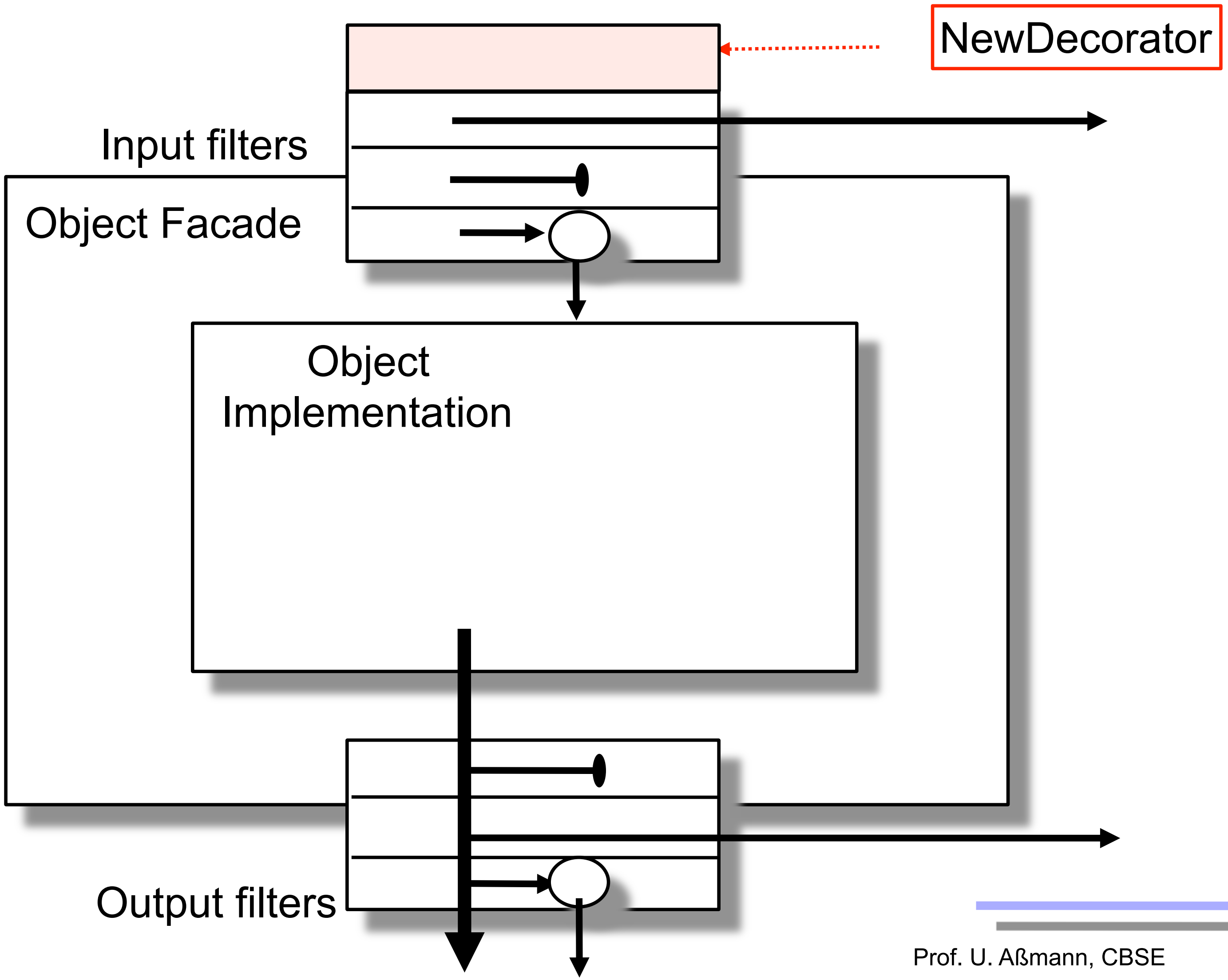
21.4 Implementations of the Filter Concept in Standard Languages

Implementation with Decorator

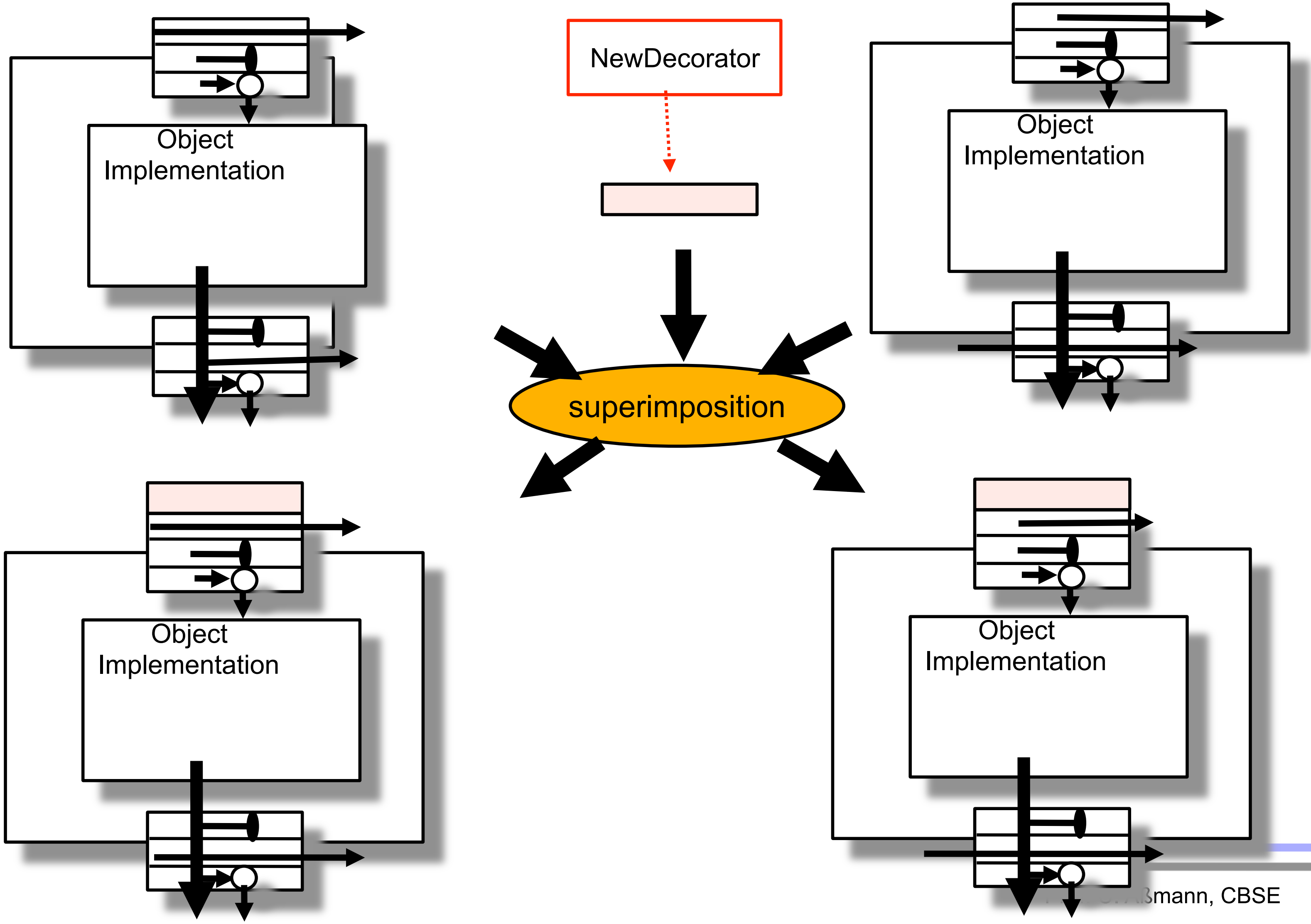
- The superclass of the Decorator pattern implements the object interface
  - The decorating classes are the filters
  - Problem: Decorators do not provide access to the “inner” object or the “self” object
- Filters also can be regarded as ChainOfResponsibility
  - However, there is a final element of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

Filters Can be Composed From Outside

- Filter superimposition



Filters Can be Composed From Outside



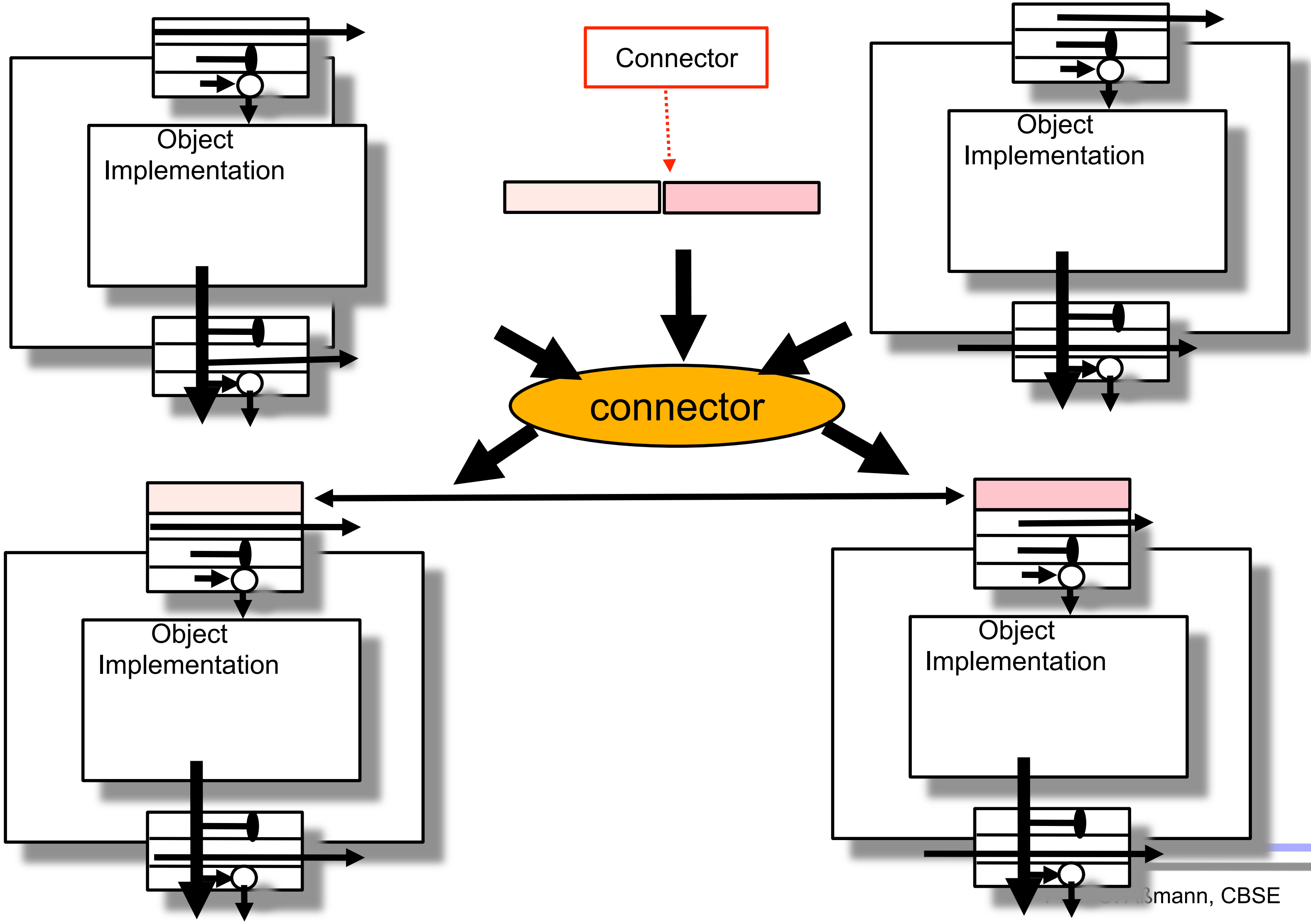
Superimposing a Decorator in Hand-Written Code

- 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

- All Decorator-Connectors 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

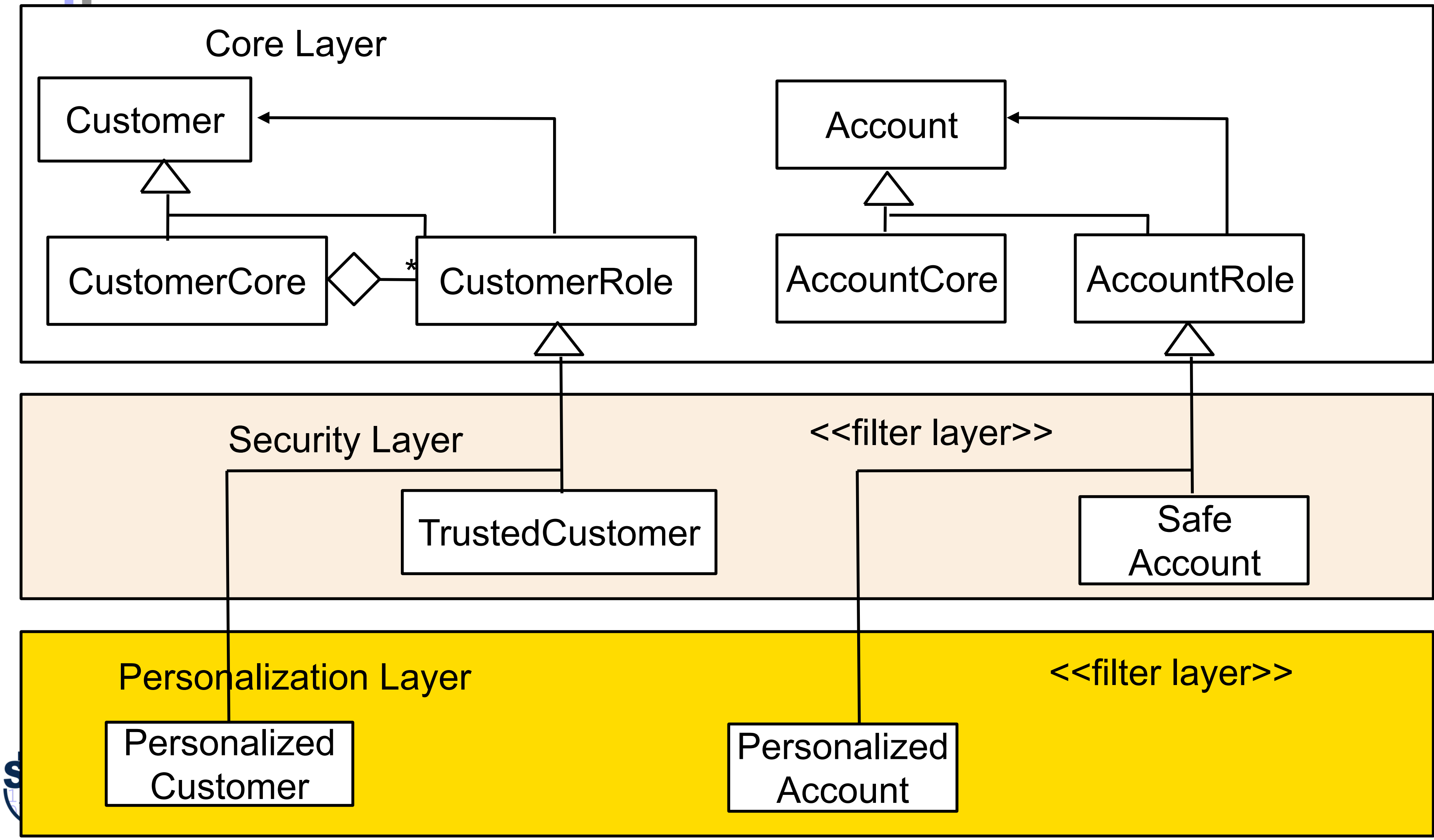
```
class TracingFilter extends Filter {
  public void matches(Method method) { return true; }
  public Object acceptAction(Method method) {
    trace();
    return substitute(method);
  }
  public Object substitute(Method method) {
    return method;
  }
  public void trace() {
    System.out.println("Here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

21.5 Filters and The Role Object Pattern

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

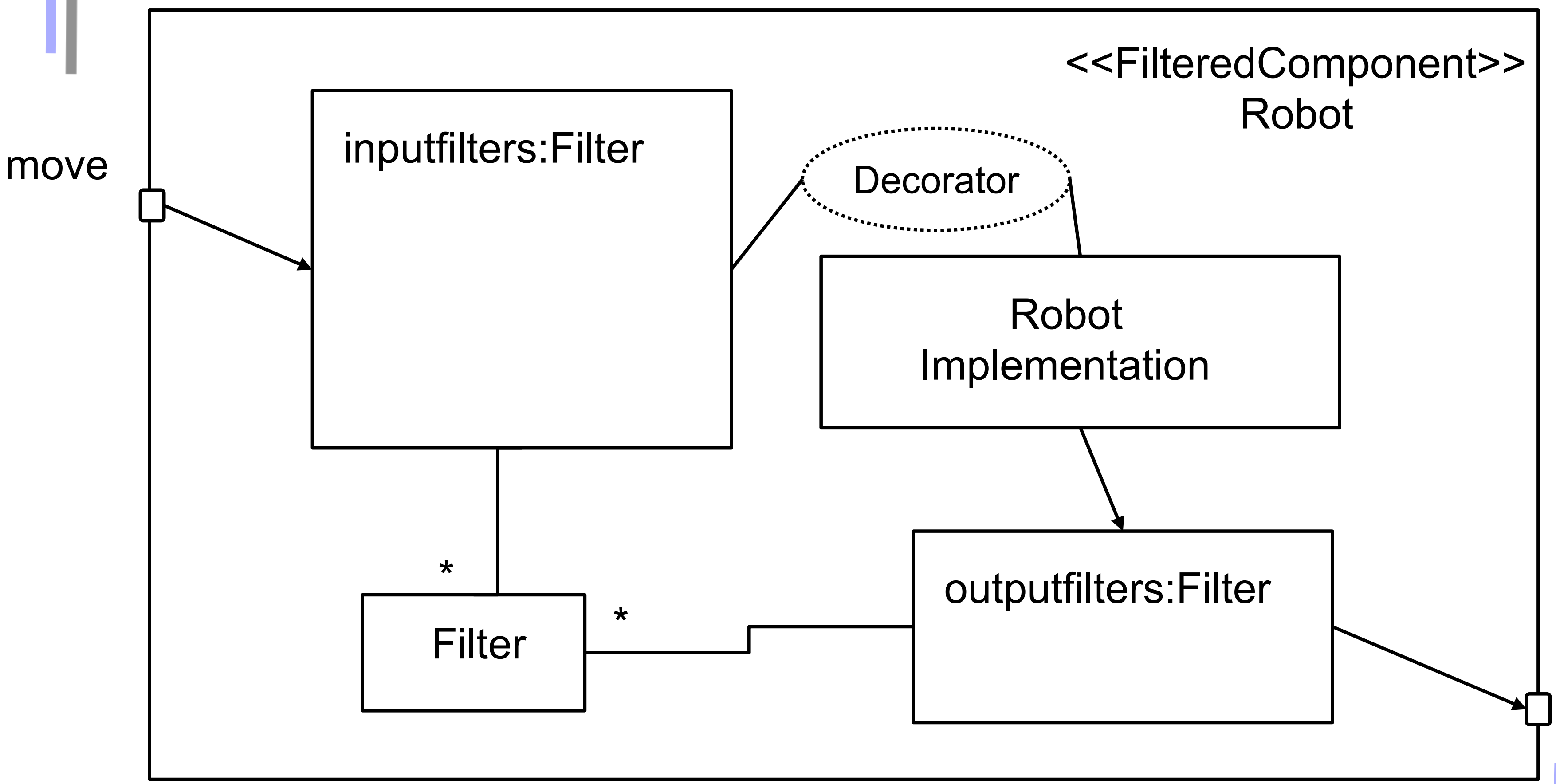


Using Filters

- Filters can implement a supercall (upcall) in the inheritance hierarchy
  - Delegating to an object of the superclass
  - 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

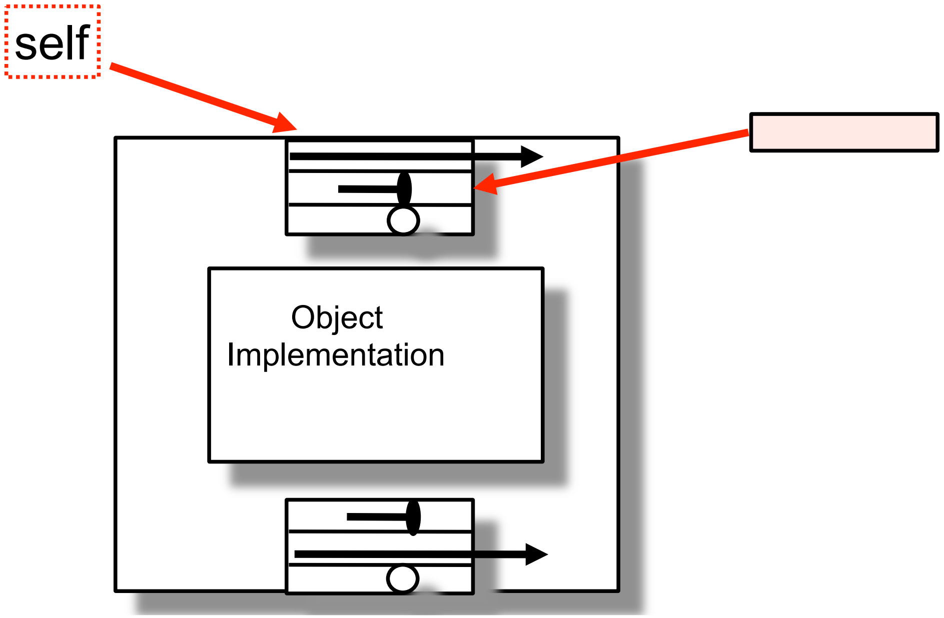
Filters In UML

- Realize as inner components



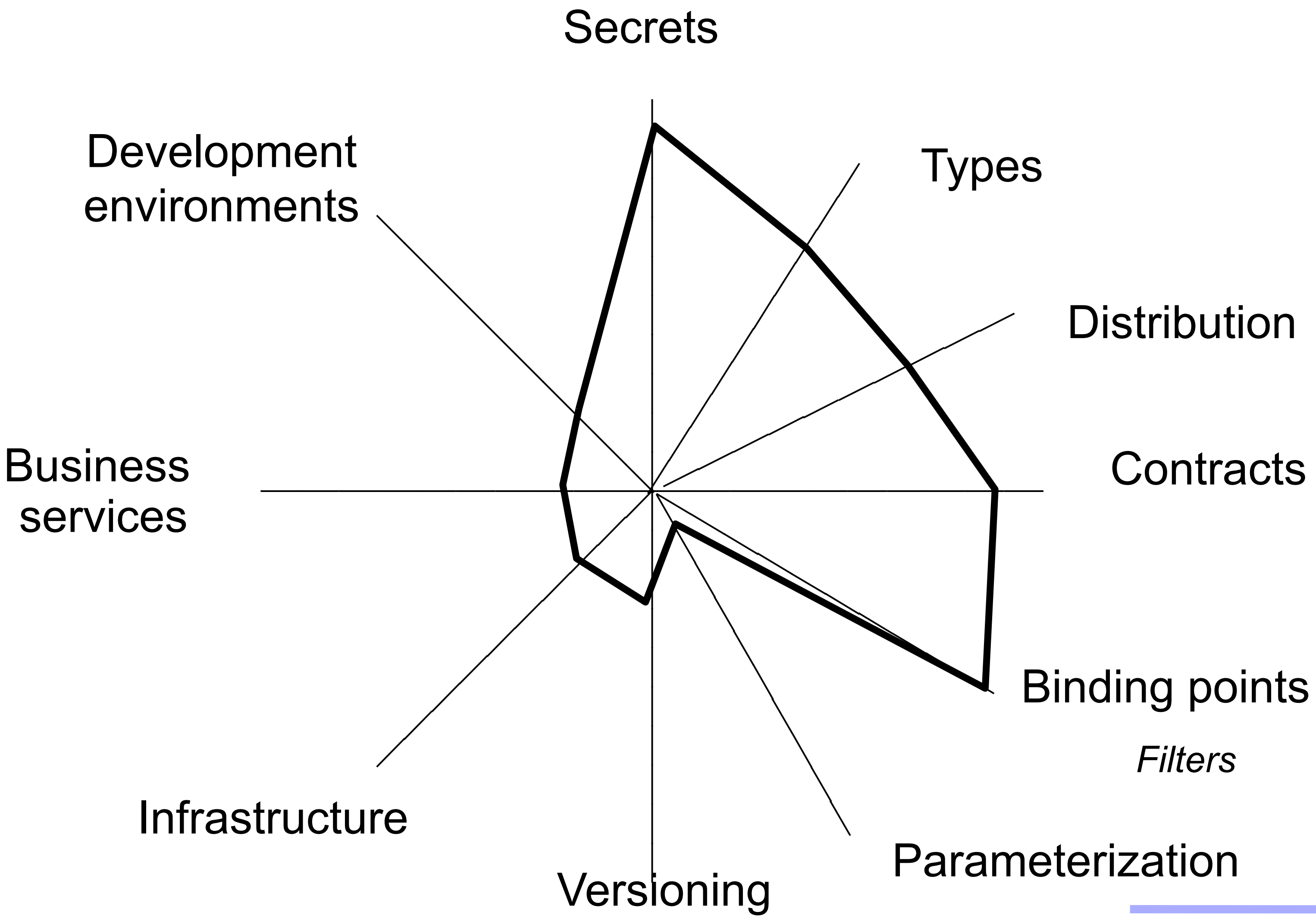
Insight: Greybox Composition Relies on Extensibility

- 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

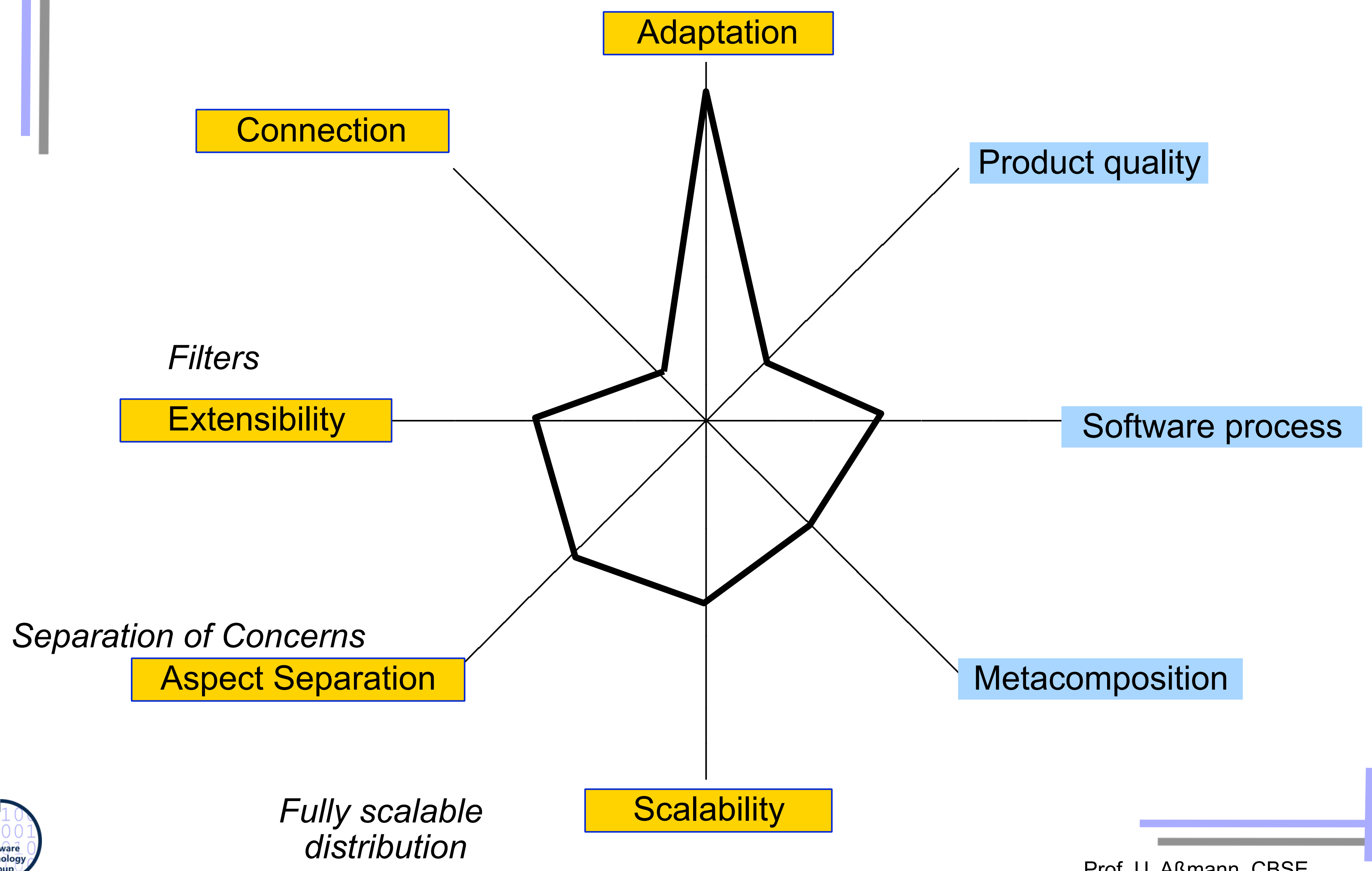


21.6 Evaluation as Composition System

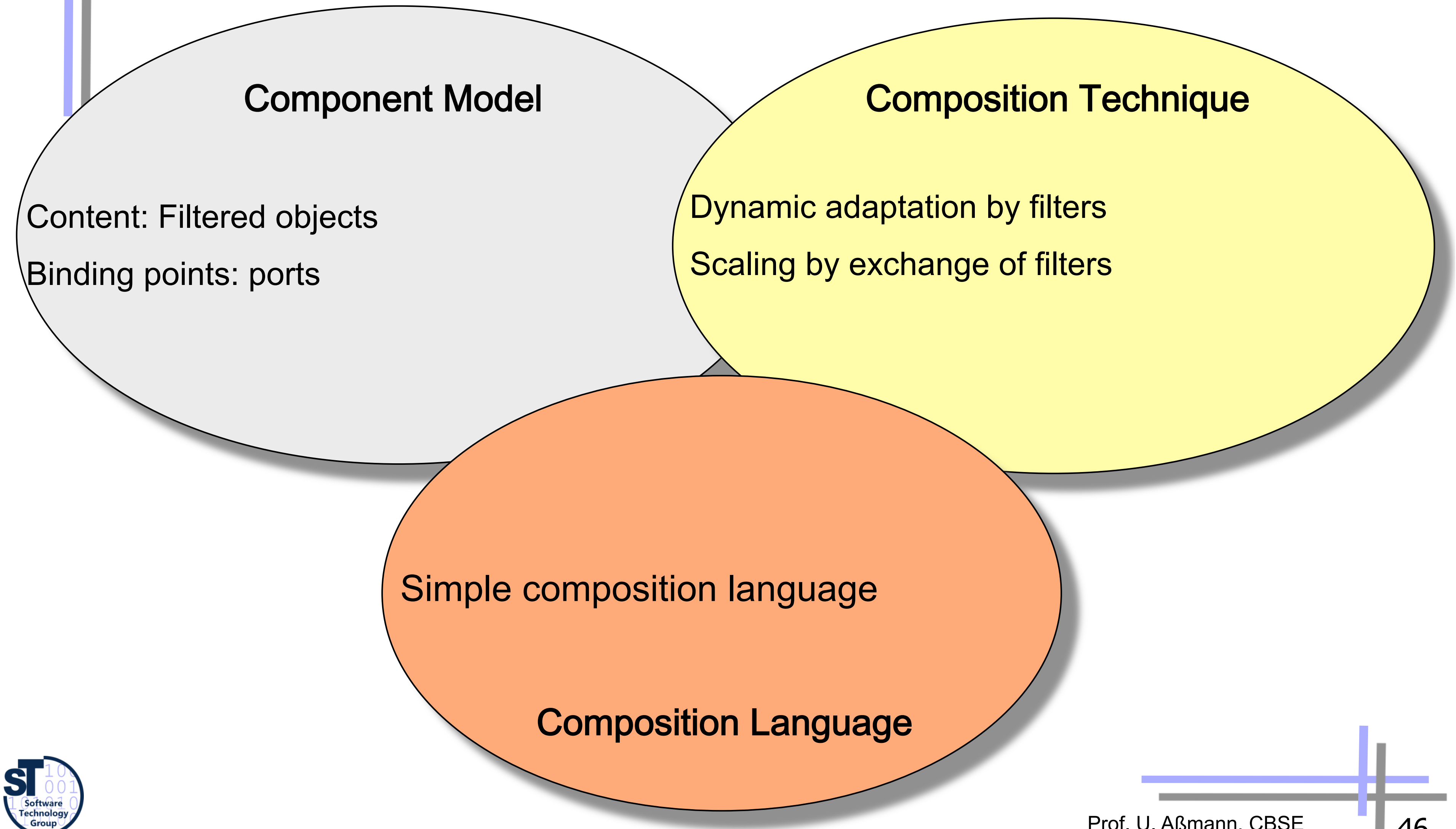
CF - Component Model



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