

11. Frameworks and Patterns - Framework Variation Patterns

1

- Prof. Dr. U. Aßmann
Software Engineering
Faculty of Informatics
Dresden University of
Technology
Version 13-1.0, 12/2/13
1. Open Role Framework Hooks
 2. Framework Hook Patterns
 3. Delegation-Based Framework Hook Patterns
 4. Recursion-Based Framework Hook Patterns
 5. Unification-Based
 6. Inheritance-Based
 7. T&H in Frameworks



Design Patterns and Frameworks, © Prof. Uwe Aßmann

Literature (To Be Read)

2

- ▶ W. Pree. Framework Development and Reuse Support. In Visual Object-Oriented Programming, Manning Publishing Co., editors M. M. Burnett and A. Goldberg and T. G. Lewis, Pp, 253-268, 1995. www.softwaresearch.net/publications/J003.pdf
 - Or: D. Karlsson. Metapatterns. Paper in Design Pattern seminar, IDA, 2001. Available at home page.
- ▶ D. Bäumer, G. Gryczan, C. Lilienthal, D. Riehle, H. Züllighoven. Framework Development for Large Systems. Communications of the ACM 40(10), Oct. 1997.
<http://citeseer.ist.pst.edu/bumer97framework.html>



Secondary Literature

- ▶ W. Pree. Design Patterns for Object-oriented Software Development. Addison-Wesley 1995. Unfortunately out of print.
- ▶ M. Fontoura, W. Pree, B. Rumpe. The UML Profile for Framework Architectures. Addison-Wesley, Object Technology Series. 2002.

3

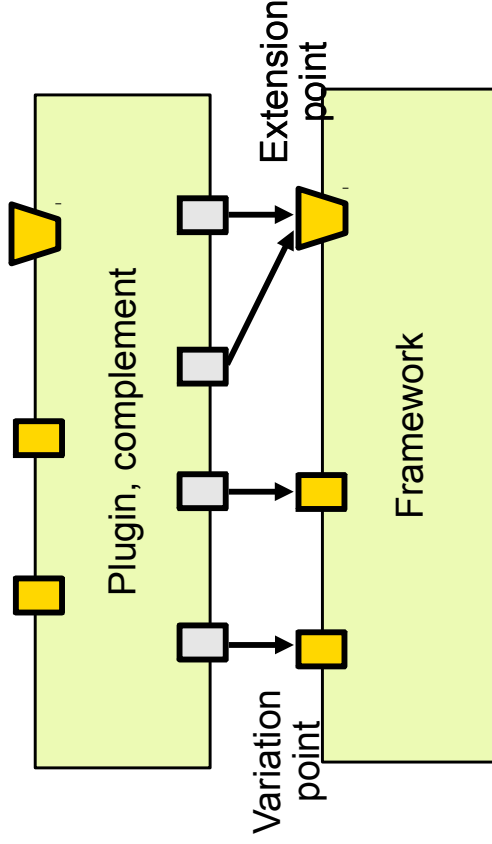
Goal

- ▶ What's a framework?
- ▶ Studying variabilities of frameworks with the T&H concept
- ▶ Introducing different types of hooks for frameworks and components (TH patterns)
- ▶ Understand framework hook patterns
 - The box-like notation for frameworks and framework hooks patterns
- ▶ More types of dimensional frameworks

4

Plugins and Extensions Points

- ▶ Frameworks are completed to products with **plugins (complements)**. Frameworks carry
 - framework extension hooks, **extension points**, which can be extended (bound) many times
 - framework variation hooks, **variation points**, which can be bound only once
- ▶ Plugins can be framework themselves (layered frameworks)



Patterns and Frameworks

- ▶ Historically, design patterns were discovered during framework development
 - Smalltalk MVC [Goldberg, Reenskaug]
 - ET++ [Gamma]
 - Interviews [Missides]
- ▶ Design patterns are *building blocks of frameworks*
 - Framework developers vary and extend classes of the framework
- ▶ Design patterns create the products of a product line
 - Application developers vary and extend classes of the framework
 - Variability design patterns can be used as *framework variation points (framework variation hooks)*
 - Extensibility design patterns can be used as *framework extension points (framework extension hooks)*

11.1 Framework Instantiation and Merging With Open Roles

7

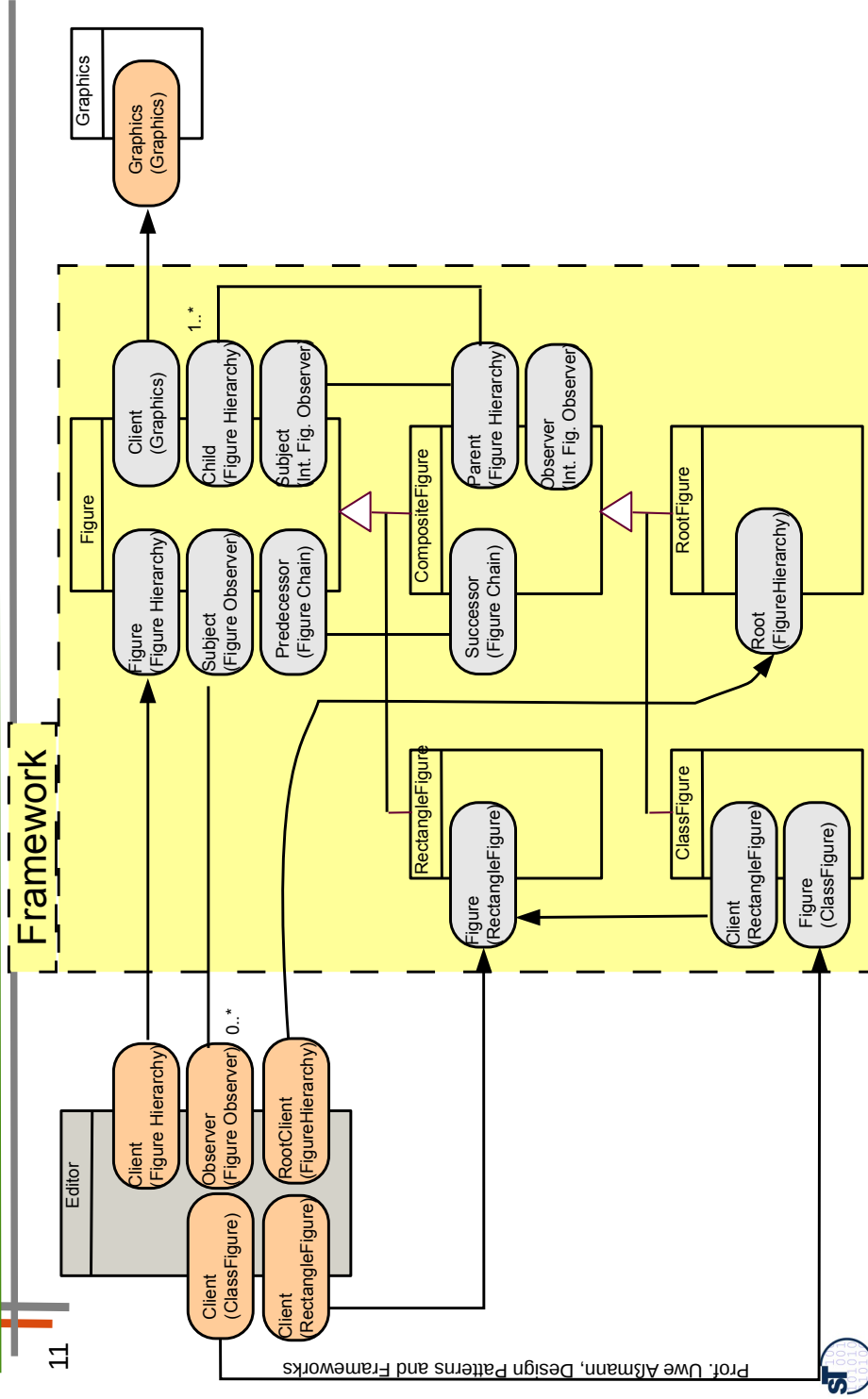
Design Patterns and Frameworks, © Prof. Uwe Aßmann

Framework Instantiation with Open Roles (Role Hot Spots)

- ▶ The most simple form of framework instantiation is Riehle/Gross' *open role instantiation* based on association
 - Here, frameworks are class models with *open role hooks* (*free, unbound abilities*), role types that have not yet been assigned to classes
- ▶ The hot spots form an *integration repertoire* (*integration role type set*)
 - the set of role types, by which the framework can be integrated into an application (*framework hooks, framework variation points*)
- ▶ A framework is *instantiated* by binding its integration repertoire to classes
 - The abilities are *bound*, role constraints have to be respected
- ▶ Hence, role models play the bridge between a framework and its clients

8

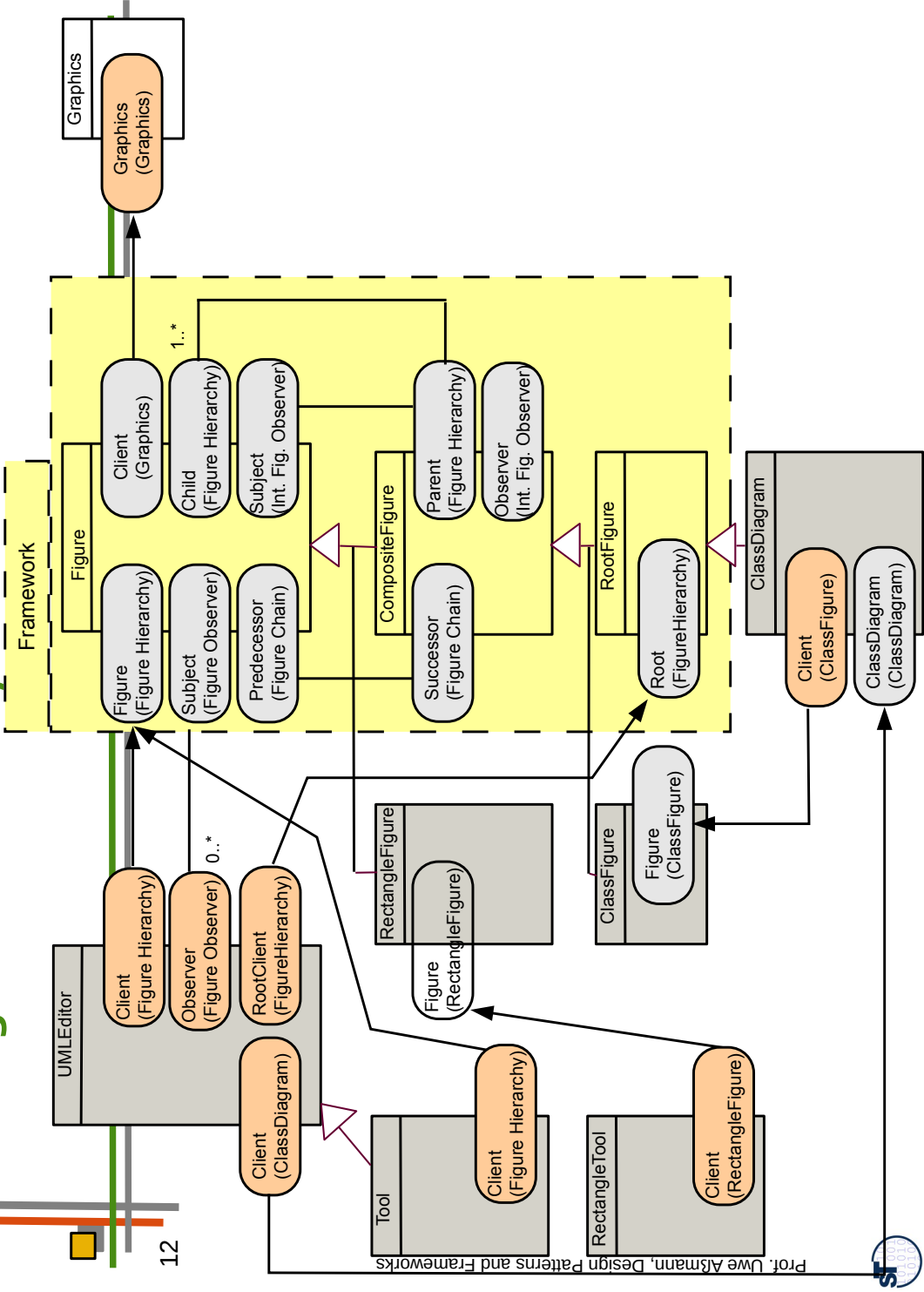
The Figure Framework, Fully Instantiated to an Editor



11



The Figure Framework, Instantiated to an UML Editor



12



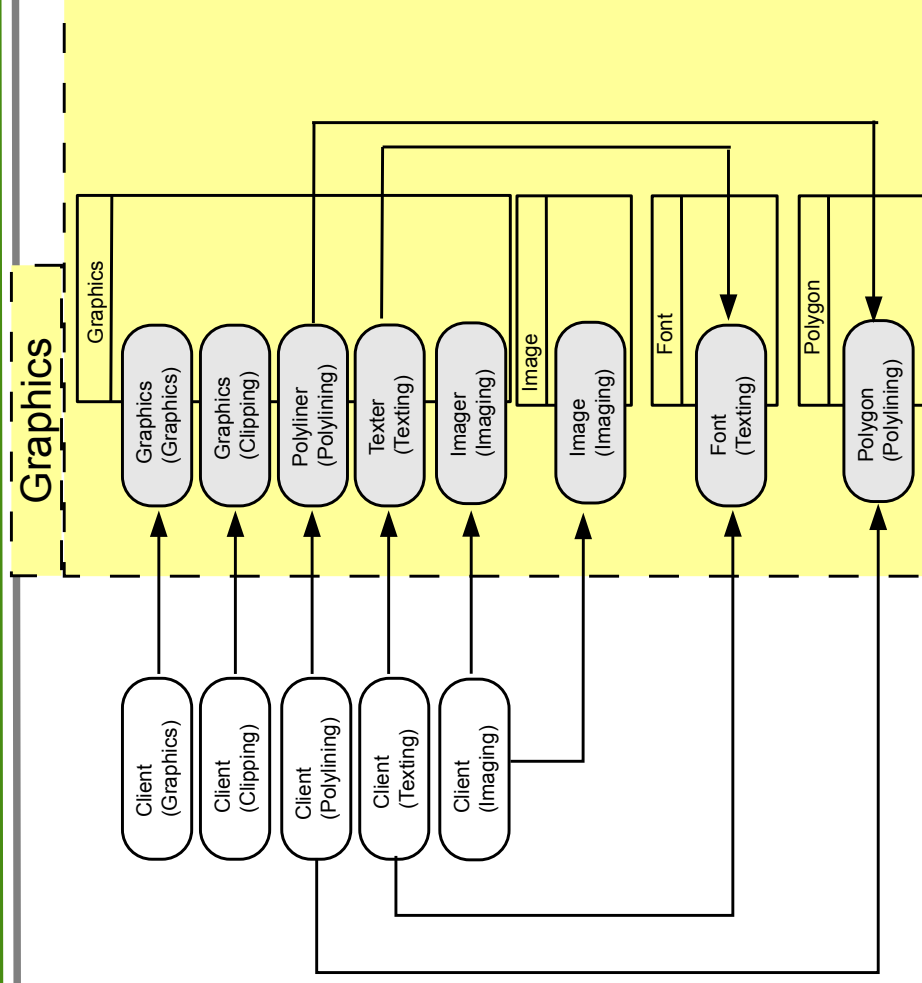
Merging of Frameworks

- ▶ Two frameworks are merged by binding the integration abilities of A to classes of B
 - Role constraints have to be respected
- ▶ Hence, role models play the bridge between different frameworks
 - Or layers of frameworks

13



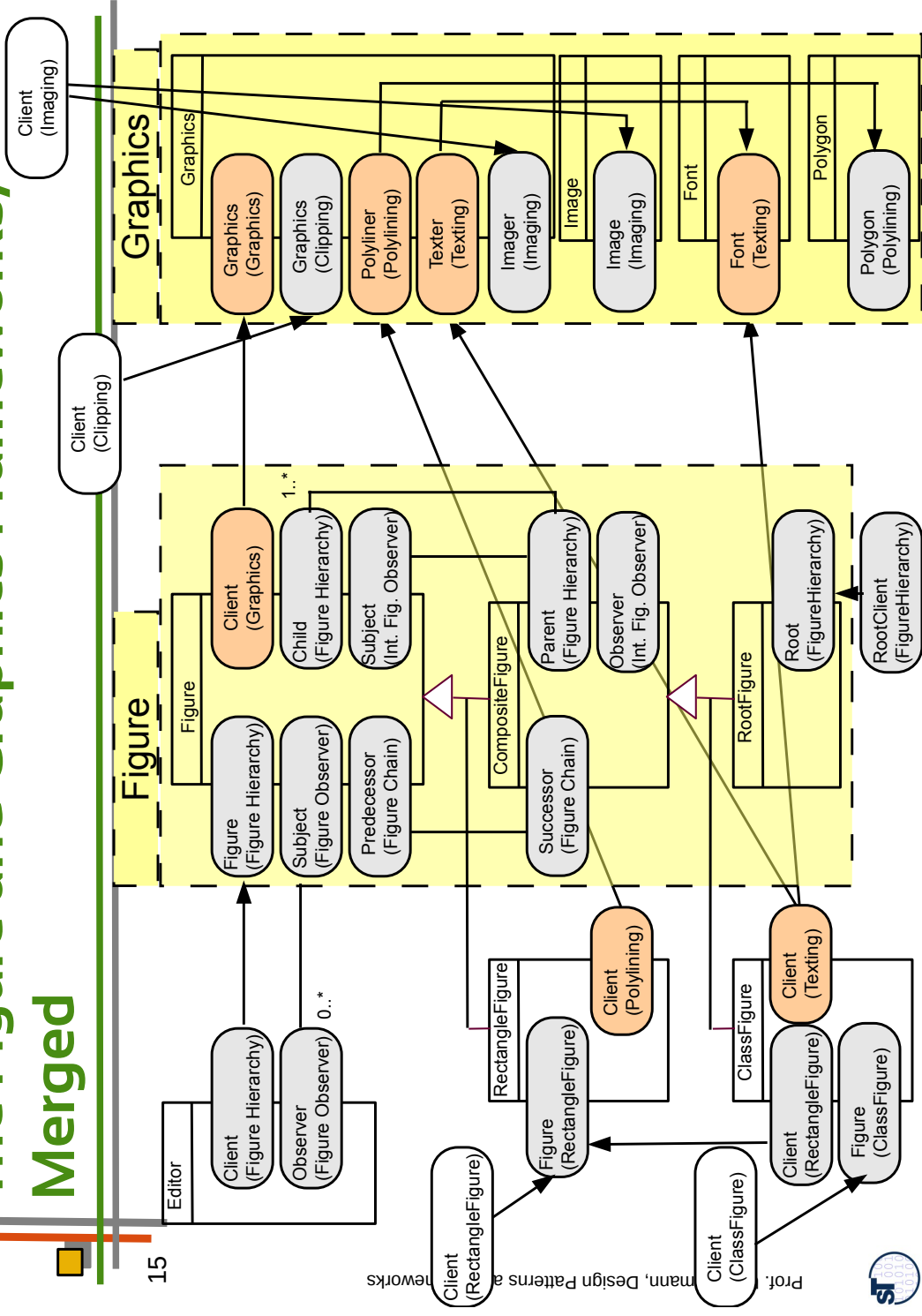
A Graphics Framework



14



The Figure and Graphics Frameworks, Merged



Limitations of Open Role Instantiation

- ▶ [Riehle/Gross] role-based framework instantiation relies on simple role binding, with role constraints
- ▶ Role binding for framework instantiation and merging can be even more elaborated

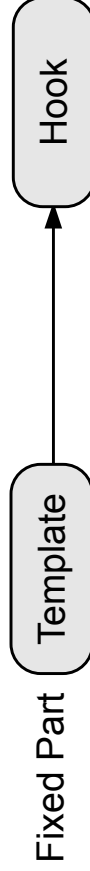


11.2 Framework Hook Patterns



Pree's Framework Hook Patterns (Template&Hook Role Models)

- ▶ In Pree's work, *framework hooks* are characterized by design patterns (*framework hook patterns*)
 - They describe the roles of classes on the *border* of the framework
 - The framework hook pattern determines the way how the classes interact with each other at the border of the framework
- ▶ A framework variation point is characterized with a *Template&Hook conceptual pattern*
 - Pree called this a *T&H metapattern*, we call this a *T&H role model*
- ▶ A T&H role model has 2 parts:
 - A template class (or *template role type*), which gives the skeleton algorithm of the framework: Fix, grasps commonalities
 - A hook class, which can be exchanged (or: a *hook role type* which can be bound to a client class): Variable, even extensible, grasps variability and extension



Fixed Part

Template

Hook

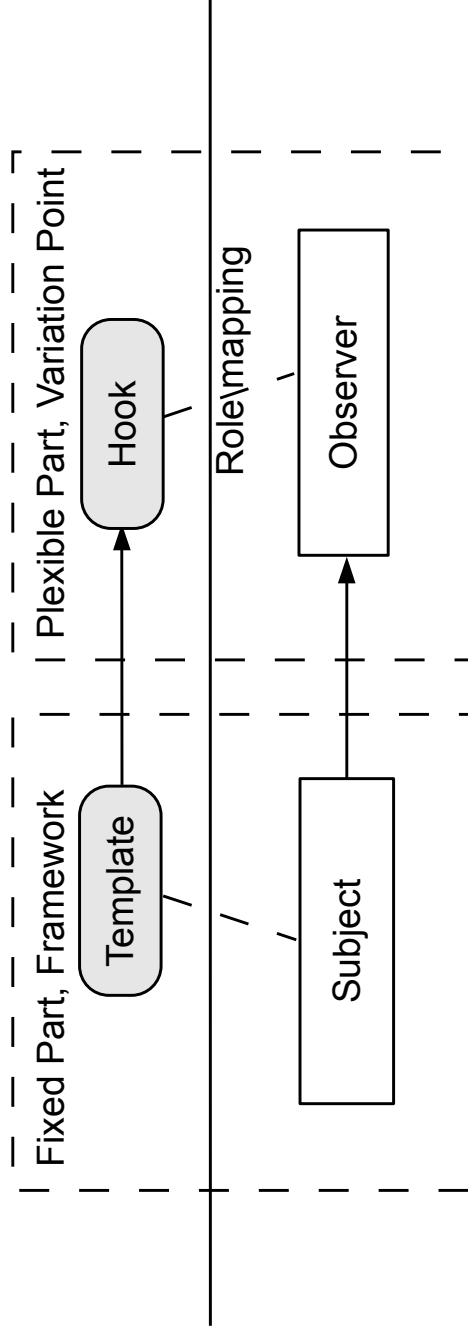
Flexible Part, Variation Point



T&H Patterns and Standard Patterns

19

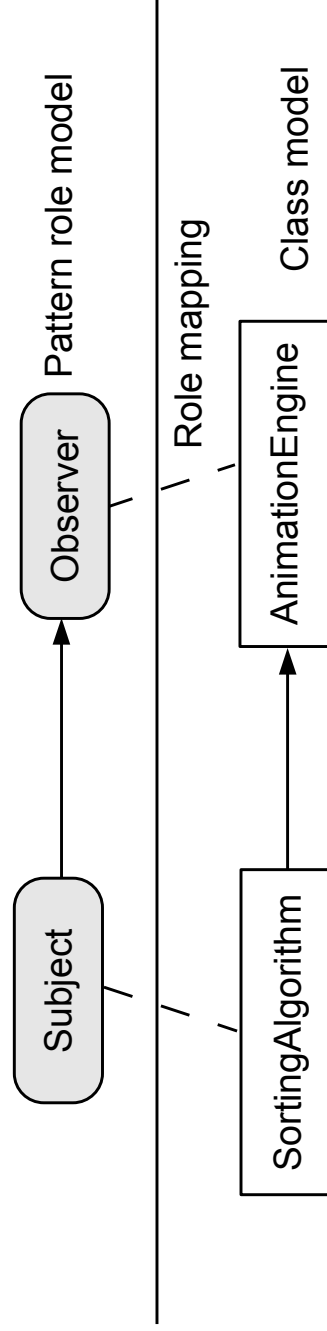
- ▶ A TH-role model overlays another pattern (hence Pree called it a *metapattern*)
 - The template part fixes parts of the pattern
 - The hook part keeps parts of the pattern variable, i.e., open for binding.



T&H in Standard Design Patterns

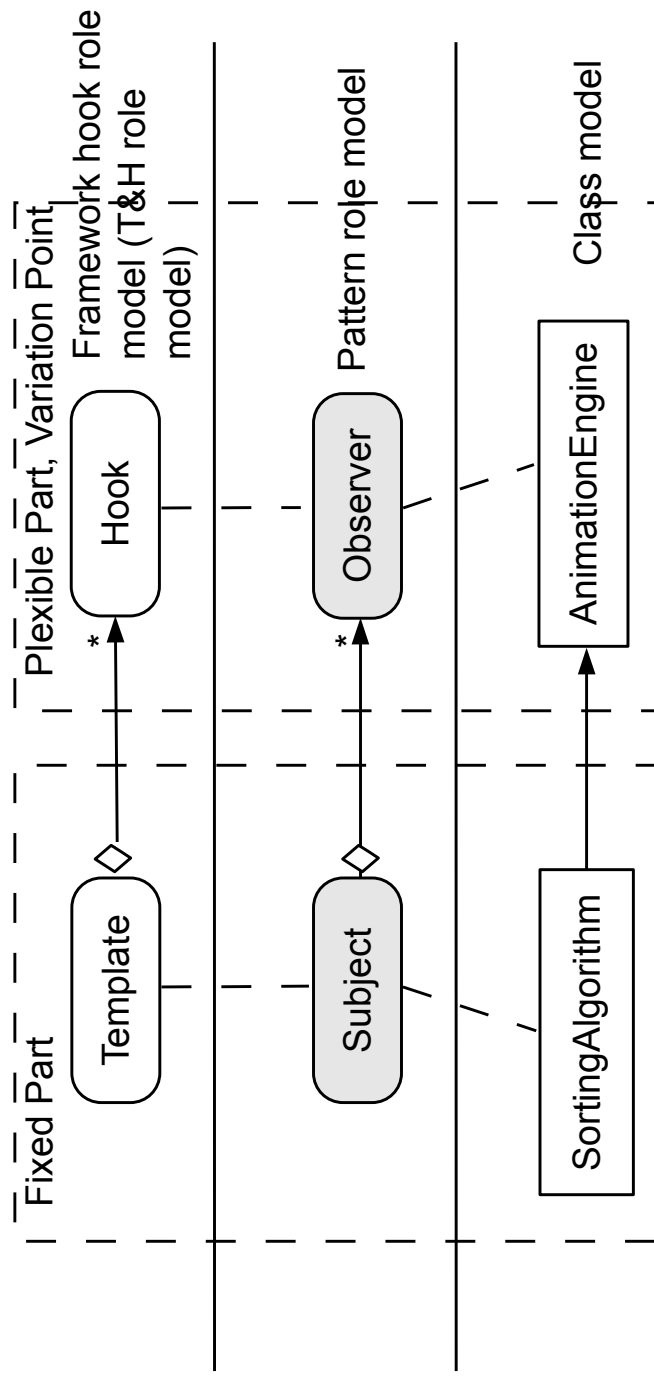
20

- ▶ Subject and Observer can vary; nothing is fixed
 - SortingAlgorithm and AnimationEngine can be exchanged



T&H in Framework Hook Patterns

- ▶ Subject can no longer vary; it is fixed
 - SortingAlgorithm cannot be exchanged (exception: DimensionalClassHierarchies)

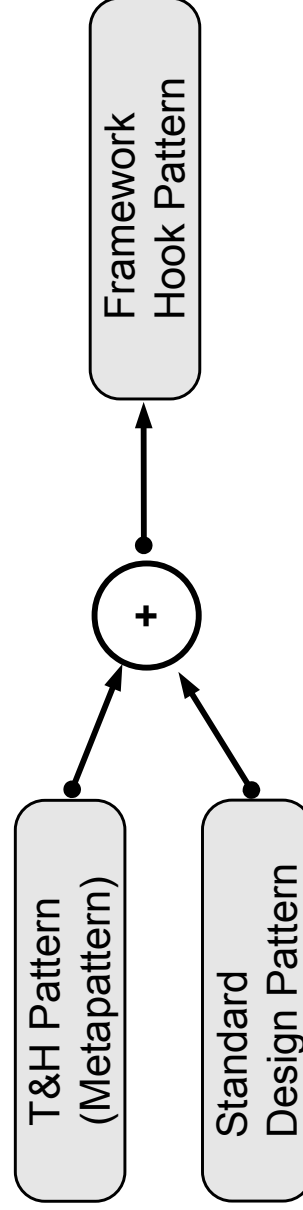


Why T&H Patterns Add More to Standard Patterns

- ▶ Due to the Riehle-Gross Law, we know that metapatterns are role models that overlay the role models of design patterns
 - Metapatterns are very general role models that can be mixed into every design pattern
 - As design patterns describe application models, metapatterns describe design patterns
- ▶ In [Pree], roles are not considered. Pree has only hook classes and hook methods. Here, we combine [Pree] and [Riehle/Gross]

If a metapattern is overlaid to a role model of a design pattern, it adds commonality/variability knowledge, describing a *framework variation point*

- The template part characterizes the framework's fixed parts
 - The hook part characterizes the framework's variation point
- ▶ Hence we call a design pattern with metapattern information **framework hook pattern**



Framework Hook Patterns

23

- ▶ The template-hook role model
 - adds more pragmatics to a standard design pattern, information about commonality and variability. Hence, framework variation points are described
 - The template-hook role model adds more *constraints* to a standard design pattern. Some things can no longer be exchanged
- ▶ Pree discovered 7 framework hook patterns, i.e., 7 template-hook role models for framework hooks
 - The template-hook role models describe the parameterization of the framework by *open role hooks*
 - They include Riehle's open role hooks, but add more variants
 - There are even other ones (see next chapter)



Remark

24

- ▶ Note: we mean in the following:
 - with the role *Template*, that the class of the role type belongs to the framework
 - with the role *Hook*, that the class of the role type belongs to the application
 - with the role *TemplateM(method)* that the role defines a template method, calling a hook method *HookM(method)*
- ▶ Problem: Pree uses *TemplateM/HookM*, but calls them *Template/Hook*
 - and varies *HookM* classes. This is misleading because the variation is actually in the framework and the fixed part in the application



Differences between Standard Patterns and Framework Hook Patterns

25

- ▶ Standard design pattern
 - Often, no template parts; everything flows (exception: TemplateClass and -Method)
 - Rich pattern and role model
 - Applicable everywhere in the framework
 - No T&H metapattern overlaid
- ▶ Framework hook pattern
 - Fixed and variable part
 - Elementary pattern and role model
 - Applicable only at the border of the framework,
 - or at the border of a component, i.e., in an “interface”
 - One T&H metapattern overlaid
- ▶ A **framework hook pattern**
 - provides a design pattern at the border of a framework
 - combines a T&H role model with standard role models

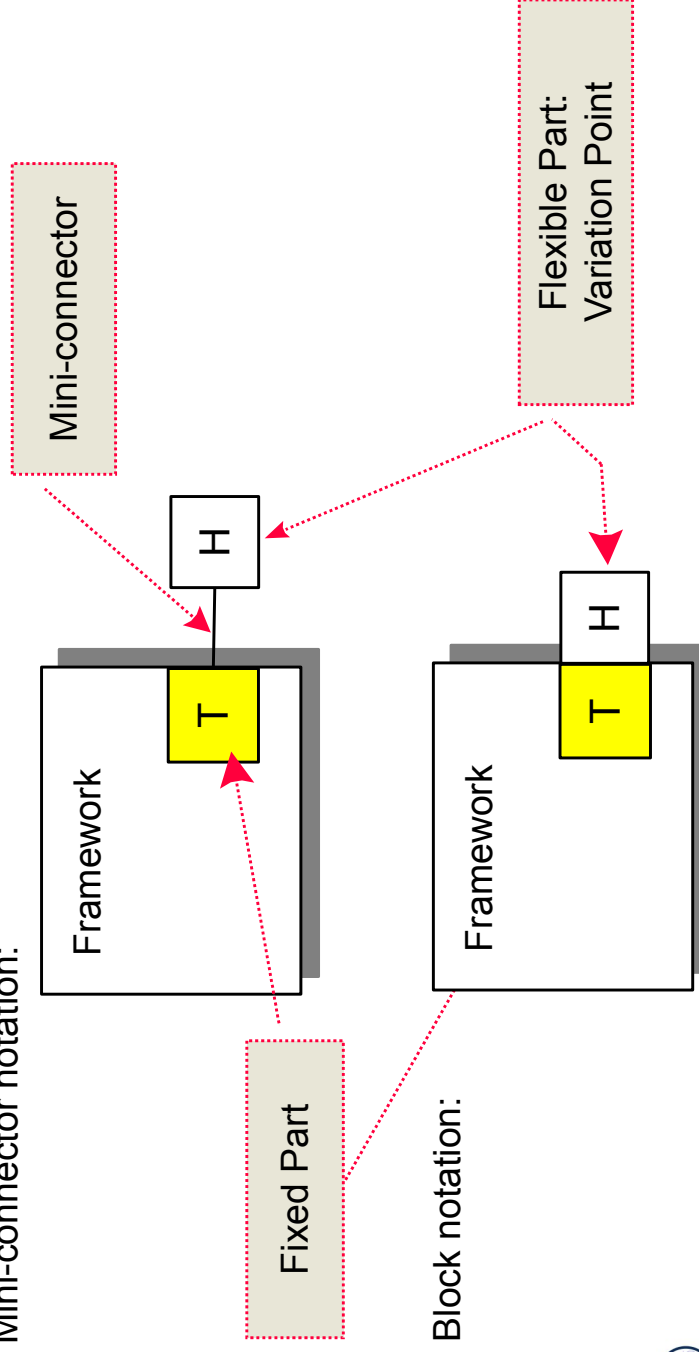


Two Simple Notations for Framework Hook Patterns

26

- ▶ Mini-connector notation: shows T, H, mini-connector
- ▶ Block notation: Shows T, H

Mini-connector notation:



11.3 Delegation-Based Framework Hook Patterns



T--H Connection Pattern

▶ T&H connection pattern (T--H framework hook)

- Similar to Riehle/Gross open role type, but with aggregation instead of association
- T and H classes are coupled by a template-hook role model, the hook is a delegatee (the relation is called a *mini-connector*)
- “Whole” is in the framework, “Part” is in the plugin

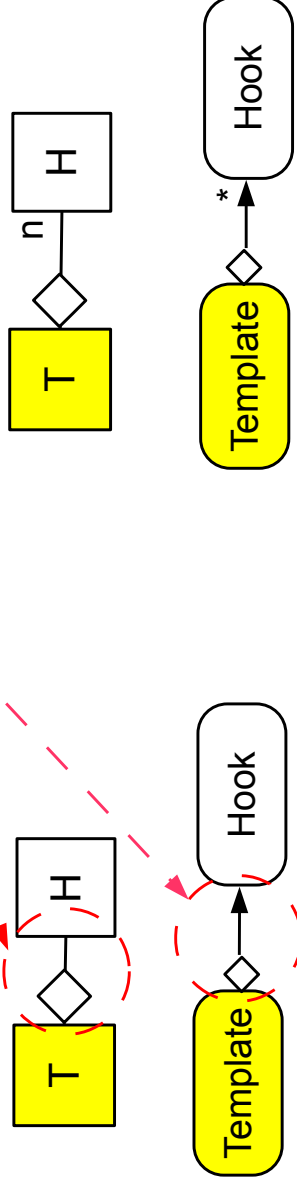
1-T—H (aggregated open role hook)

H part of T

n-T—H (flat extension)

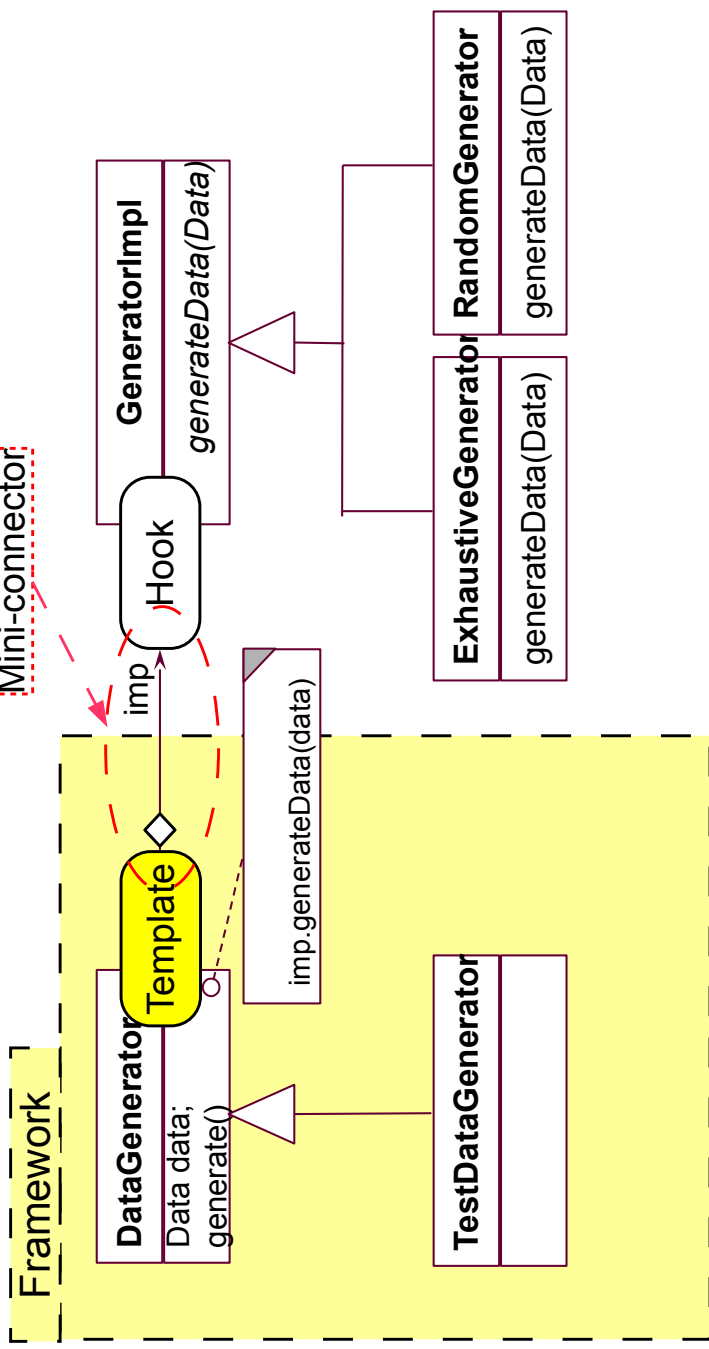
T has n H parts, n is dynamic

Mini-connector

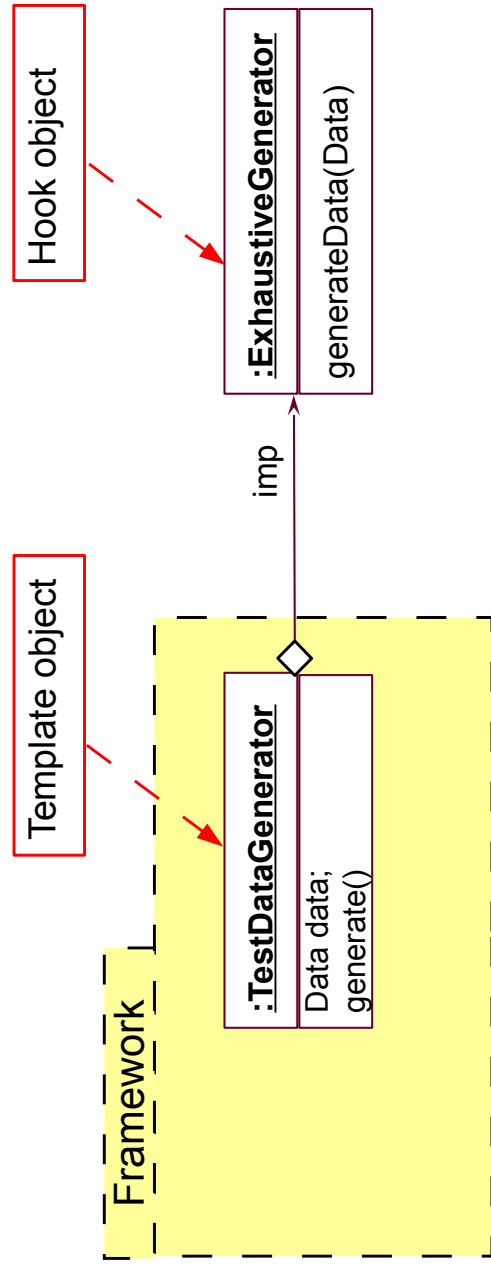


TemplateClass with 1-T--H

- Attention: in this case, the Template role also carries the TemplateM role (framework has template method, application has hook method)



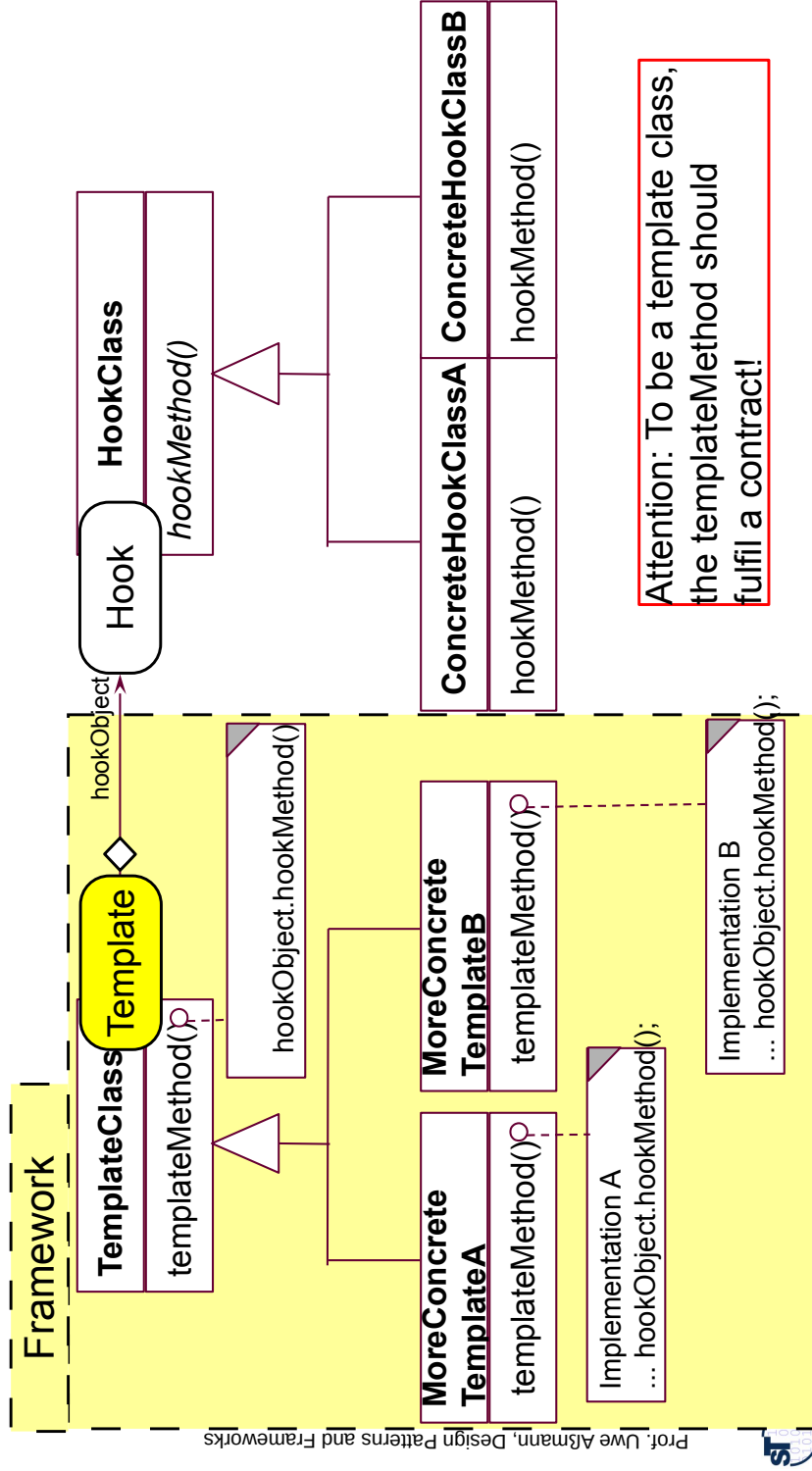
TemplateClass Runtime Scenario



Dimensional Hierarchies with 1-T--H (Bridge with Template/Hook Constraint)

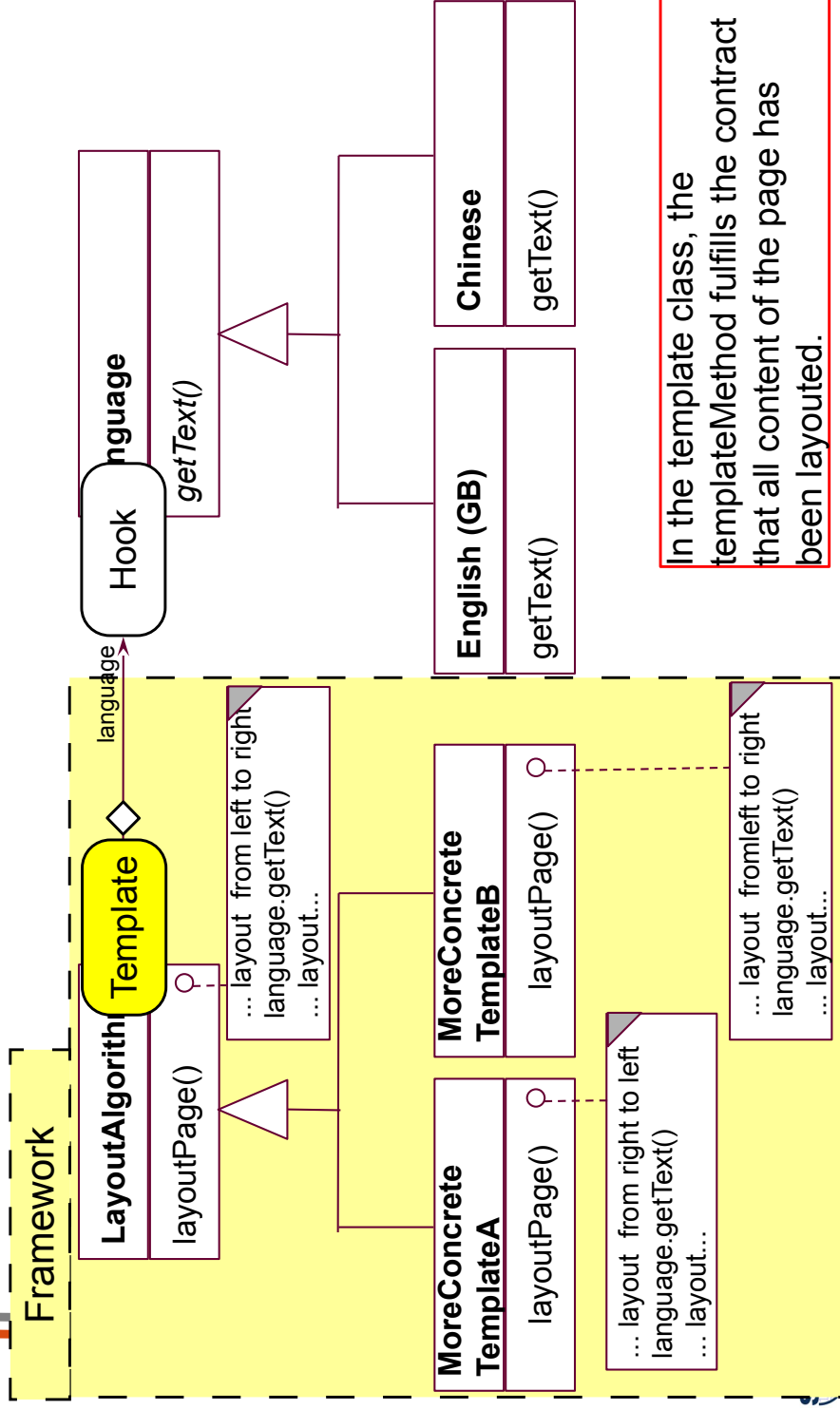
31

- ▶ Template classes cannot be varied, only the hook class



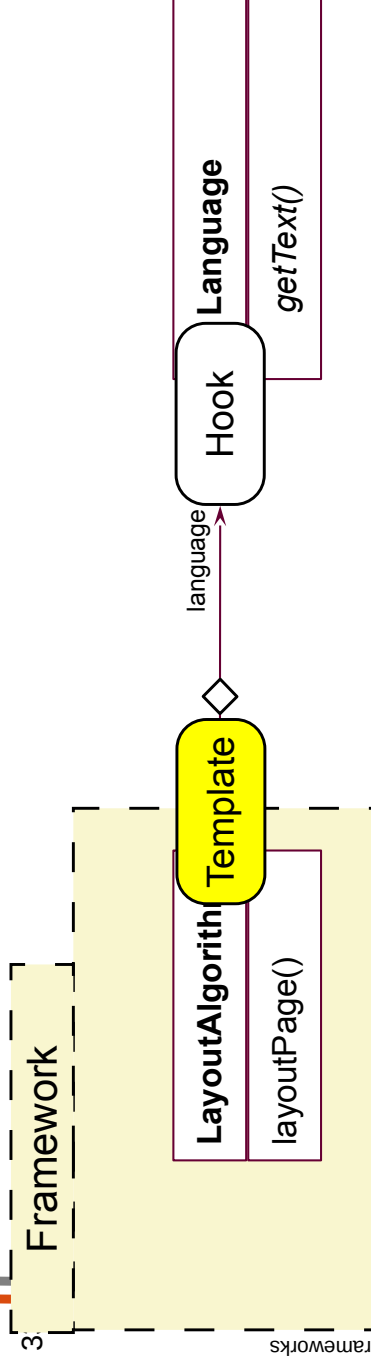
Attention: To be a template class, the templateMethod should fulfil a contract!

Ex.: Internationalization as Dimensional Class Hierarchy with 1-T--H

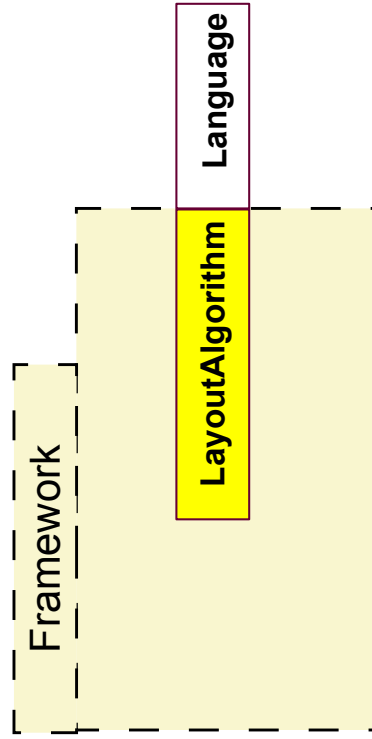


In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

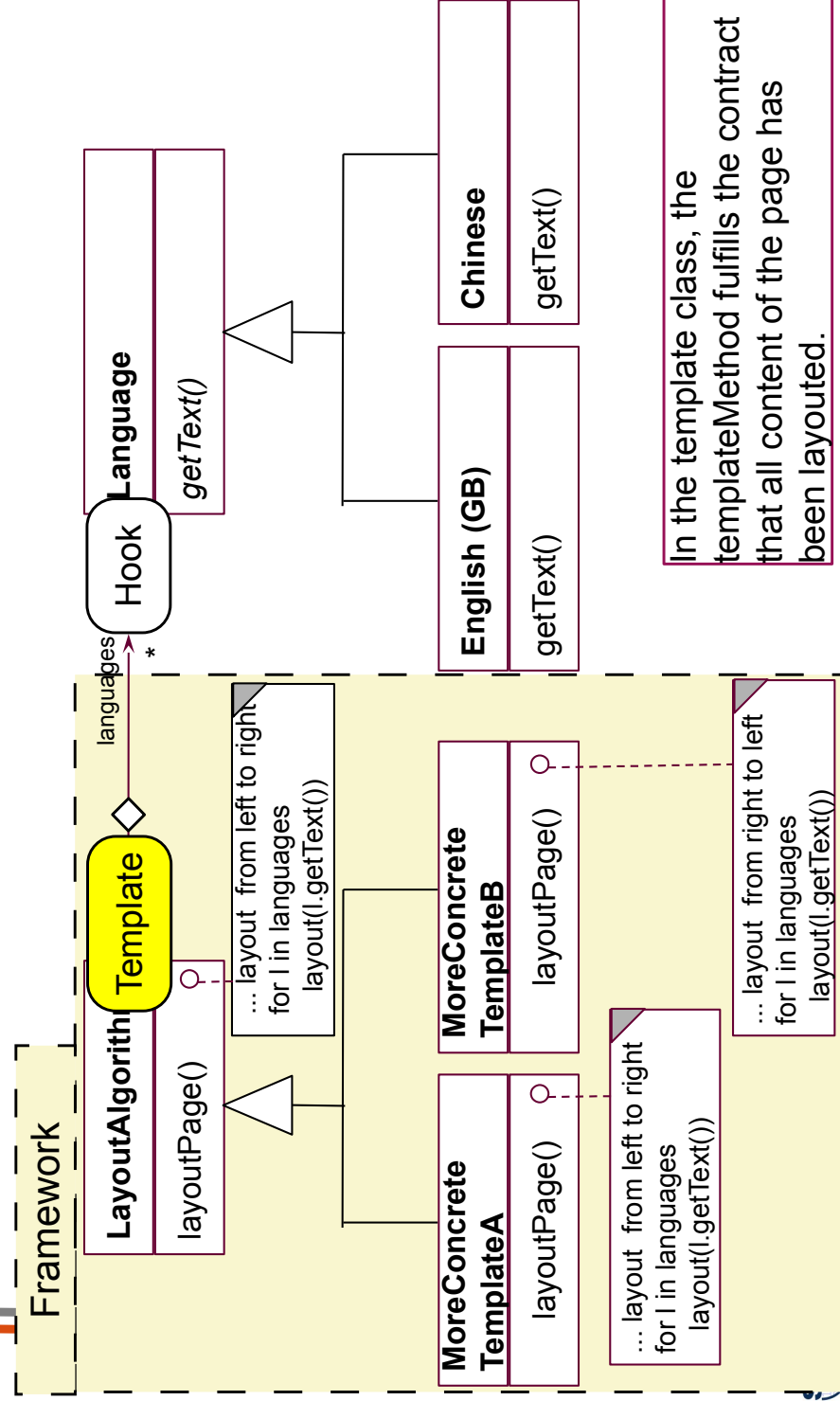
Ex.: Internationalization of Frameworks with Dimensional Class Hierarchy with 1-T--H



▶ may be abbreviated with block notation to:



Ex.: Multiple Internationalization as Dimensional Class Hierarchy with n-T--H



In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

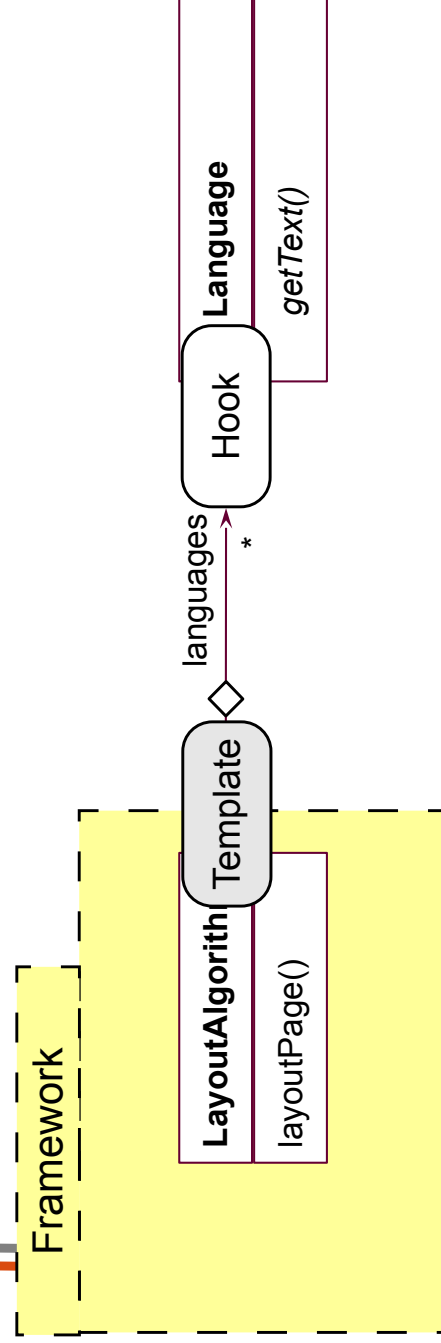
Ex.: Multiple Internationalization as Dimensional Class Hierarchy with n-T--H

35

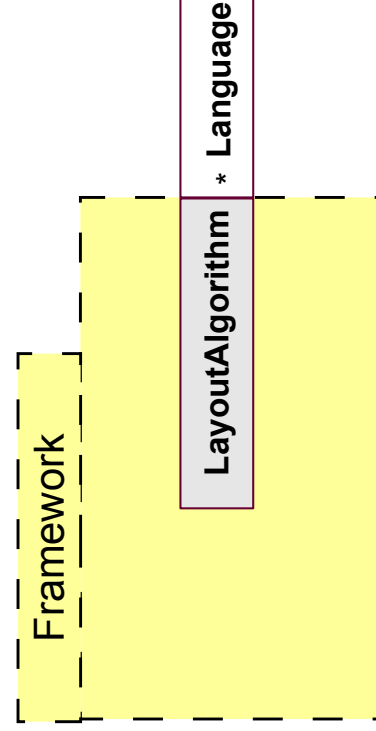
- ▶ n-T—H is based on *-Bridge pattern
- ▶ This framework hook allows for multiple internationalized texts
 - An application can layout several languages at the same time
- ▶ The layout algorithm can be coupled with different languages that use the same layout (multiple internationalization)
- ▶ However, mixin of different layout languages freely with languages is impossible!
- ▶ Here, you can see the power of the T—H concept:
 - 1-T--H: dynamic variability
 - n-T—H: dynamic extension (flat, non-recursive)



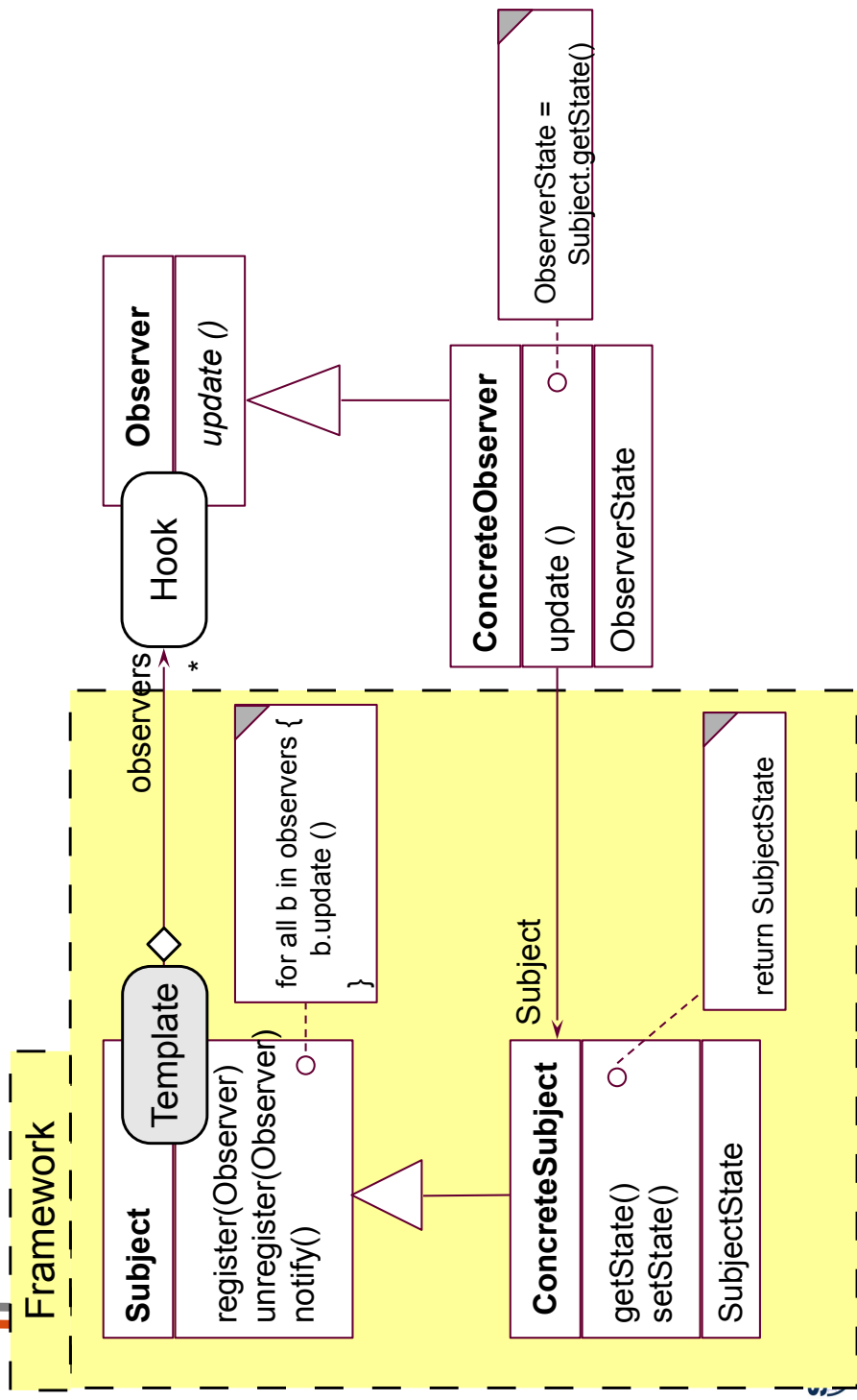
Ex.: Multiple Internationalization as n-T—H Dimensional Hierarchy



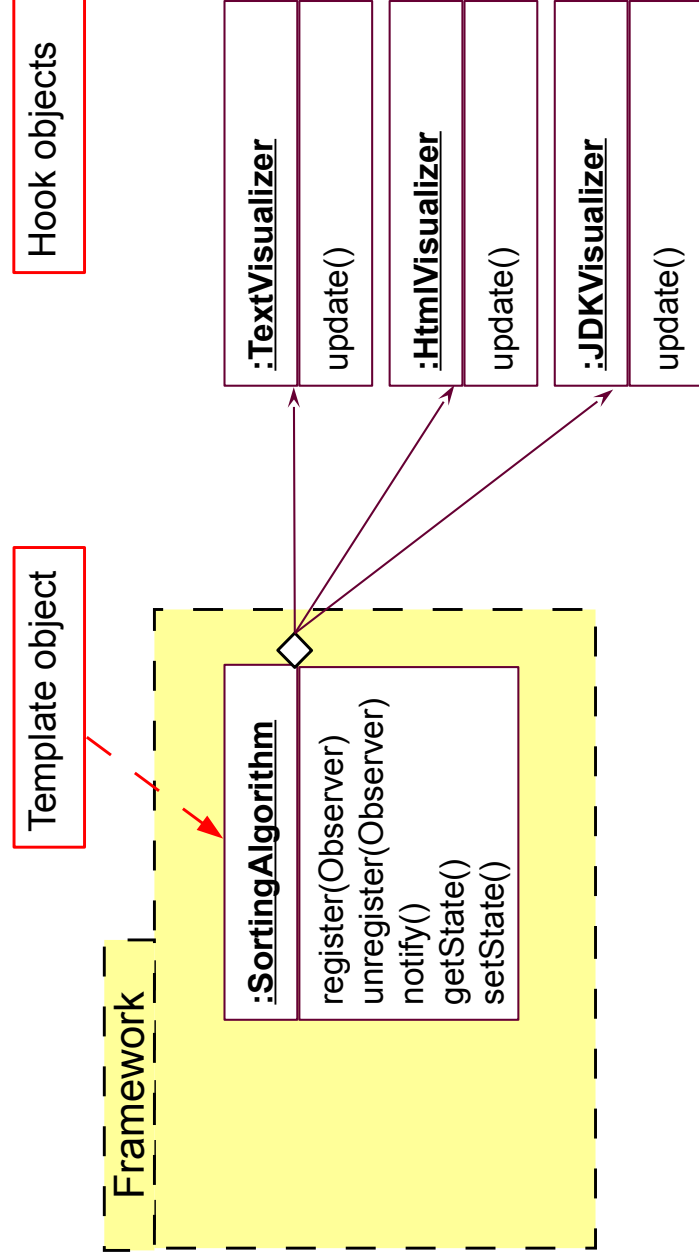
Block notation:



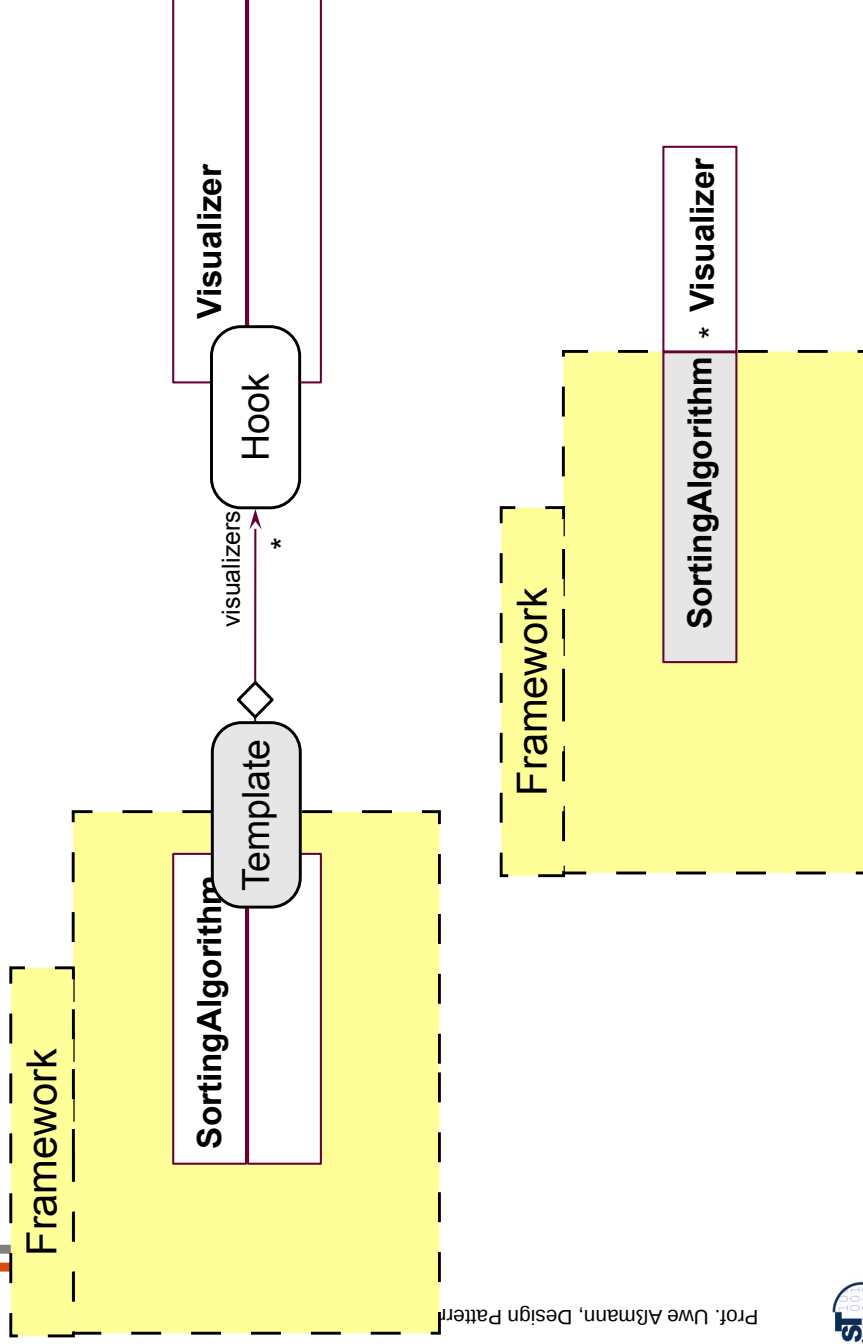
Observer as n-T—H of a Framework



Observer Runtime Scenario: Several Visualizers in Parallel



Observer-Based Extensible Frameworks

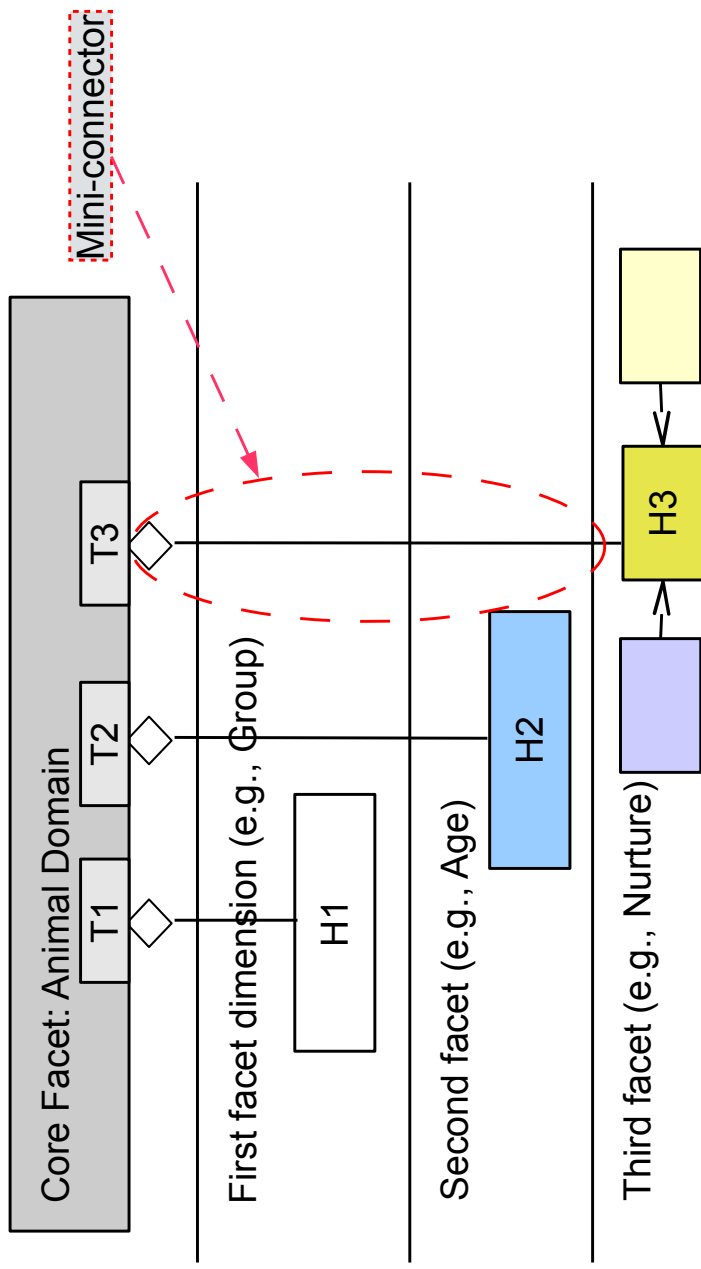


Observer

- ▶ The Observer pattern is used for extensibility
- ▶ With T&H, it becomes clear that Observers are a perfect way to achieve product lines with new feature extensions:
 - Model a critical template algorithm as Subject (template of the n-T--H)
 - Model an extension as a new Observer (hook of the n-T--H)

Bridge Frameworks Have T—H Hooks

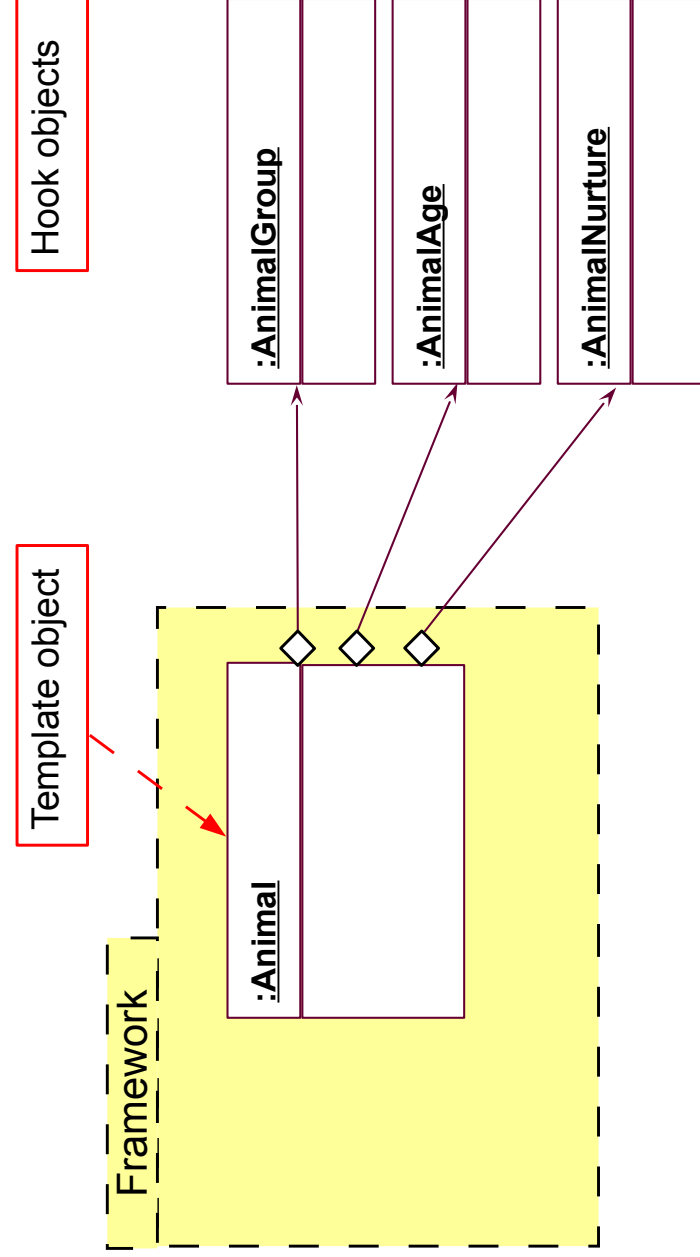
- ▶ Every dimension corresponds to a T—H hook
- ▶ Bridges, Strategy, Adapter can be used as mini-connectors



41



Ex.: Bridge Framework Runtime Scenario

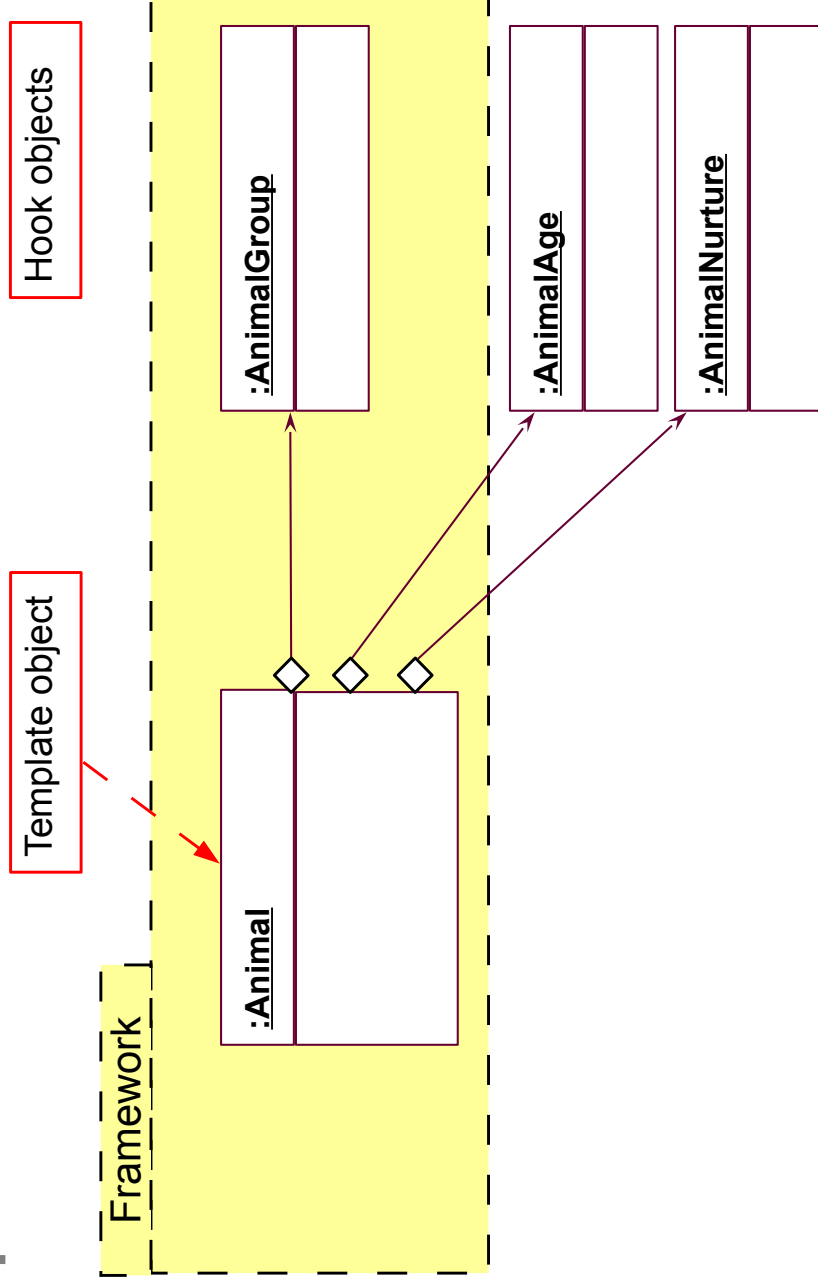


42



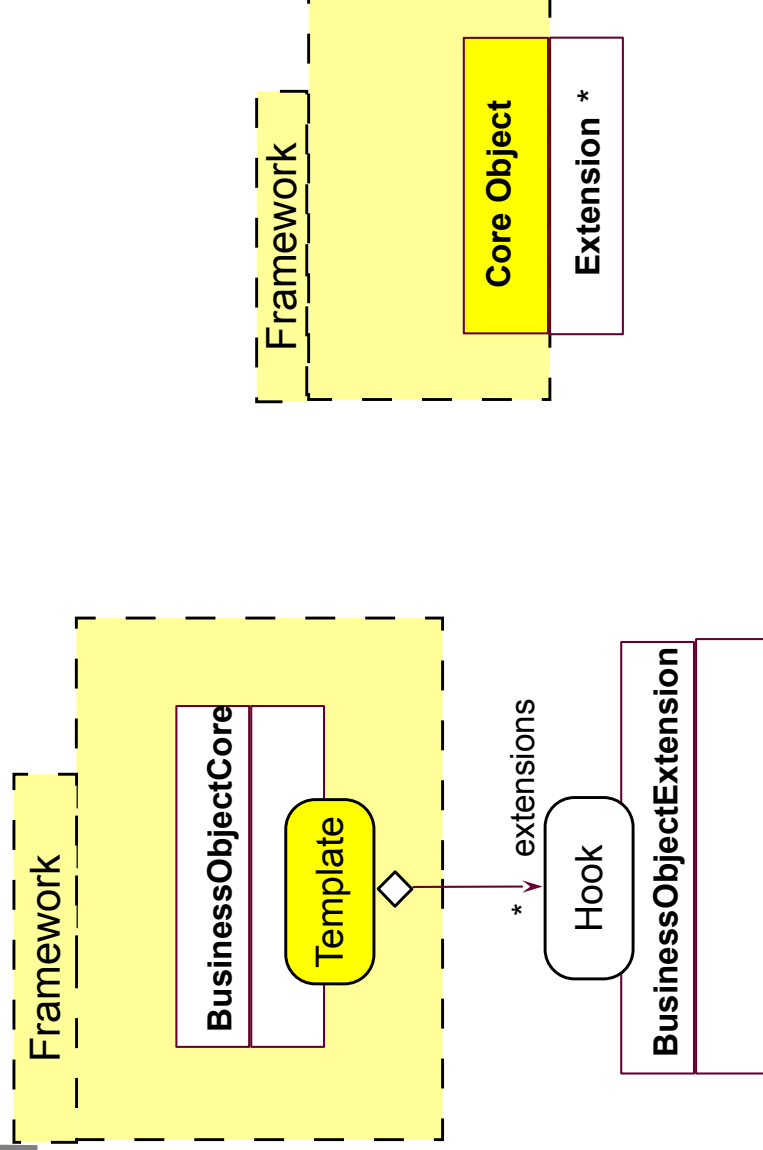
Ex.: Bridge Framework Runtime Scenario, with Dimension 1 in Framework

43



Extensible Bridge Framework with n-T--H

44



n-T—H Makes Bridge Frameworks Extensible

- ▶ An n-T—H framework hook makes dimensional bridge frameworks extensible with new dimensions *at run time*
- ▶ New extensions in new dimensions can be added and removed on-the-fly
- ▶ Applications
 - Business applications
 - System software
 - 3- and n-tier architectures

45



T—H Patterns Result in Blackbox Frameworks

- ▶ The main relation between T and H is *delegation*.
- ▶ Hence, when overriding and instantiating H, the framework is untouched (*blackbox framework*)
- ▶ 1-T—H gives variability
- ▶ n-T—H gives extensibility

46



11.4 The $H \leq T$ Recursion Metapattern

47



Design Patterns and Frameworks, © Prof. Uwe Alßmann

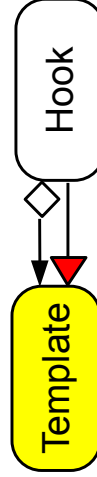
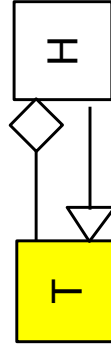
$H \leq T$ Recursive Connection

▶ T&H recursive connection pattern ($H \leq T$ framework hook, deep extension pattern)

- with 1- or n-ObjectRecursion
- H-class inherits from T; T is part of H
- H is decorator of T (1:1) or a composed class in a composite pattern (1:n)

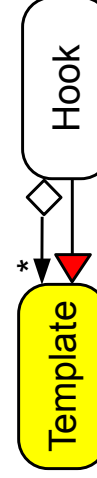
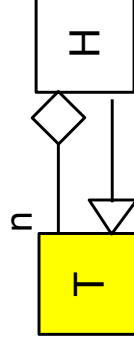
$H \leq T$ (deep list extension)

T part of H
H inherit from T
1-ObjectRecursion/Decorator



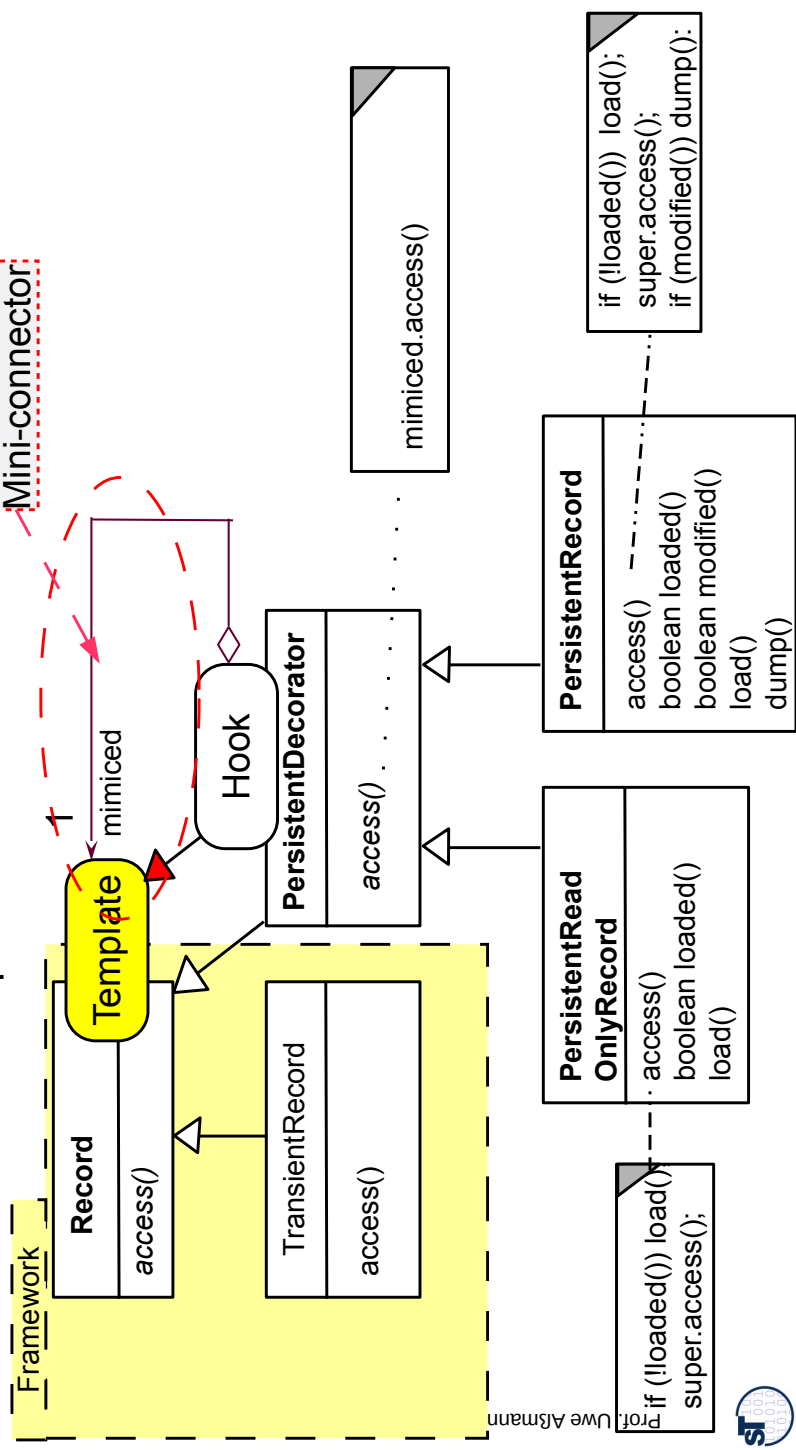
$n-H \leq T$ (deep graph extension)

H has n T parts
T inherit from H
n-ObjectRecursion/Composite



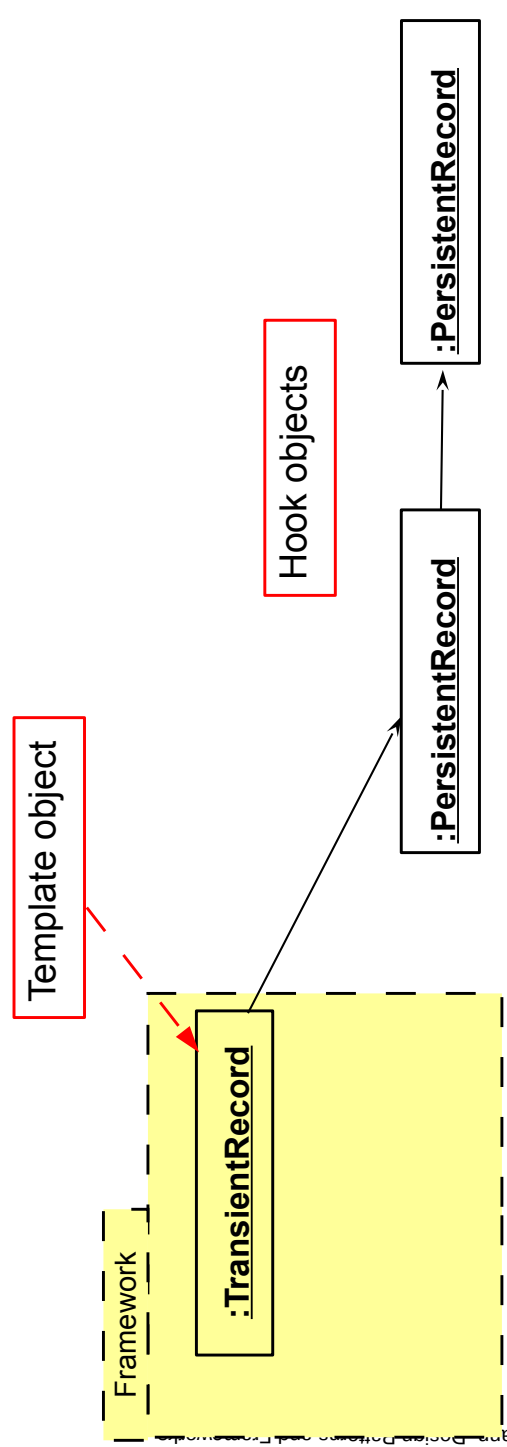
Decorator as $1-H \leq T$

- ▶ All decorator objects have to conform to the template class of the Decorator pattern



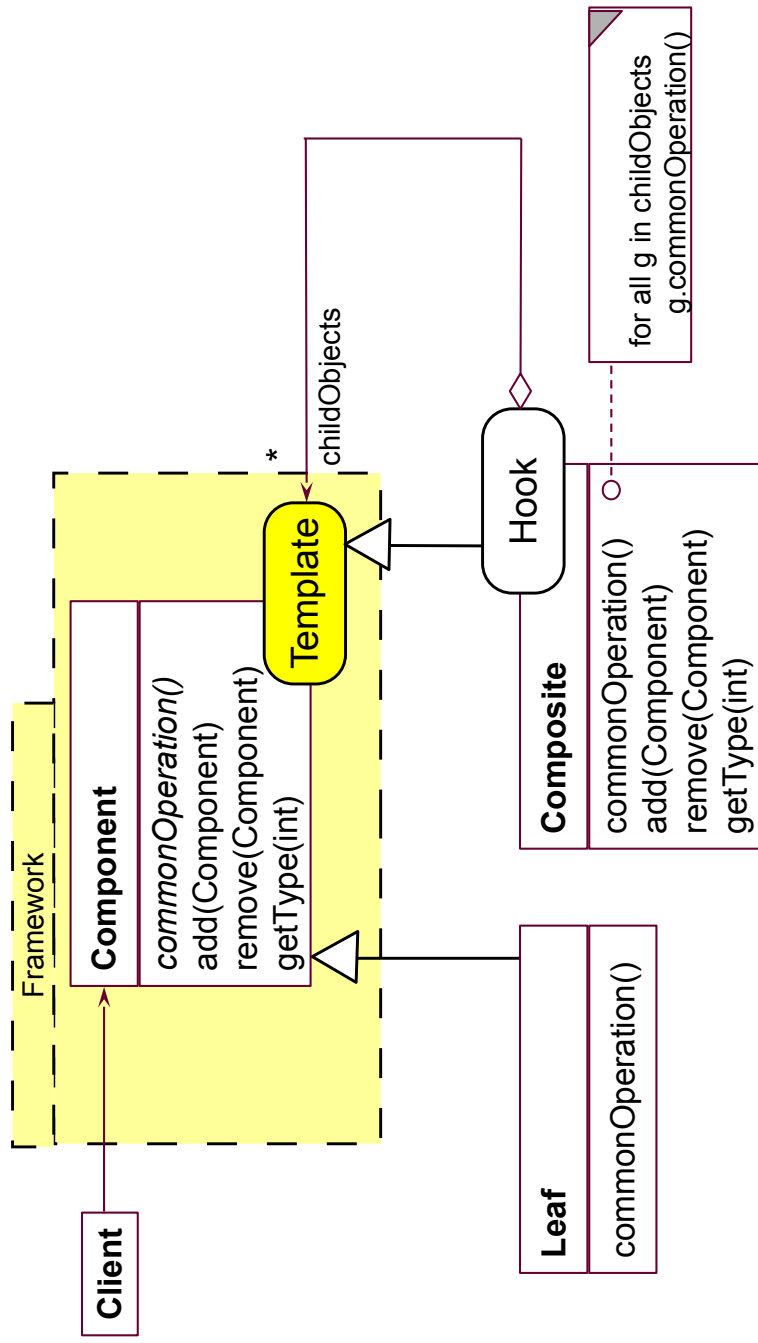
Ex.: Run-Time Snapshot of Decorator as Framework Hook Pattern

- ▶ Lists extend the framework



Composite as $n-H \leq T$

- ▶ Composite is as instance of n -ObjectRecursion and $n-H \leq T$

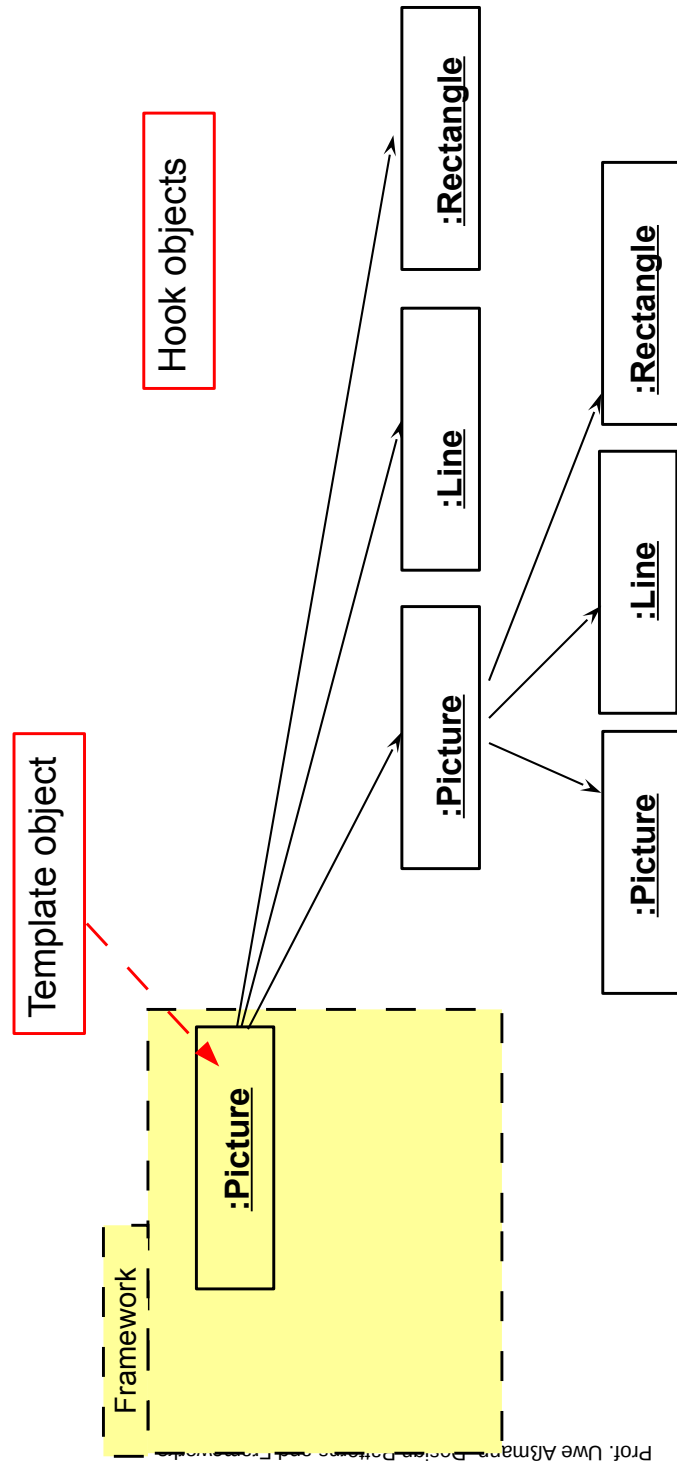


51



Ex. Run-Time Snapshot of Composite as Framework Hook Pattern

- ▶ Part/Whole hierarchies extend the framework

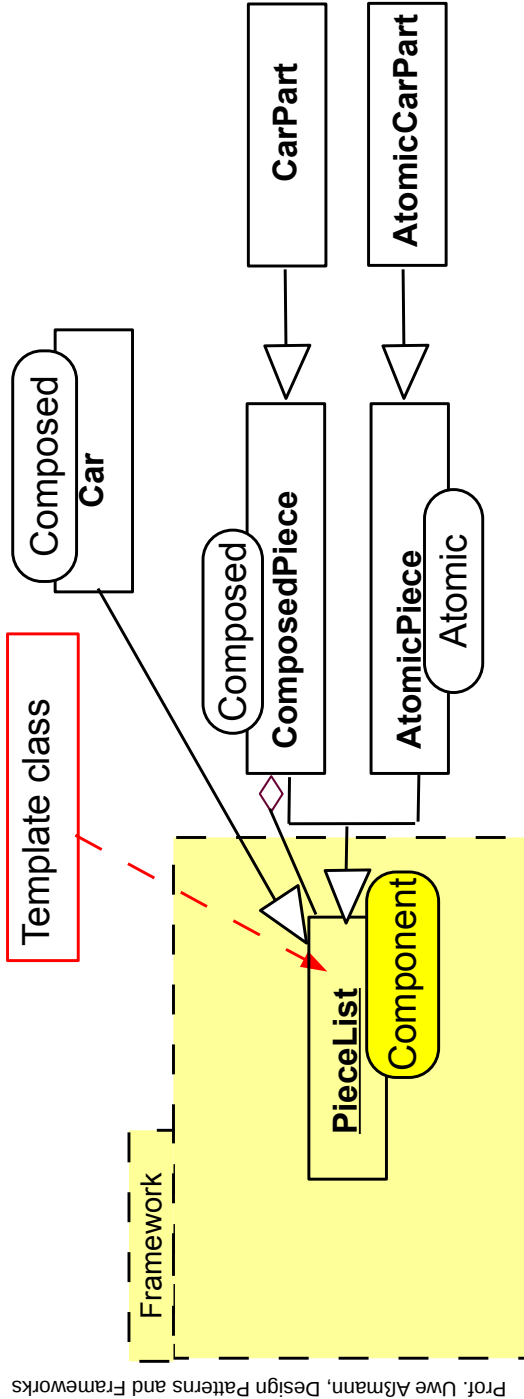


52



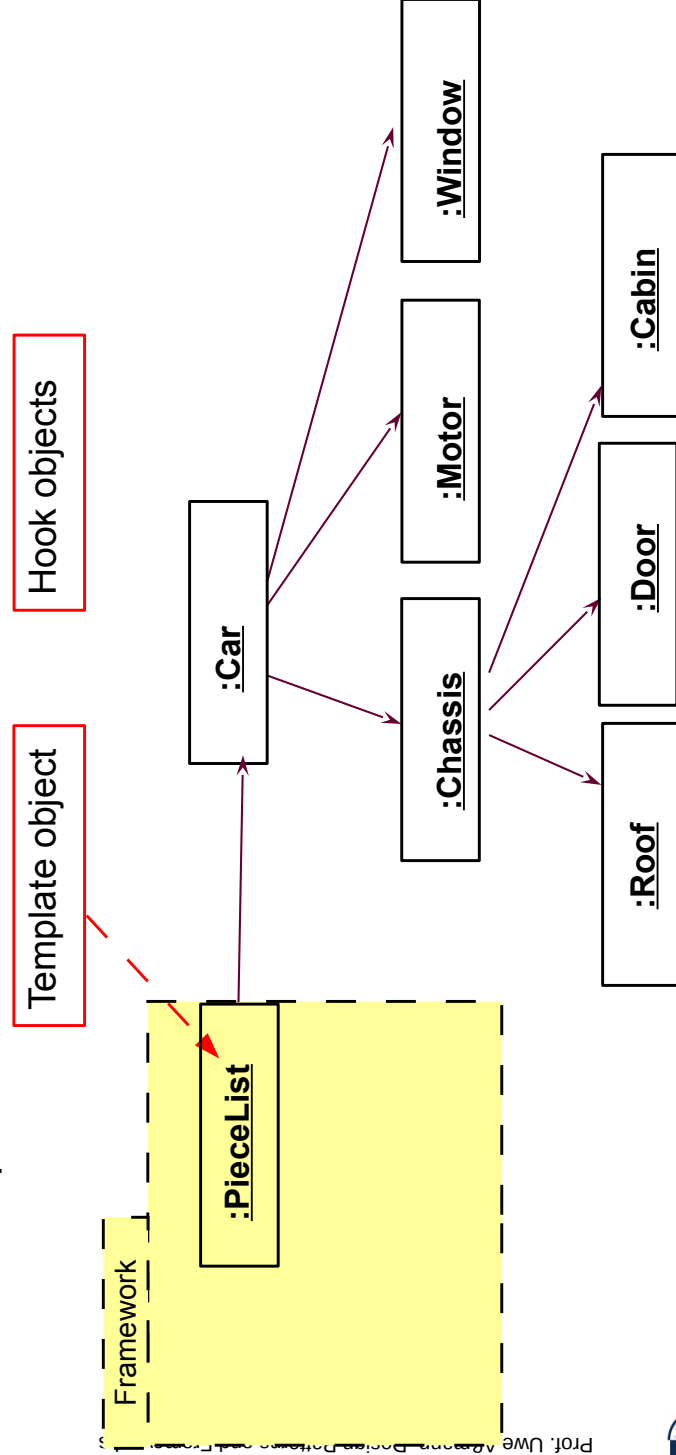
Production Data Systems

- ▶ Piece lists are part/whole hierarchies of technical artefacts in production
- ▶ The roles of a composite form the hook of the framework



Ex. Snapshot of a Production Data System

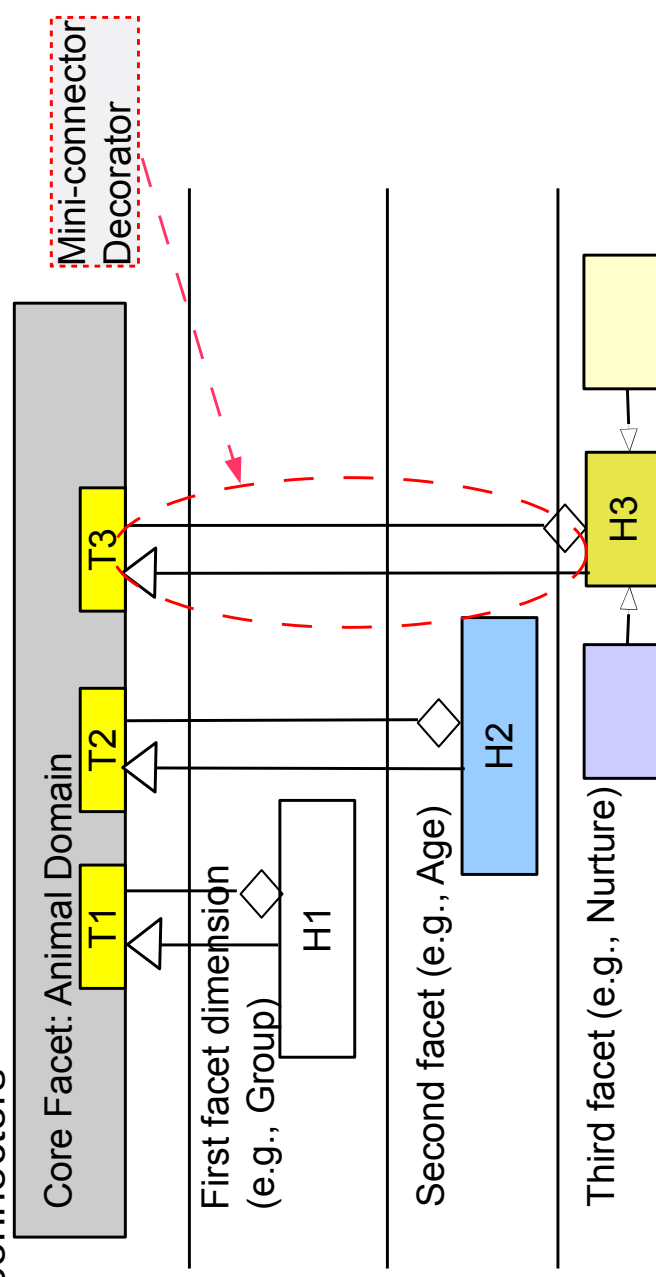
- ▶ Piece lists are part/whole hierarchies of technical artefacts in production
- ▶ Example: SAP PDM module, IBM San Francisco



- ▶ H<=T framework hooks result in frameworks between black-box and white-box
- ▶ Mini-connector H<=T is used
- ▶ Attention: The class with the Template role carries the HookM role, the class with the Hook role carries TemplateM role
 - The template (fixed) class in the framework is called from the hook class in the application (which carries the template method role)
 - Pree calls the pattern T<=H, but means TemplateM <= HookM !!

Bridge Frameworks Can Be Done with H<=T (Bridge H<=T Framework)

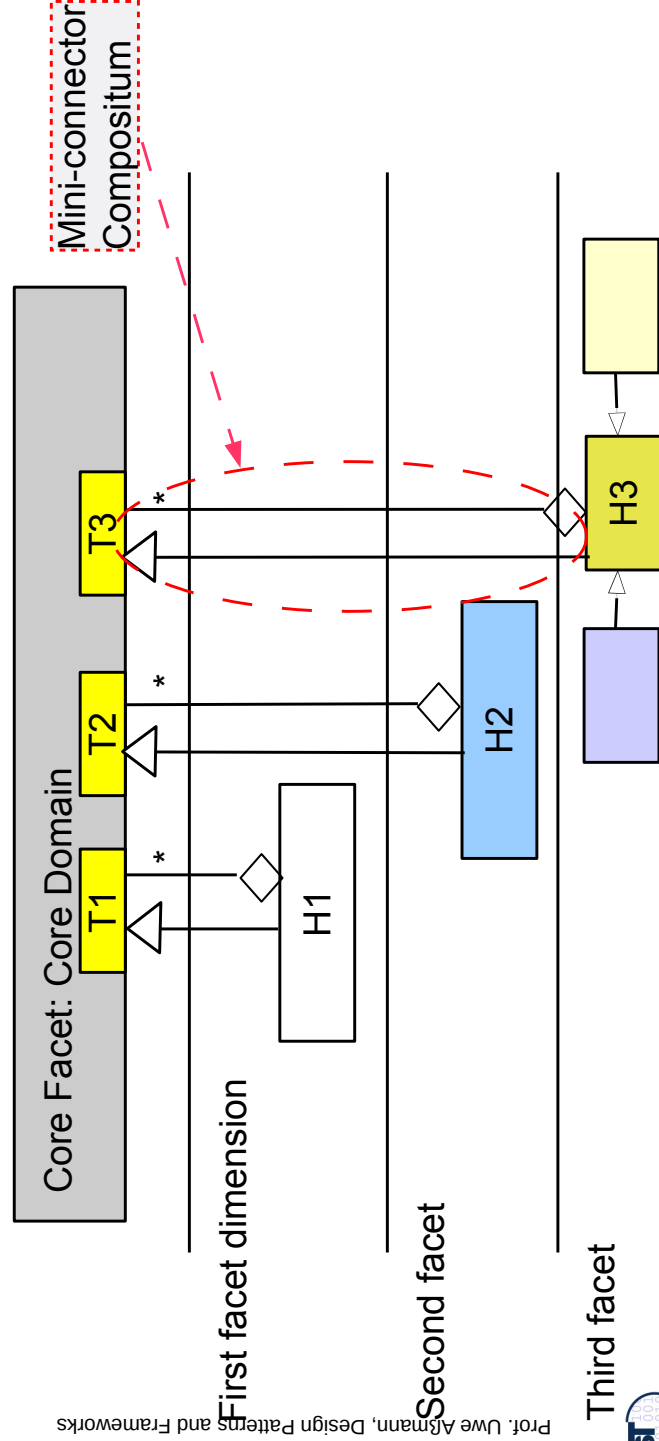
- ▶ A dimension may correspond to a H<=T hook of the core framework
- ▶ Composite, Decorator, Bureaucracy can be used as mini-connectors



Bridge Frameworks Can Be Done with $H <= T$ (Bridge $H <= T$ Framework)

57

- ▶ Composite as mini-connector



Prof. Uwe Alßmann, Design Patterns and Frameworks



11.5 The TH Unification Metapattern

58

Unification Hooks replace a framework object by a plugin object



TH

► Unified T&H pattern (TH framework hook)

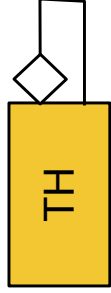
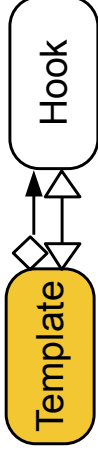
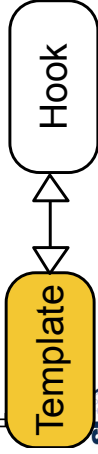
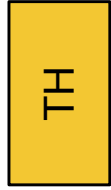
- T-class == H-class

59

TH

T == H

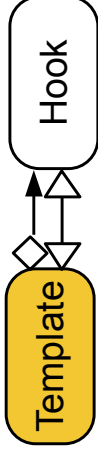
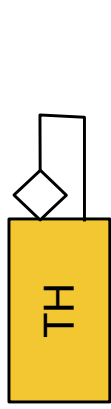
TH part of TH
“funny” Decorator



1-TH (deep list extension)

T == H

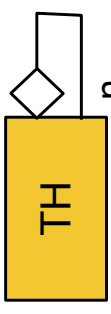
TH part of TH
“funny” Decorator



n-TH (deep tree extension)

T == H

TH has n TH parts
“funny” 1:n-Composite

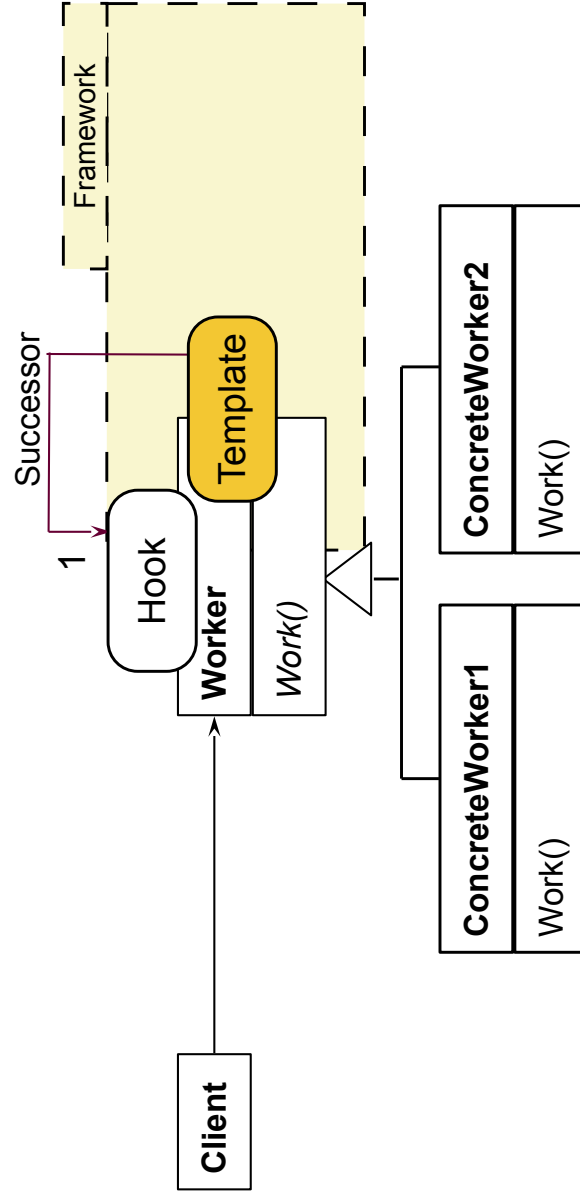


ChainOfResponsibility as 1-TH

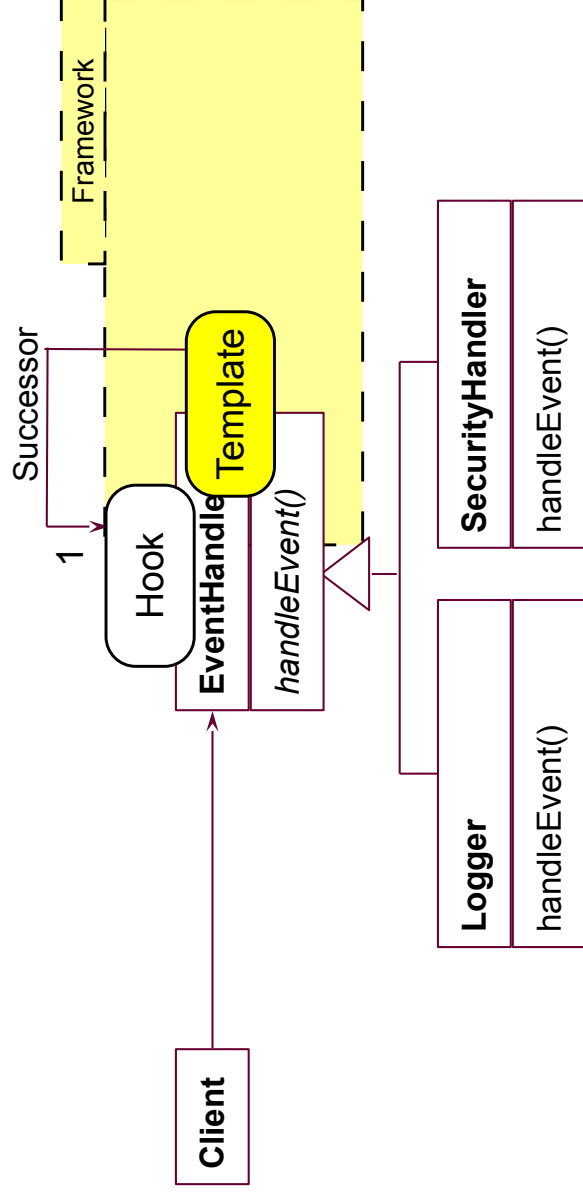
► A Chain is recursing on the abstract super class, i.e.,

- All classes in the inheritance tree know they hide some other class (unlike the ObjectRecursion)

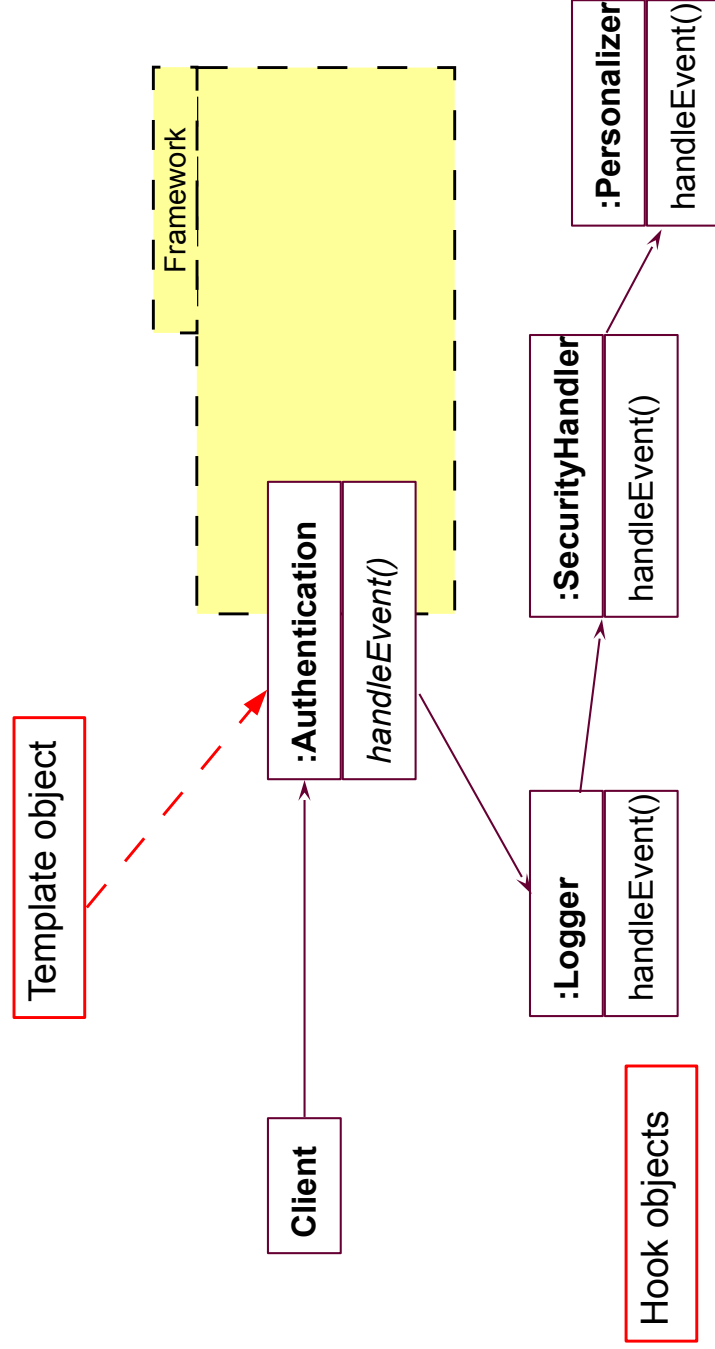
60



Ex.: Event Handlers



Ex.: Snapshot of Event Handlers



Why TH Unification Makes Sense

- ▶ If a hook class is the same as the template class,
 - Some methods are template methods, others are hook methods
 - Together with the template, the hooks can be exchanged
- ▶ Template methods in the template class are not abstract, but concrete
 - They are build from referencing hook methods of the hook class
- ▶ As we saw in the last chapter, merging role types in one class can make an application faster, but less flexible

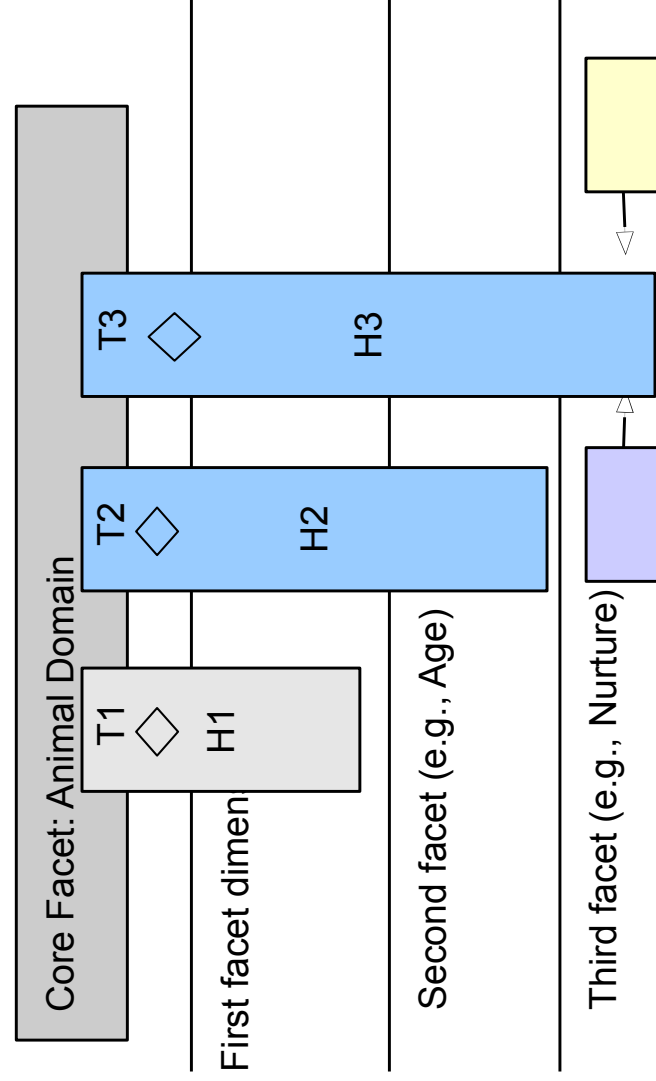
63



Bridge Frameworks Can Be Done with TH (Bridge TH Framework)

- ▶ A dimension may correspond to a $H \leq T$ hook
- ▶ Chain can be used as mini-connector

64



11.5.2 The H<T Whitebox Inheritance Metapattern

65

- The object of a plugin, typed by the subclass, replaces the object of the framework, typed by the superclass

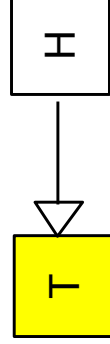


Design Patterns and Frameworks, © Prof. Uwe Alßmann

H<T

- ▶ If H inherits from T, H<T framework port (whitebox framework pattern)
 - Whitebox reuse of T in the framework, while deriving H in the application
 - (not of Pree, earlier known)
- ▶ If a hook class inherits from a template class, it inherits the skeleton algorithm
 - Template methods in the template class are not abstract, but concrete
 - They are build from referencing hook methods of the hook class
- ▶ A H<T framework hook means a *whitebox framework*

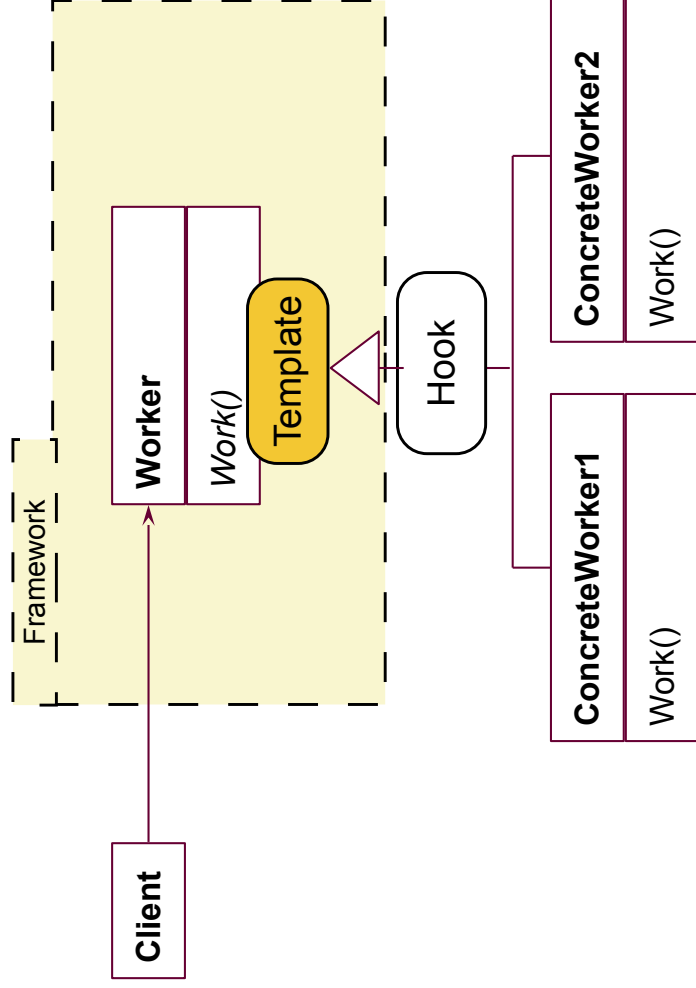
H<T



Whitebox Framework with H<T Framework Hook

67

- ▶ Also TemplateMethod can be applied (HookM <= TemplateM)



Summary of T&H Patterns and Framework Hooks

68

Cardinalities and Extensibility of Framework Hooks

Hooks

▶ 1:1 – T and H correspond 1:1

- T has 1 H part
- Hooks are not extensible at runtime
- 1:1 T&H framework hooks should be used when the behavior of the framework should be varied, but not extended at the variation point

- Because variability patterns form the mini-connector between T and H, derived from 1-ObjectRecursion

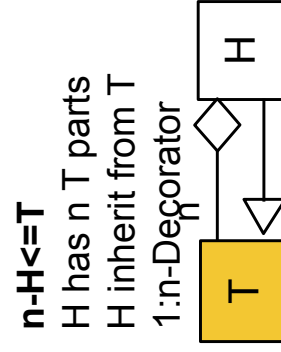
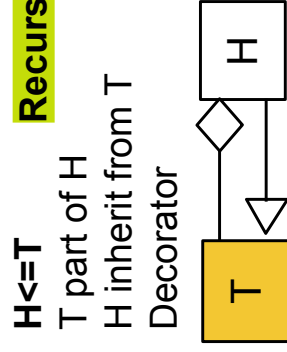
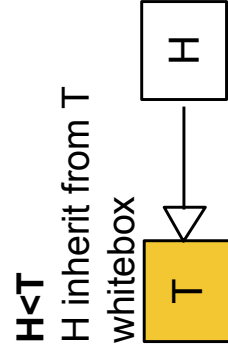
▶ 1:n – T and H correspond 1:n

- T has n H parts
- Hooks are extensible, also dynamically
- 1:n T&H framework hooks should be used when the behavior of the framework should not only be varied, but also *extended* dynamically at the variation point

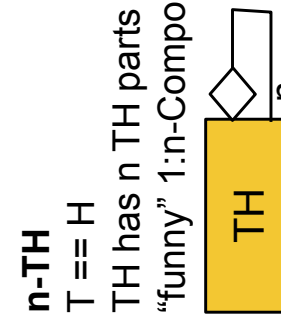
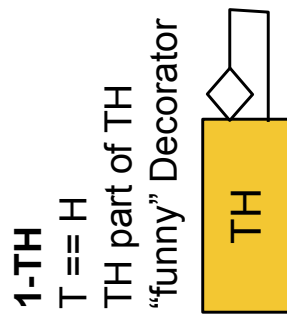
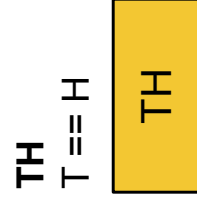
- Because extensibility patterns form the mini-connector between T and H, derived from n-ObjectRecursion

Framework Hook Patterns

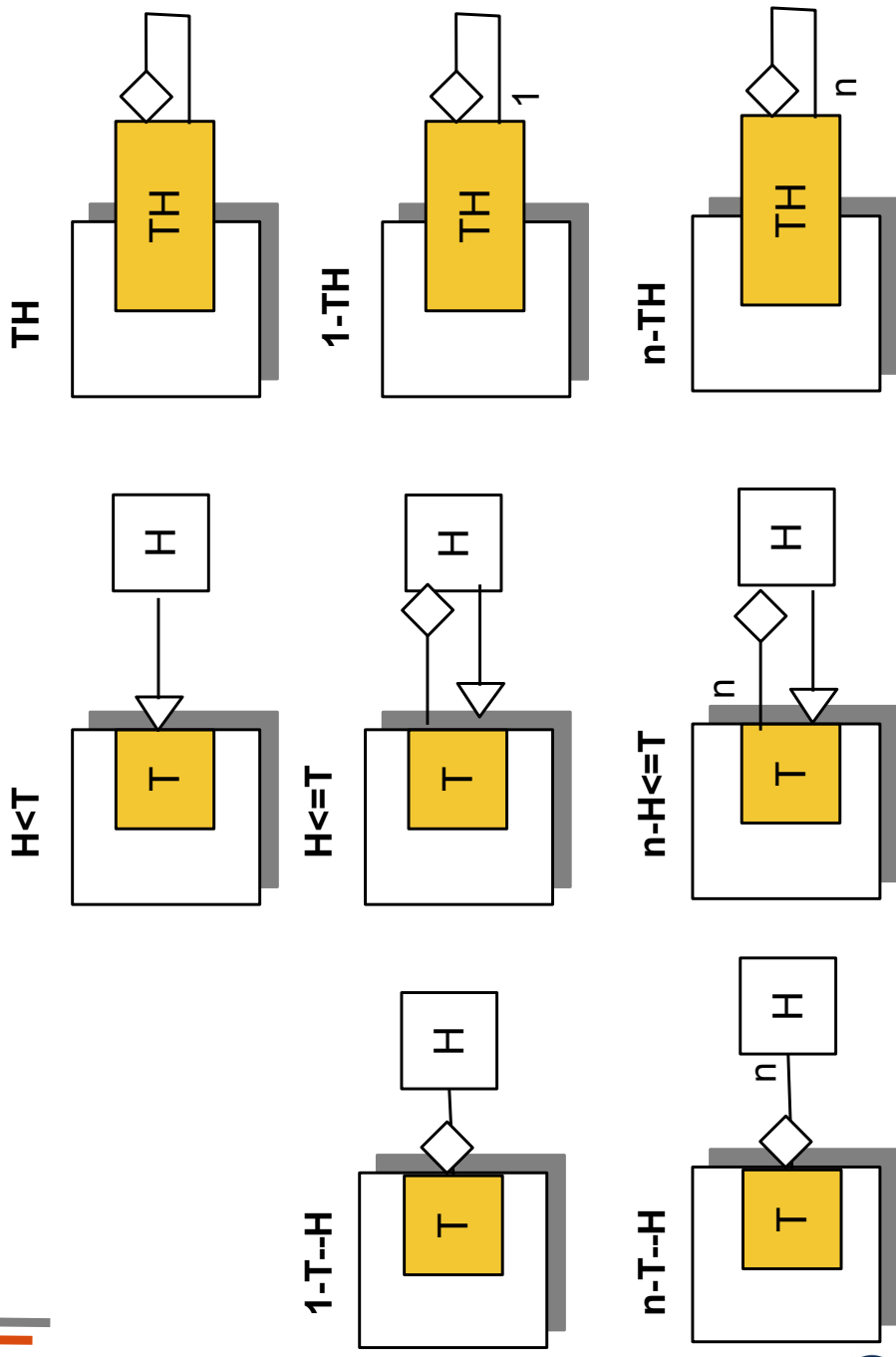
Inheritance



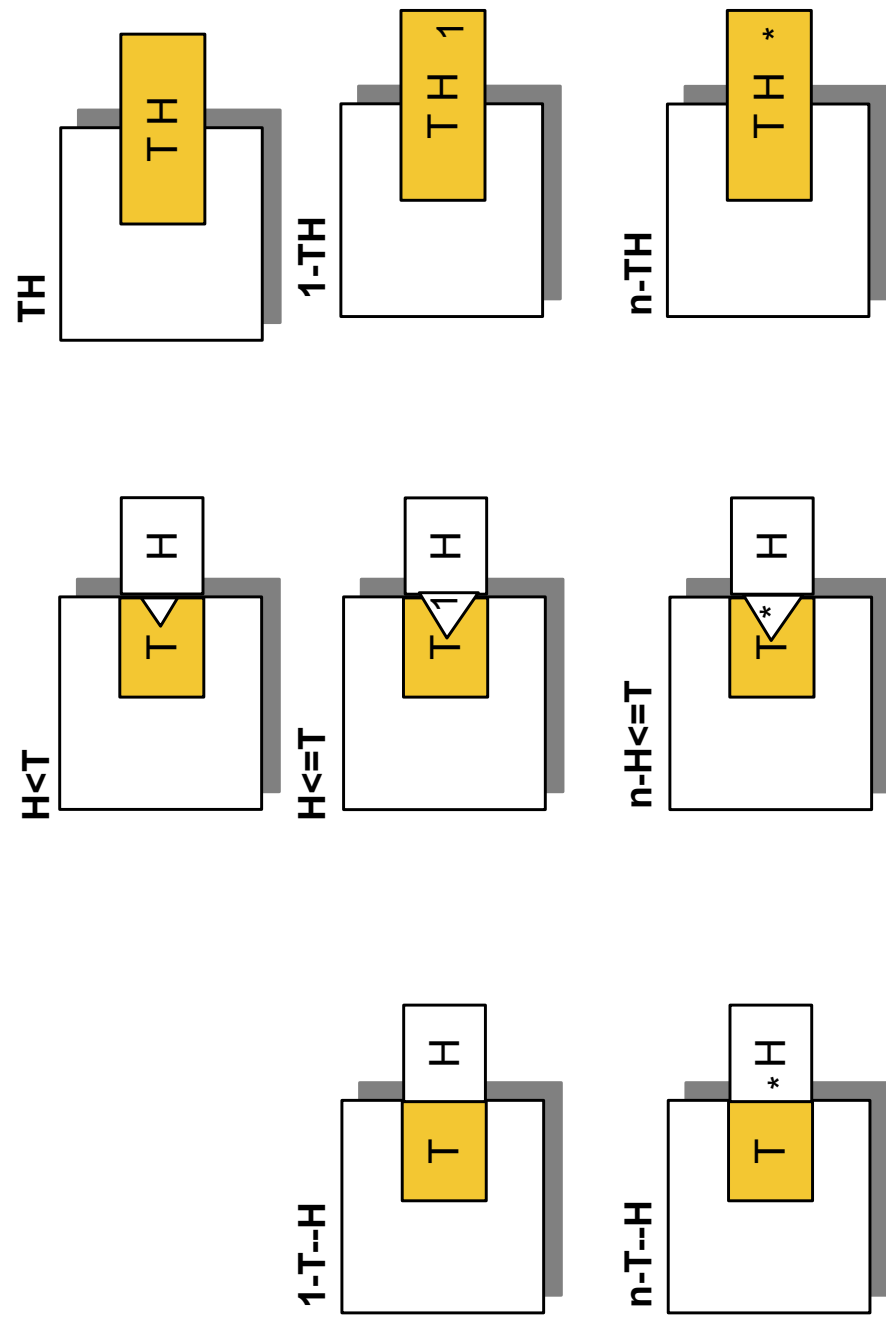
Unification



Mini-Connector Notation for Framework Hooks



Block Notation for Framework Hooks



11.7 T&H in Frameworks

73



Design Patterns and Frameworks, © Prof. Uwe Alßmann

Advantages of T&H Framework Hook Patterns

- ▶ One big mess with frameworks is the *trustworthy framework instantiation problem*:
 - If a framework is instantiated by inheritance (whitebox) or delegation (blackbox), illegal combinations of parameters appear
 - Applications may not run stabel
- ▶ Framework Hook Patterns describe much more precise *how the* variation points of a framework should be instantiated
 - They allow for determining whether the framework is *varied or extended* in a product line

74



Pree's First Law of Framework Instantiation

▶ Variability-based framework hooks define *framework variation points*

- If you want to constrain the uses of a framework to a fixed set of variations, use variability patterns for framework hooks (1-TH patterns)

If a framework hook is based on a variability pattern, the framework is varied, but NOT extended

75

Pree's Second Law of Framework Instantiation

▶ Extensibility-based framework hooks define *framework extension points*

- If you do *not* want to *constrain* the uses of a framework to a fixed set of variations, use extensibility patterns for framework hooks (n-TH patterns)

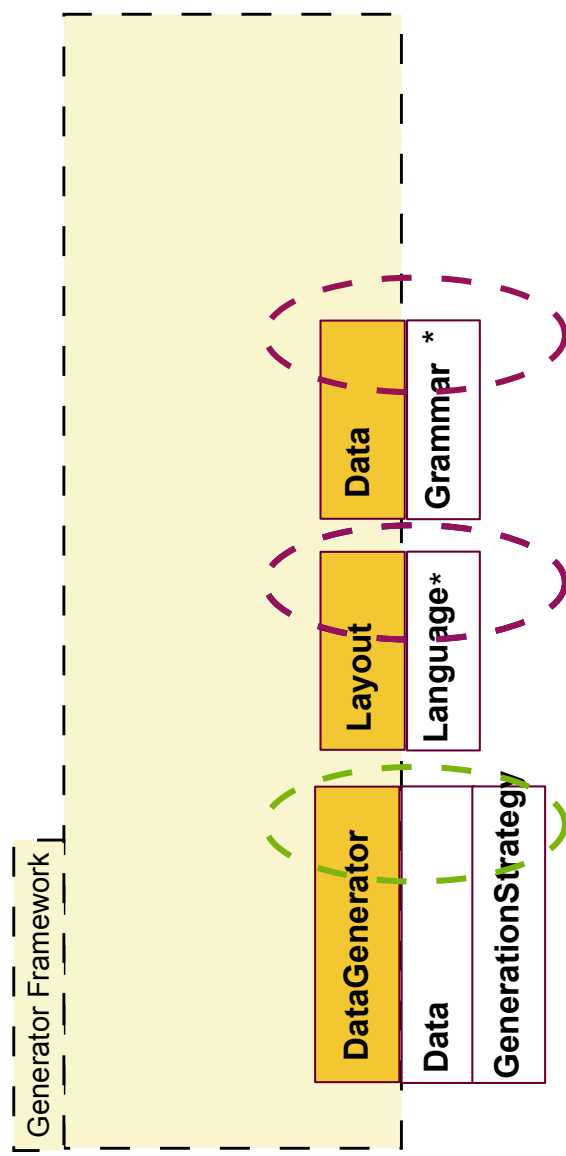
If a framework hook is based on an extensibility pattern, the framework is extended, but not varied

76

A Multi-Lingual Dimensional Data Generator

- One framework hook may have several bridge dimensions

77



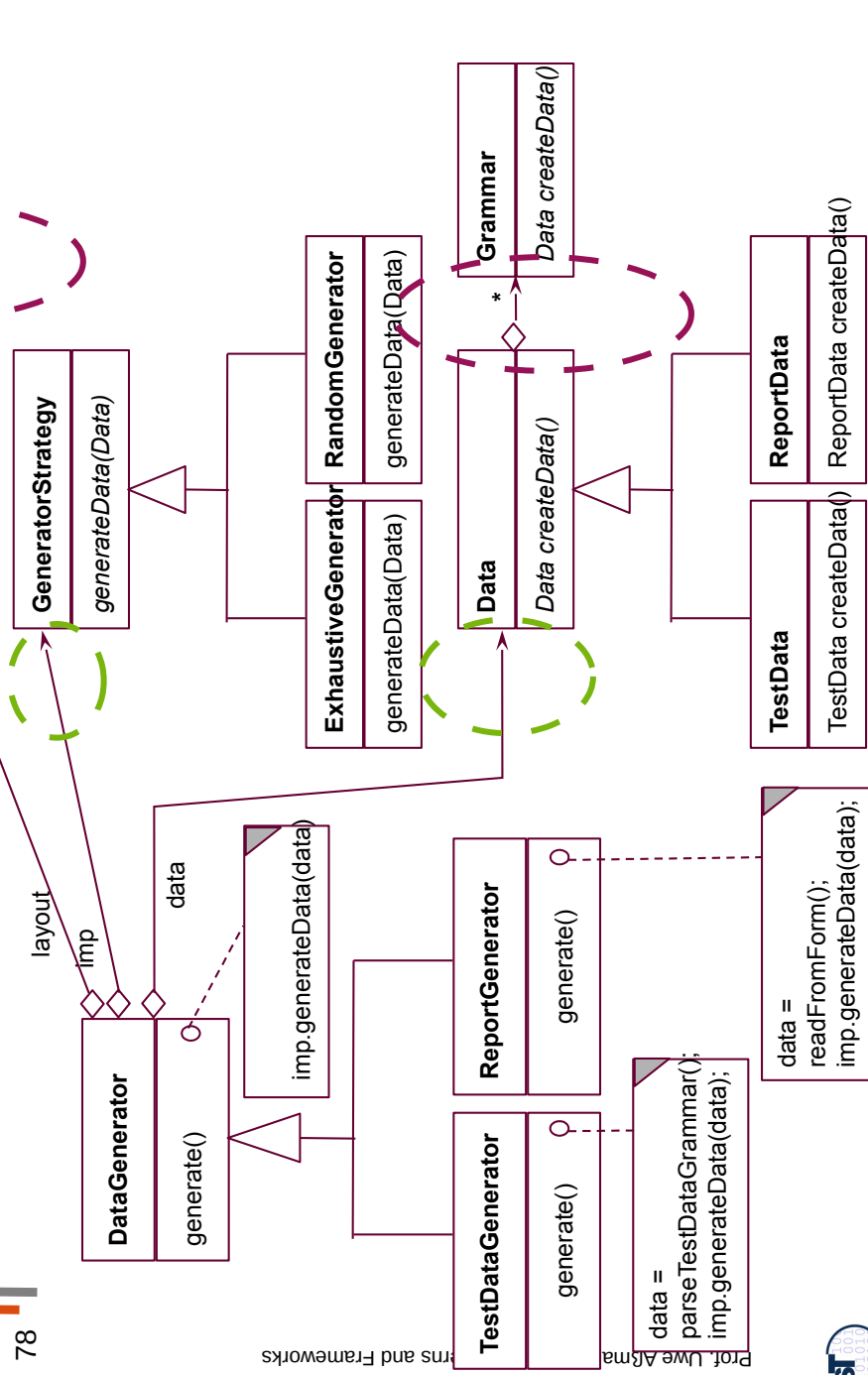
Variable Variation Point

Extensible Extension Points



Class Diagram

78



Framework Instantiation Market

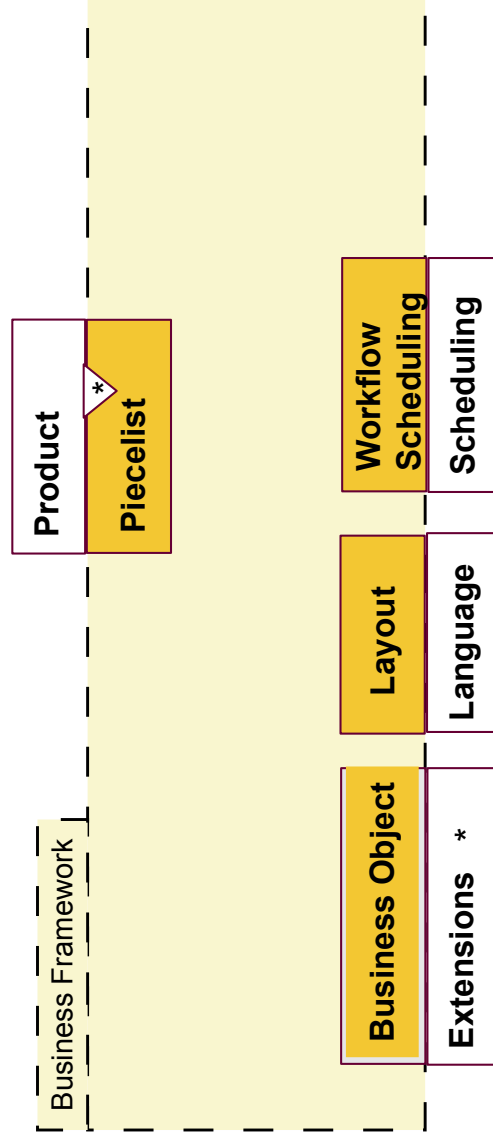
- ▶ Today, frameworks are the most important software technology for product lines in large companies
- ▶ Instantiating big frameworks is very hard
 - Requires special *instantiation consultancy*, which is a big market
 - SAP Germany has a marker for instantiation companies of their framework!
 - If you go to a big company, teach them framework instantiation patterns!

79



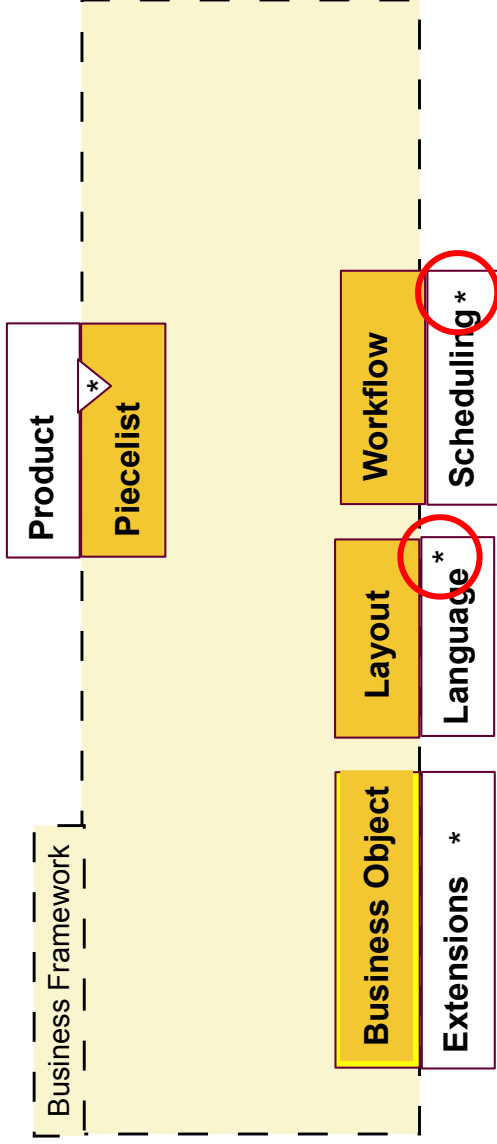
A Multi-lingual Business Framework (Block Notation)

80



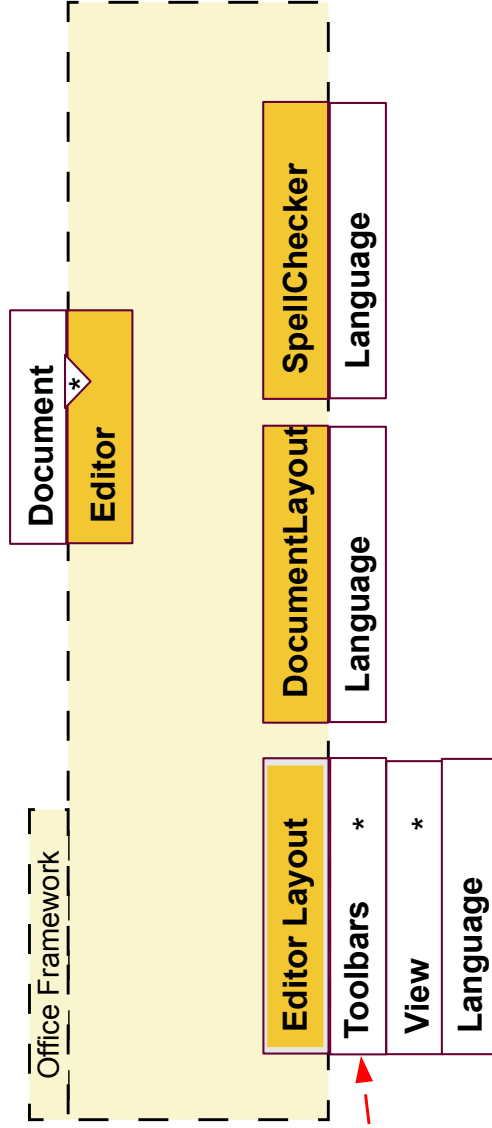
A Business Framework with Several Languages Simultaneously (Block Notation)

- ▶ Problem: business frameworks have an enormous number of framework hooks



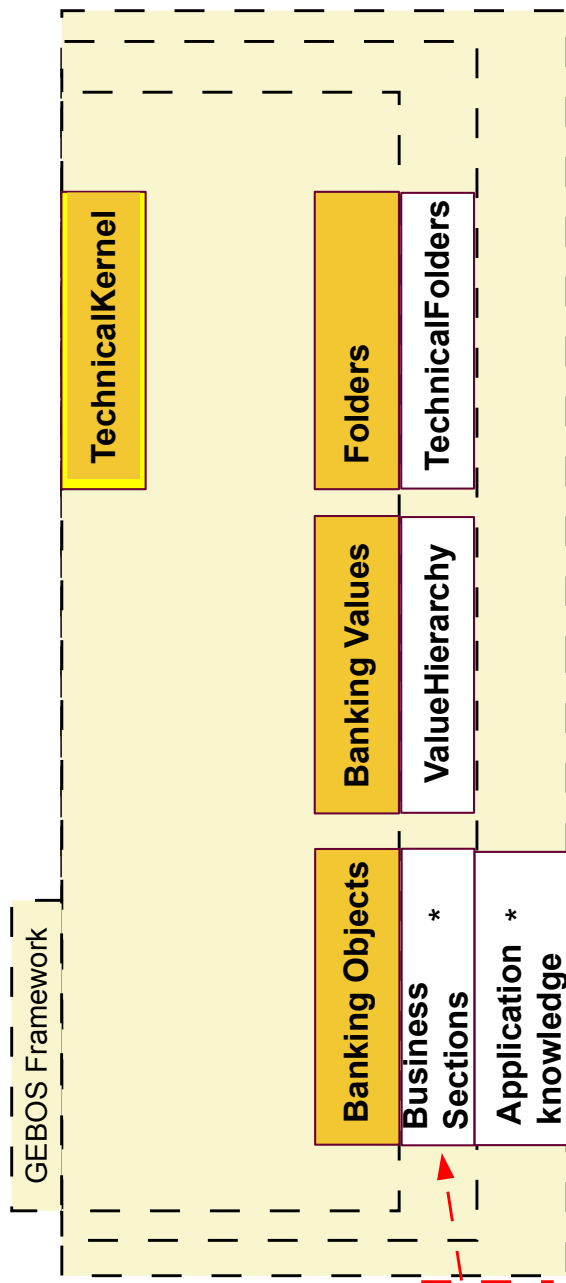
OpenOffice (Block Notation)

- ▶ Variabilities
 - Type of program (word, slides, drawings, calc, ...)
 - Structured documents (Composite pattern)
 - Embeddings of all document types into other document types possible
 - Language
 - GUI
 - Visible toolbar (visibility, position) of MainToolBar, FunctionBar, ObjectBar, ColorBar, OptionBar, PresentationBar, HyperlinkBar
 - Views, such as StandardView, OutlineView, HandoutView

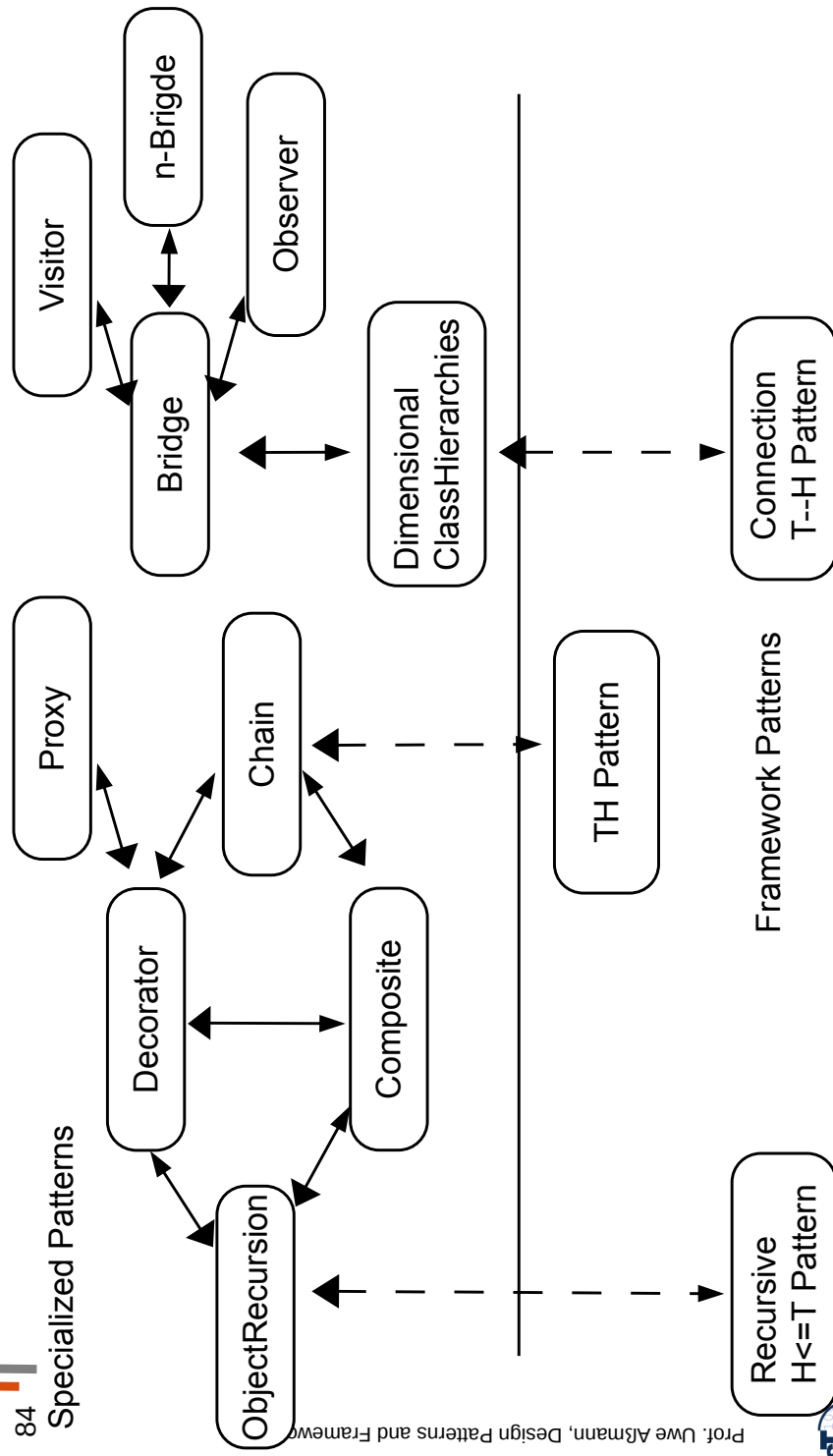


GEBOS Banking Layered Framework

- ▶ If a template class of a framework hook has several hook classes (e.g., as an n-Bridge), then the Framework becomes layered



Relations Extensibility Patterns



Summary

- ▶ When overlaid with a T--H metapattern, a design pattern becomes a *framework hook pattern* for the interface of a framework
- ▶ These are *mini-connectors* between a framework and its application classes
 - More flexible that just generic classes (generic frameworks) or delegation (blackbox) or inheritance (whitebox)
- ▶ The framework hook patterns determine very precisely how a framework is to be instantiated
- ▶ There are more kinds of dimensional frameworks
 - Dimensional T—H (n-Bridge LF), $H \leq T$, TH, $T > H$ dimensional frameworks
- ▶ 1-T&H framework hook patterns can be used for variability of the framework
- ▶ n-T&H for extensibility.

85

The End

86