11. Frameworks and Patterns - Framework Variation Patterns

Prof. Dr. U. Aßmann
Software Engineering
Faculty of Informatics
Dresden University of Technology
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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

Literature (To Be Read)

- 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. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.28.4711

- D. Bäumer, G. Gryczan, C. Lilienthal, D. Riehle, H. Züllighoven. Framework Development for Large Systems. Communications of the ACM 40(10), Oct. 1997. http://dirkriehle.com/computer-science/research/1997/cacm-1997-frame

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.

Goal

- 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

Patterns and Frameworks

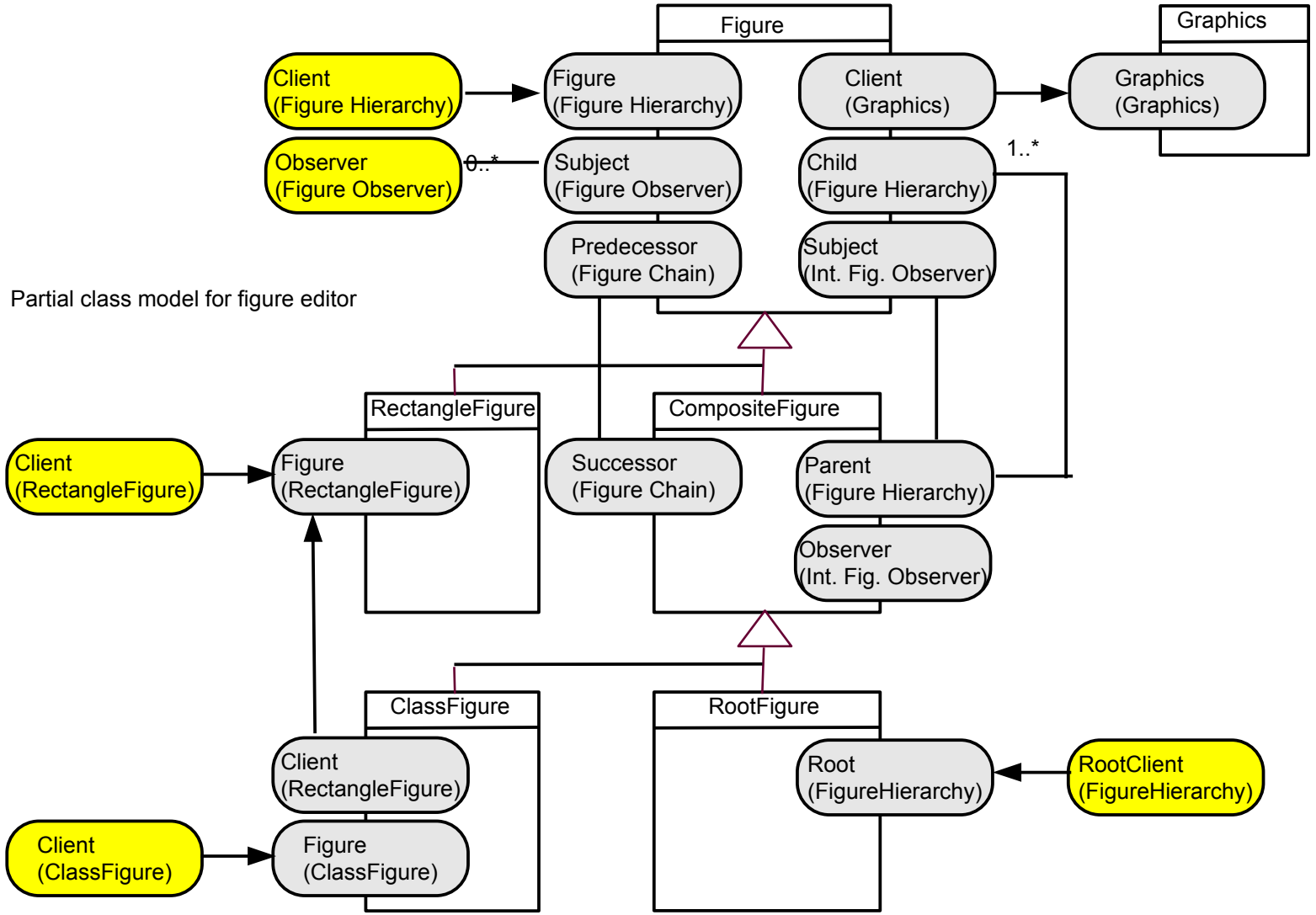
- Historically, design patterns were discovered during framework development
  - Smalltalk MVC [Goldberg, Reenskaug]
  - ET++ [Gamma]
  - Interviews [Vlissides]
- Design patterns are building blocks of frameworks
  - Framework developers vary and extend classes of the framework
- Design patterns are for the making of the products of a product line architecture
  - 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

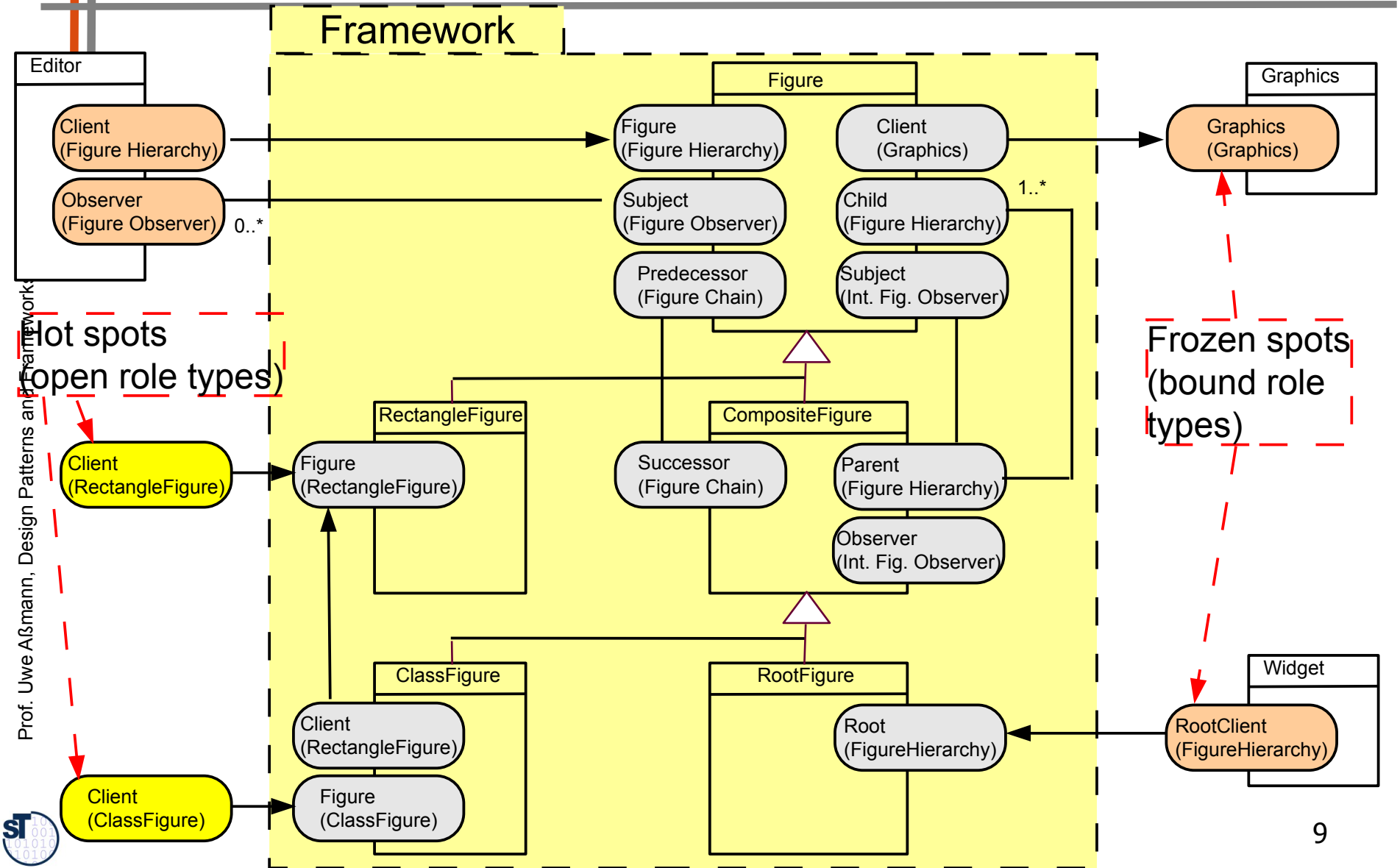
Framework Instantiation with Open Roles (Role Hot Spots)

- The most simple form of framework instantiation is Riehle/Gross' *open role instantiation*
  - Here, frameworks are class models with “open” role hot spots
  - *Open role hooks (free, unbound abilities)* are 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
  - *Aka framework hooks, framework variation points*
- A framework is *instantiated* by binding its integration repertoire to classes
  - The abilities are *bound, r*ole constraints have to be respected
- Hence, role models play the bridge between a framework and its clients

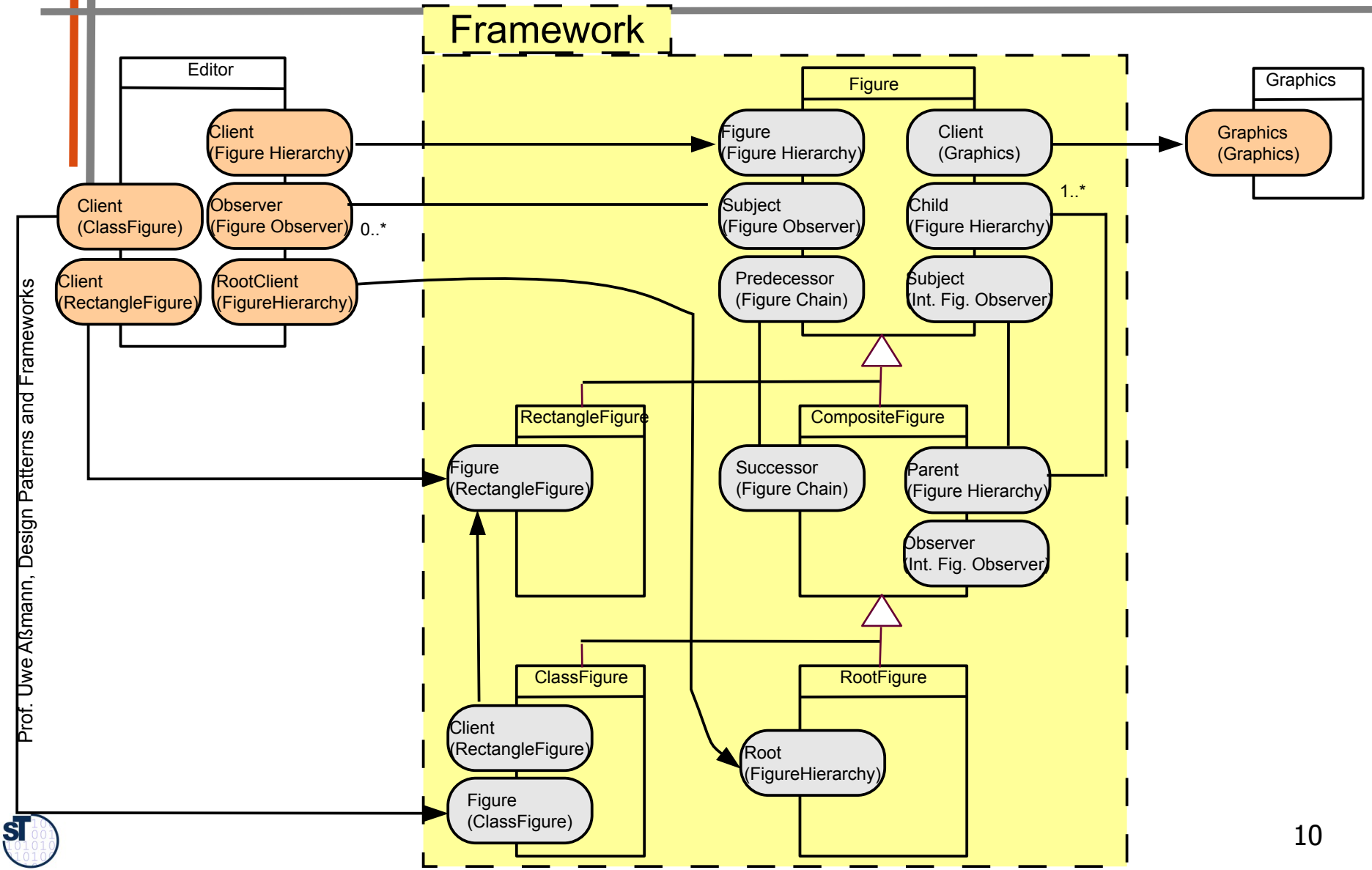
Remember: The Partial Figure Model, a Standard Class-Ability Model



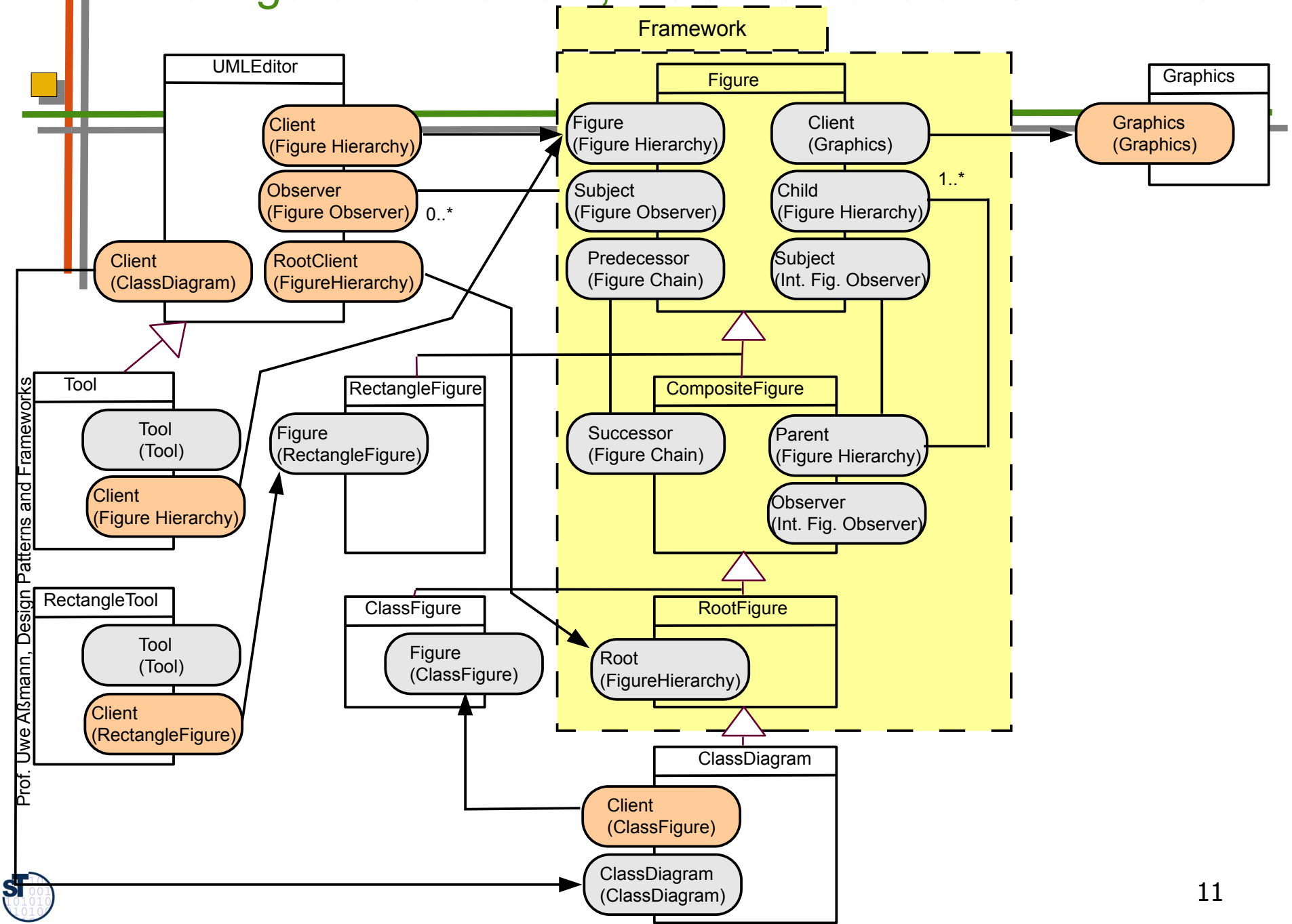
The Figure Framework, Partially Instantiated



The Figure Framework, Fully Instantiated to an Editor



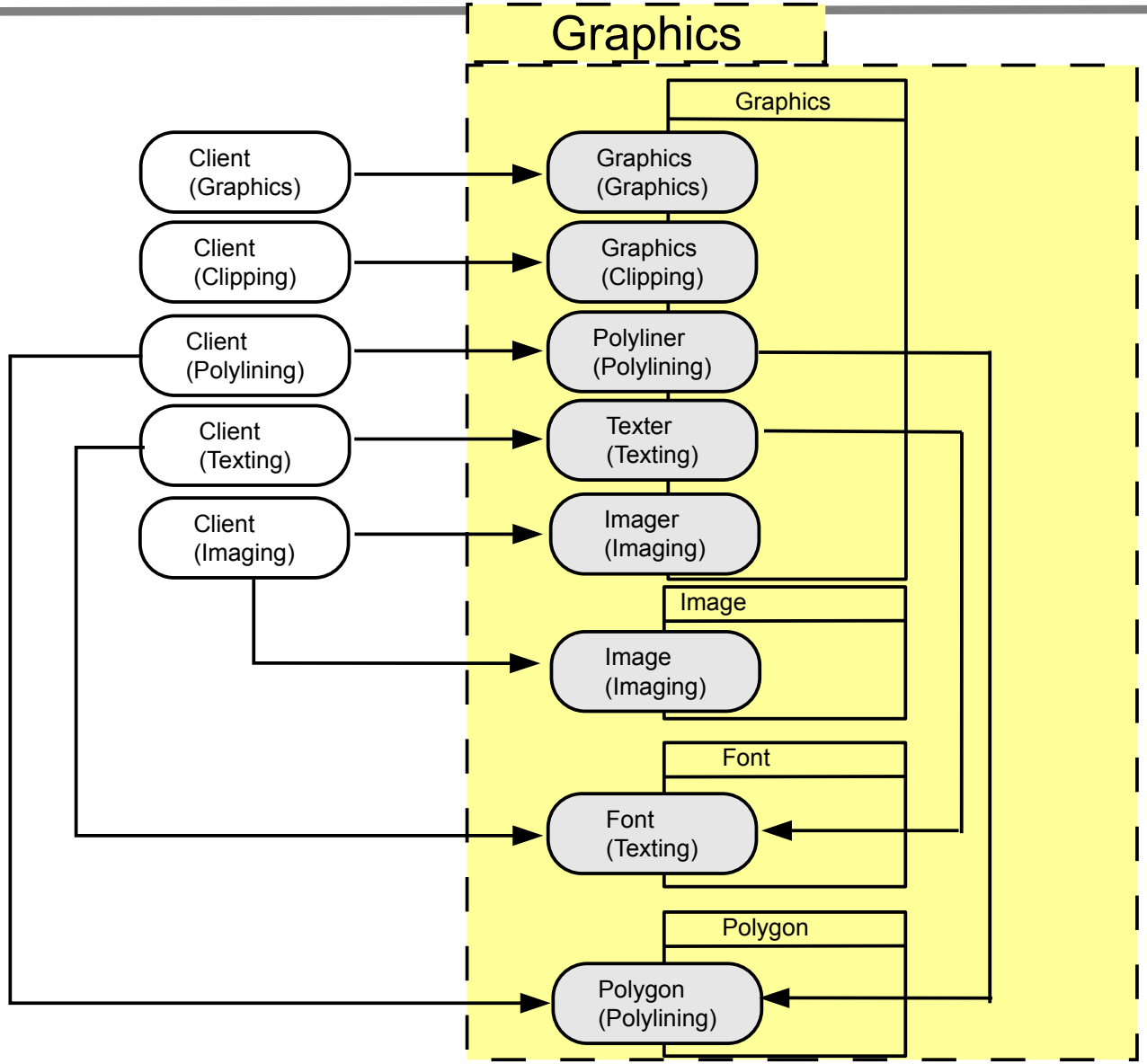
The Figure Framework, Instantiated to an UML Editor



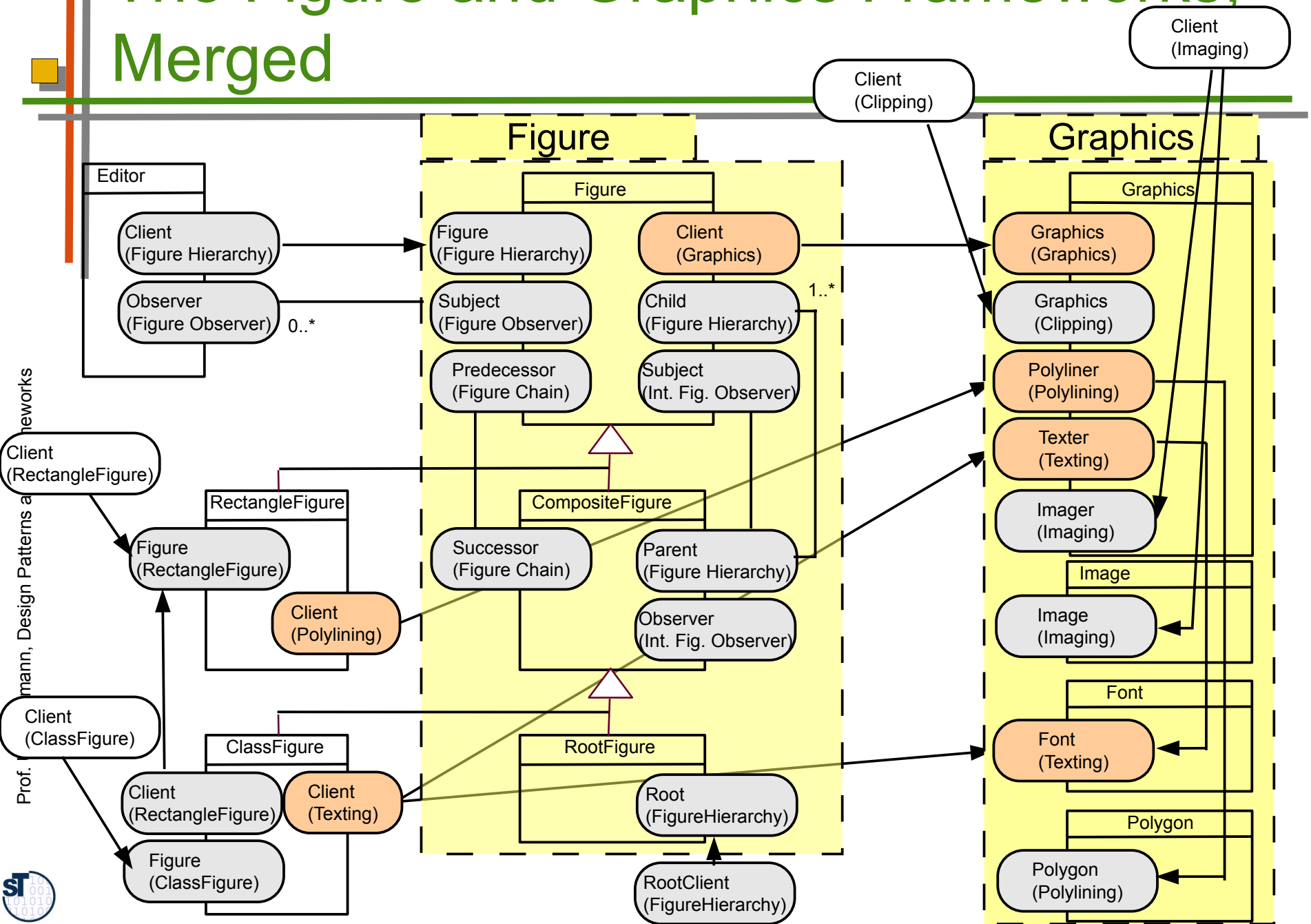
Merging of Frameworks

- 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

A Graphics Framework



The Figure and Graphics Frameworks, Merged



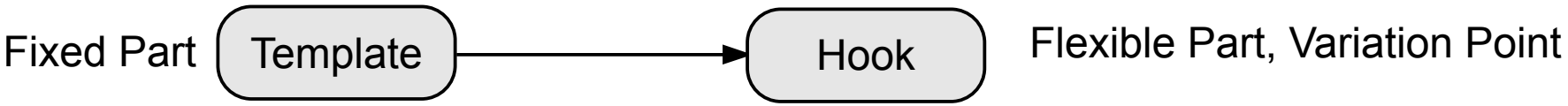
Limitations of Open Role Instantiation

- [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

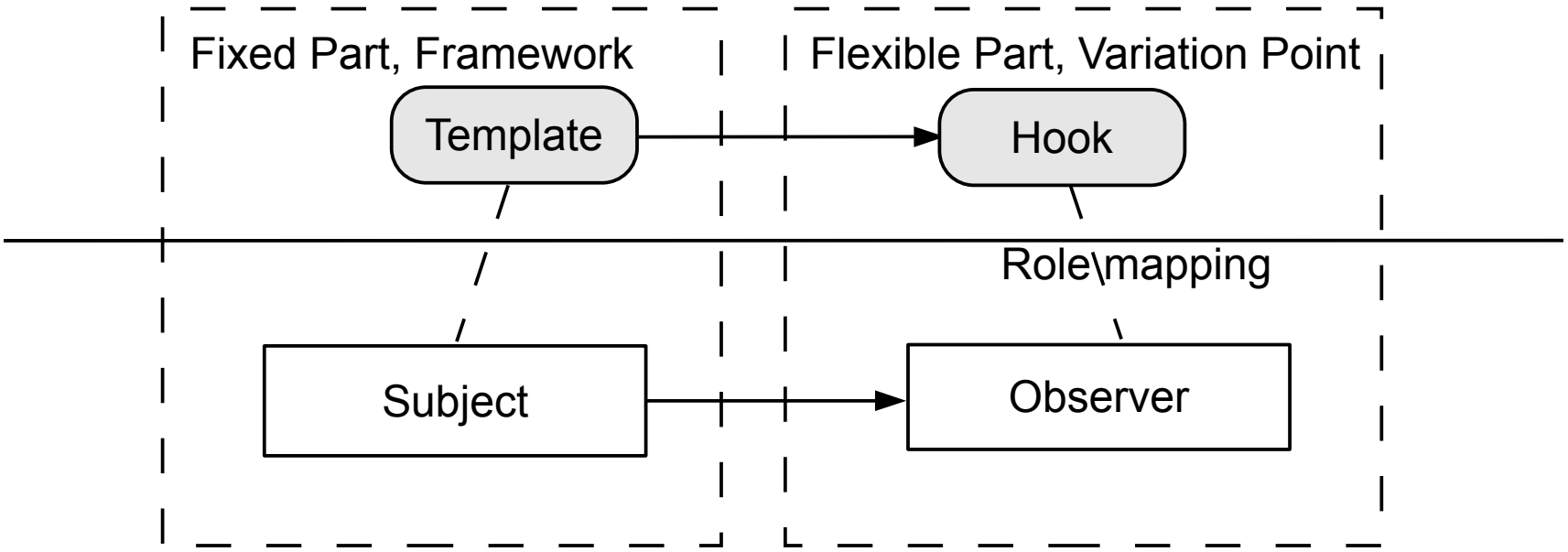
Pree's Framework Hook Patterns (Template&Hook Role Models)

- 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



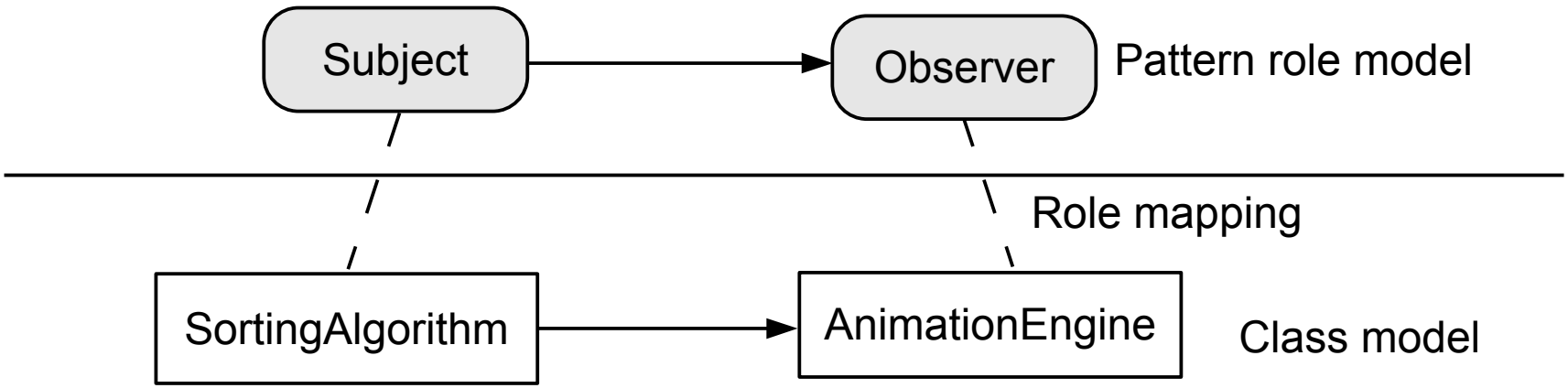
T&H Patterns and Standard Patterns

- 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.



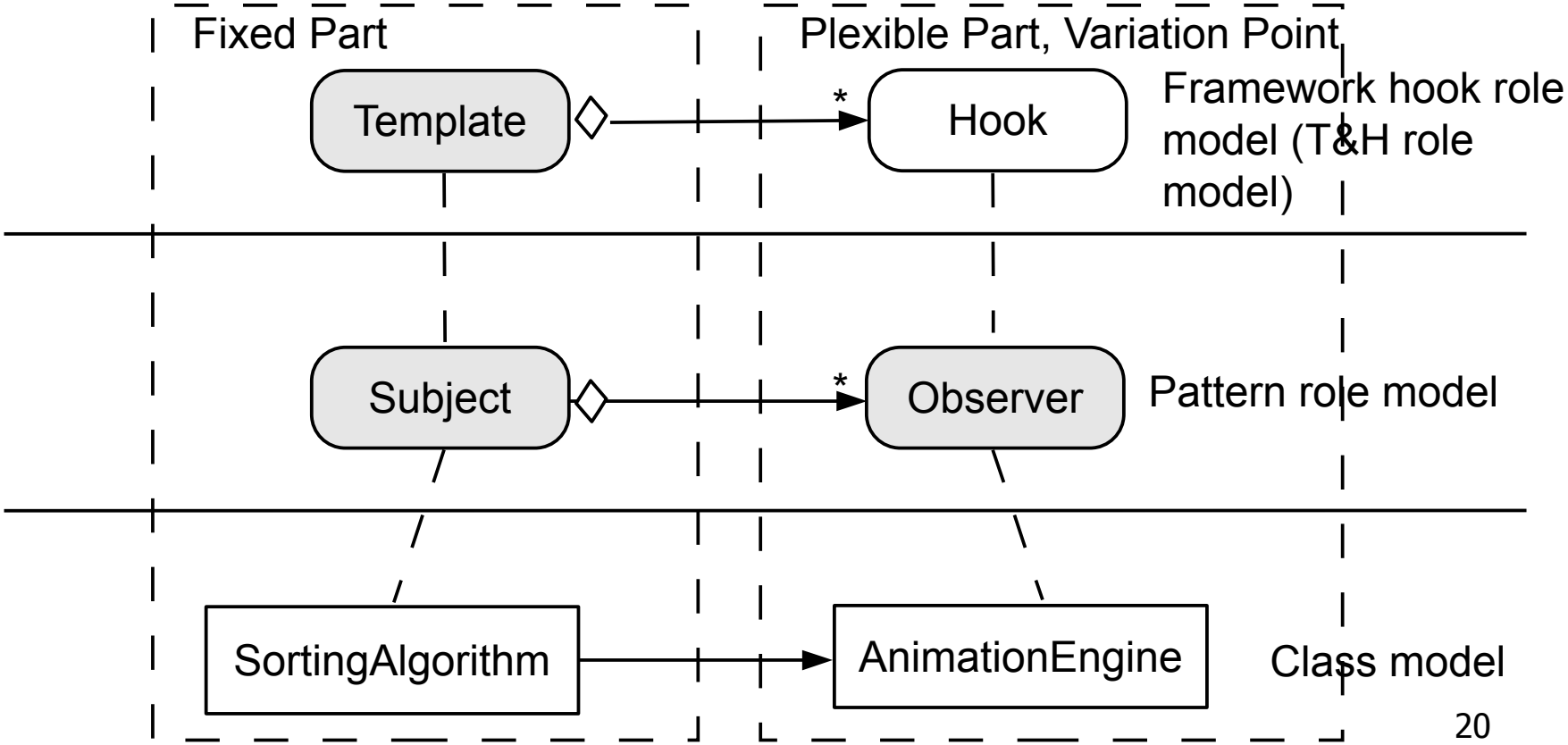
T&H in Standard Design Patterns

- 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 (exeption: DimensionalClassHierarchies)

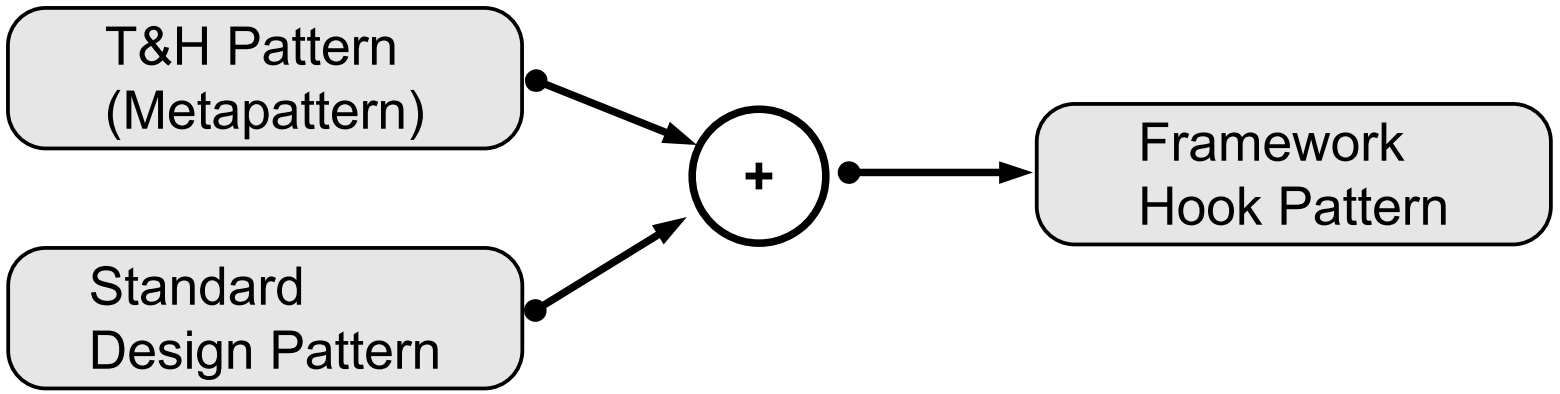


Metapatterns are Special Role Models

- 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]

Why T&H Patterns Add More to Standard Patterns

- If a metapattern is overlayed to a role model of a design pattern, it adds commonality/variability knowledge
  - It describes 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

- 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

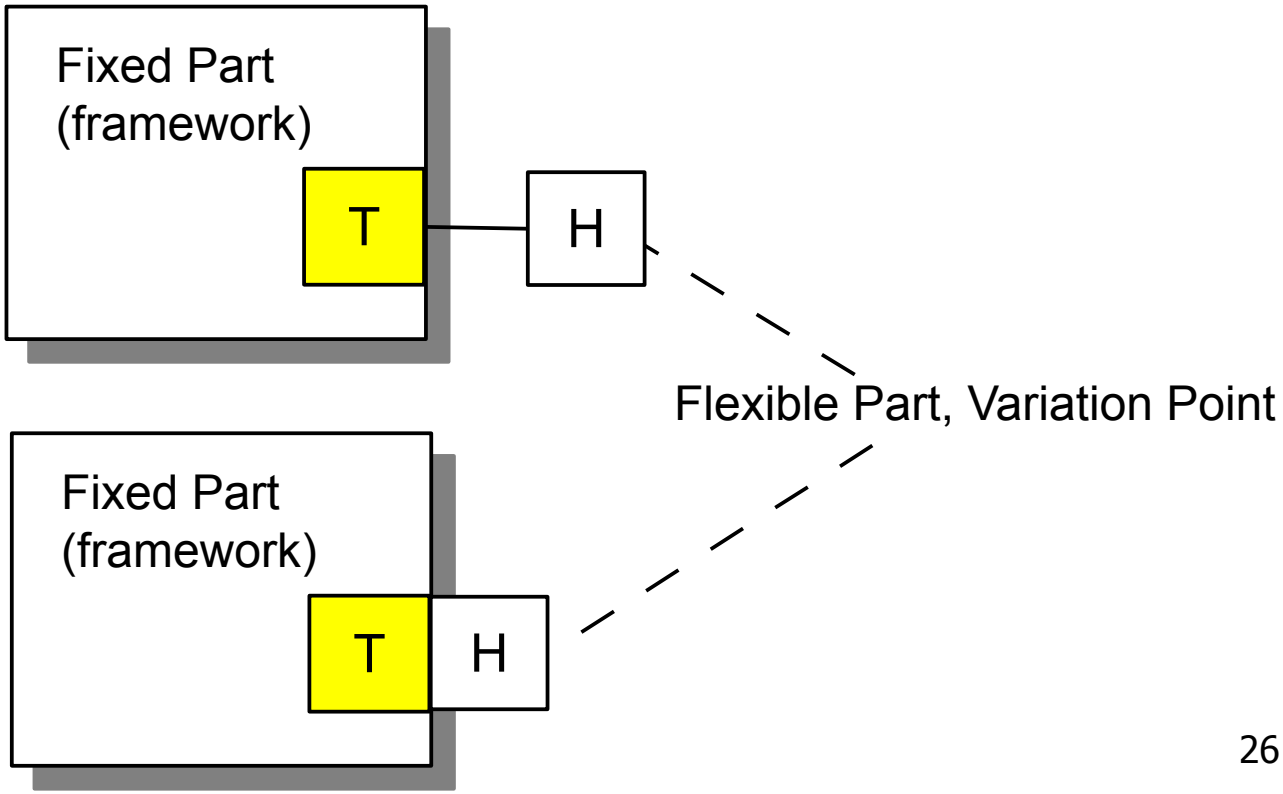
- Note: we mean in the following:
  - with the role *Template*, that the class of the role type belongs to the framework
  - with the role *Hook*, that the class of the role type belongs to the application
  - with the role *TemplateM(ethod)* that the role defines a template method, *calling* a hook method *HookM(ethod)*
- Problem: Pree uses *TemplateM/HookM,* but calls them Template/Hook
  - and varies HookM classes, which 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

- 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 overlayed
- 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 overlayed

A Simple Notation for Framework Hook Patterns

- Insight: A framework hook pattern does something like this
  - It provides a design pattern at the border of a framework
  - It combines a T&H role model with standard role models

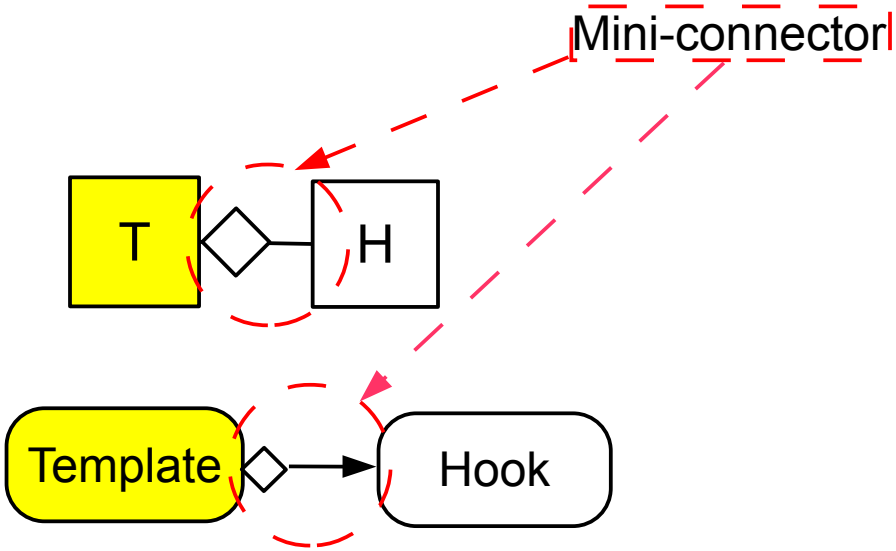


11.3 Delegation-Based Framework Hook Patterns

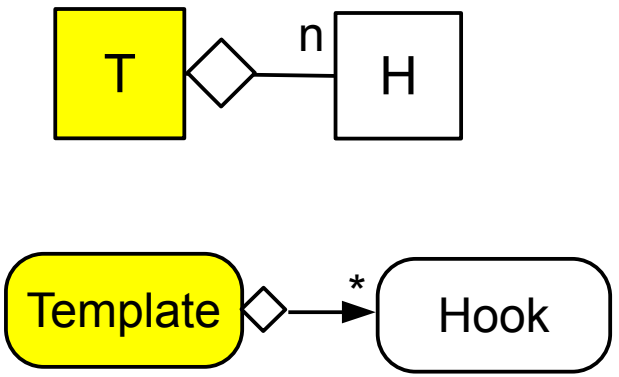
T—H Connection Pattern

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

1-T—H (open role hook)
H part of T

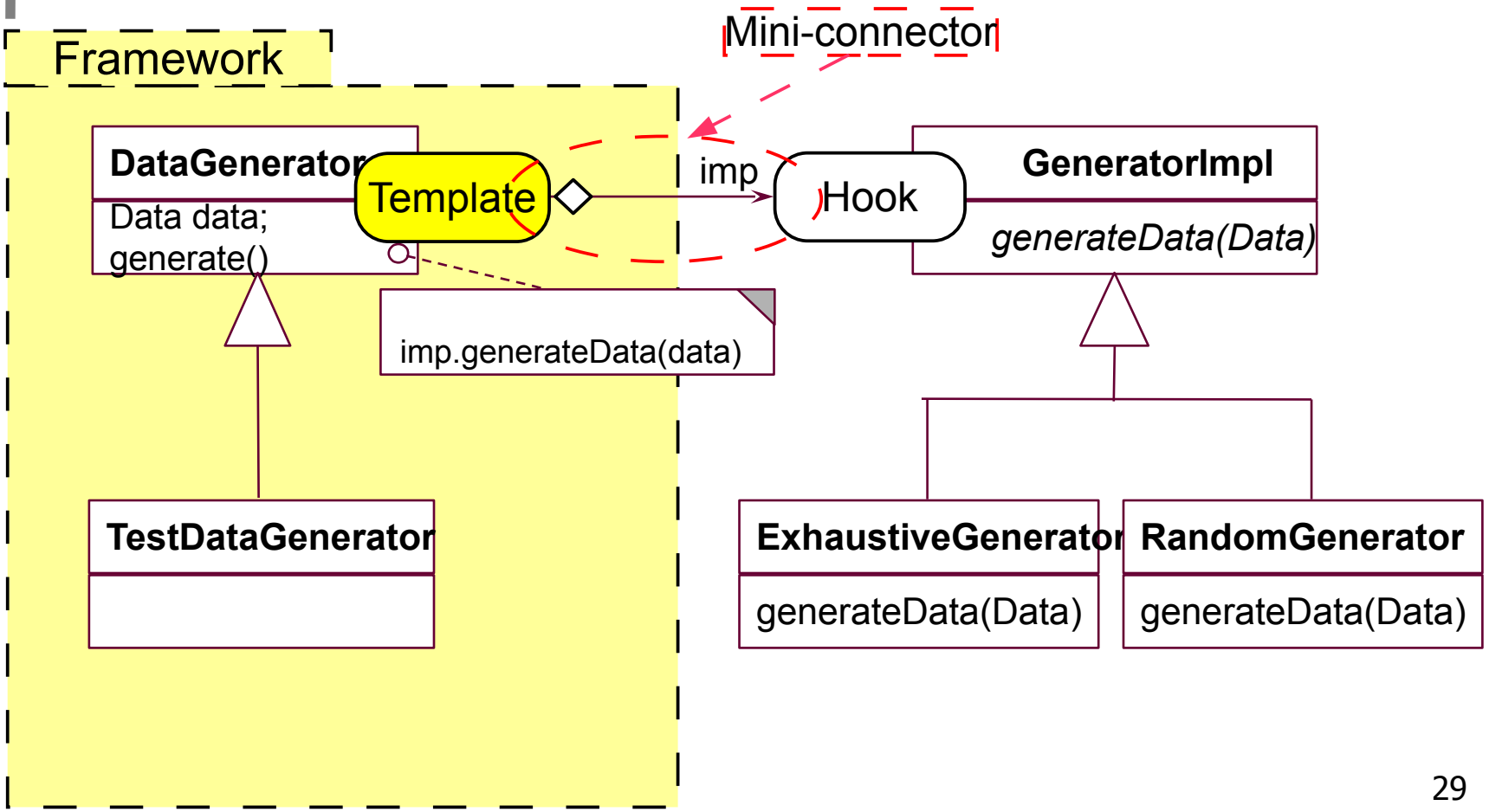


n-T—H (flat extension)
T has n H parts, n is dynamic

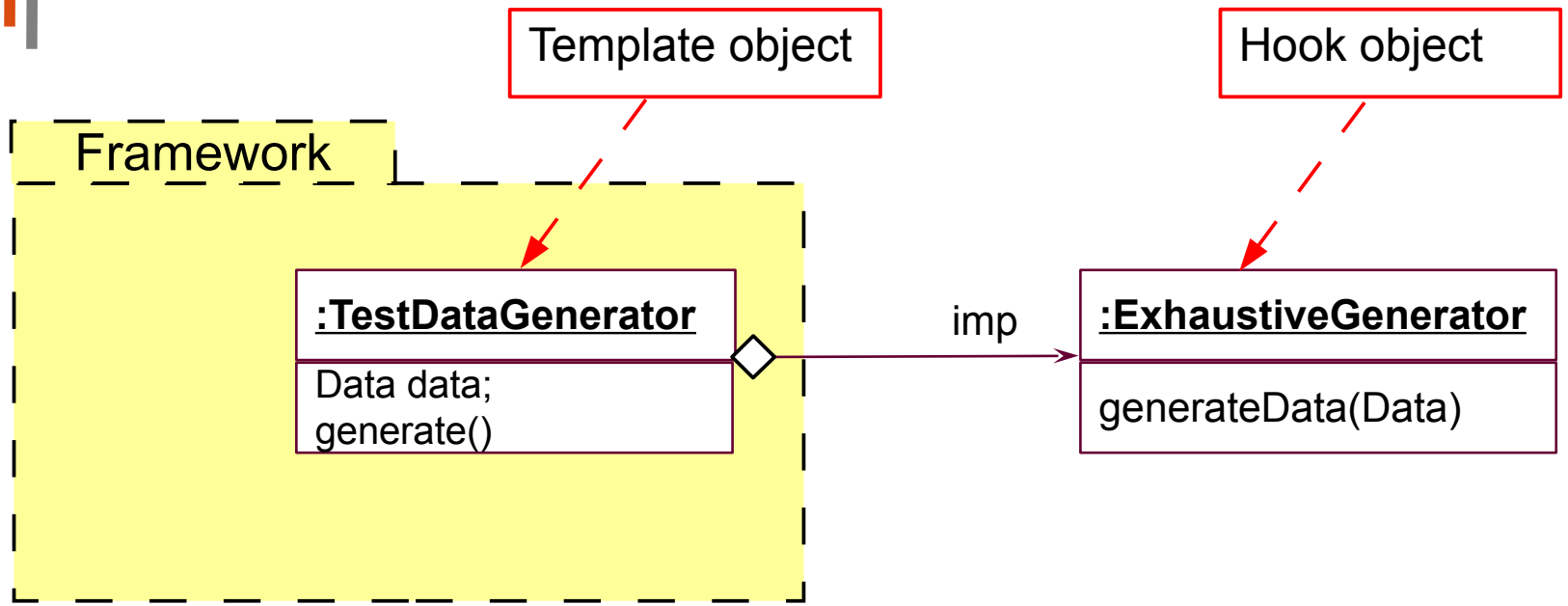


TemplateClass with 1-T--H

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

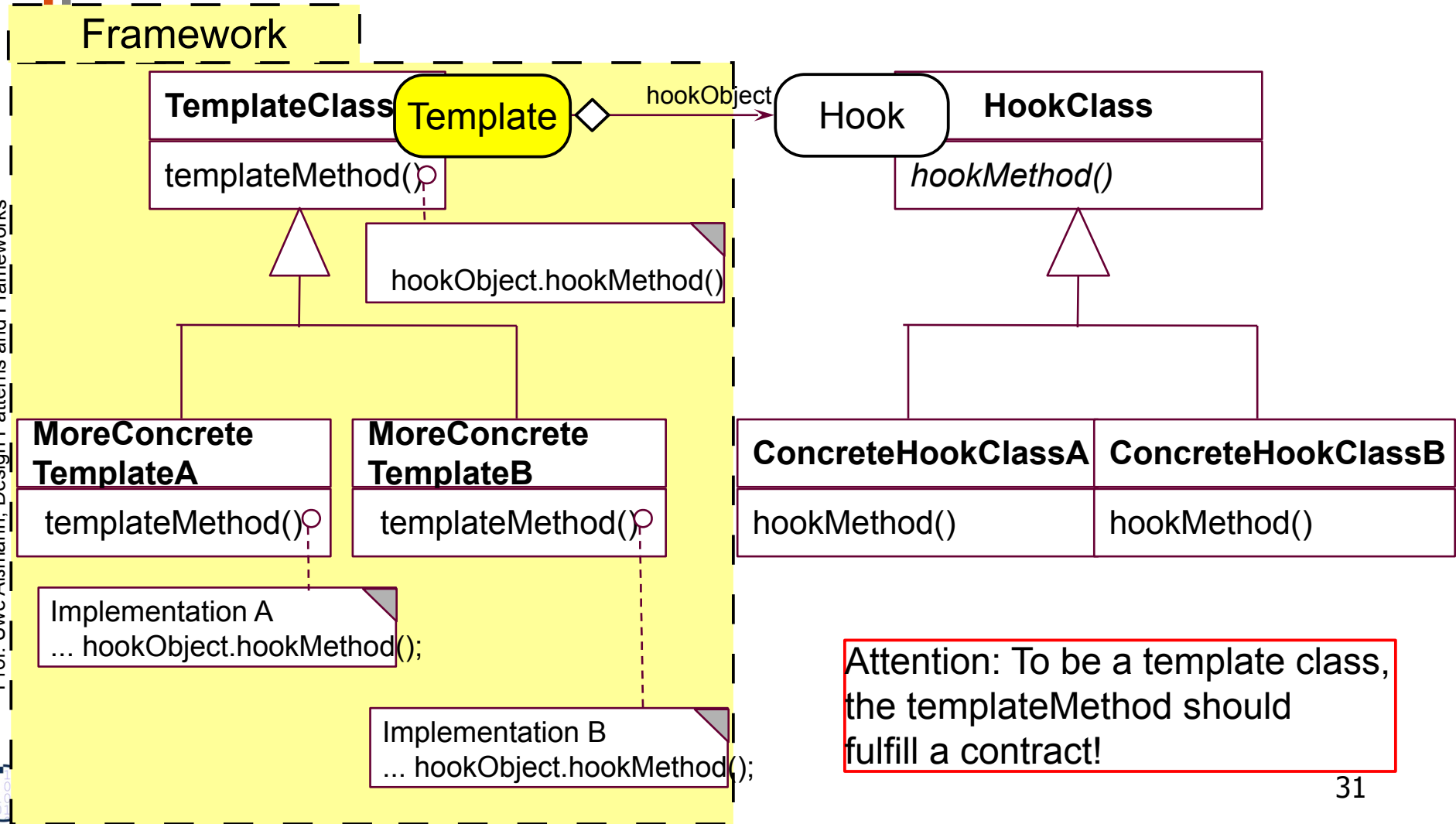


TemplateClass Runtime Scenario



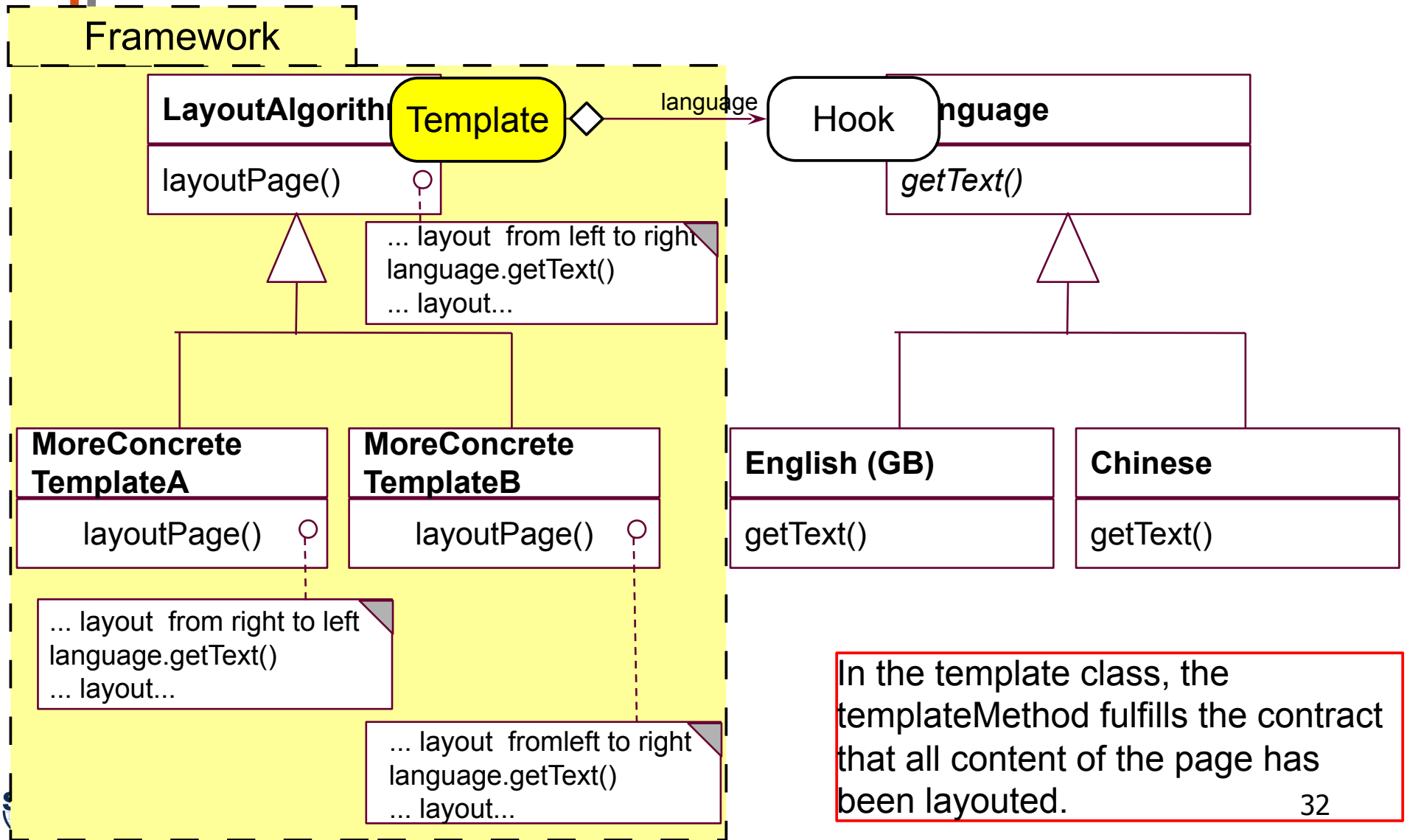
Dimensional Hierarchies with 1-T--H (Bridge with Template/Hook Constraint)

- Template classes cannot be varied by user, but by the hook subclass



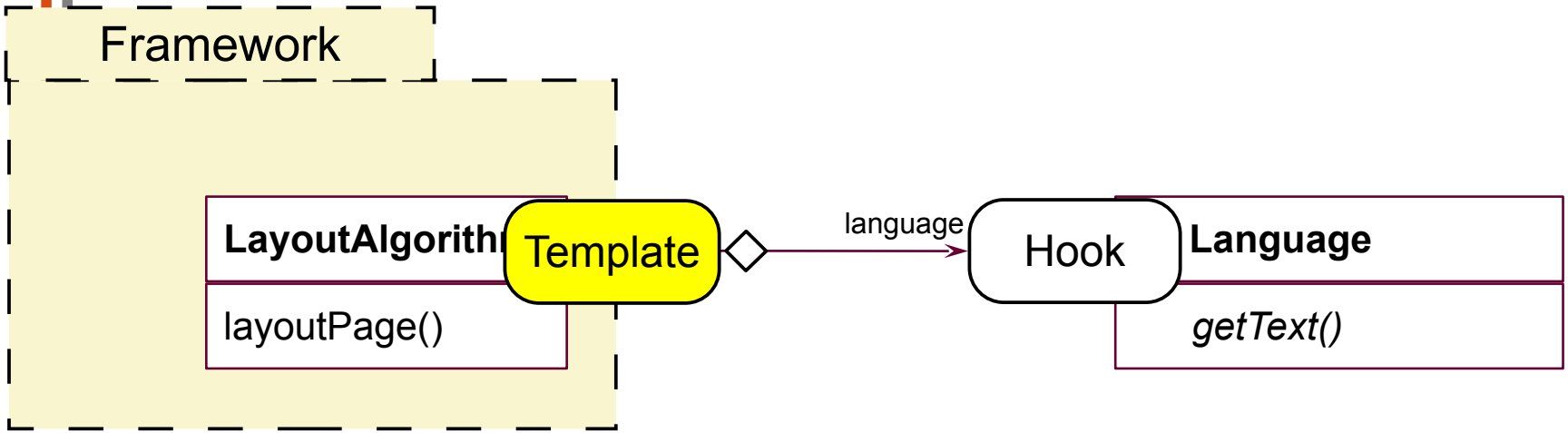
Attention: To be a template class, the templateMethod should fulfill a contract!

Internationalization as Dimensional Class Hierarchy with 1-T--H

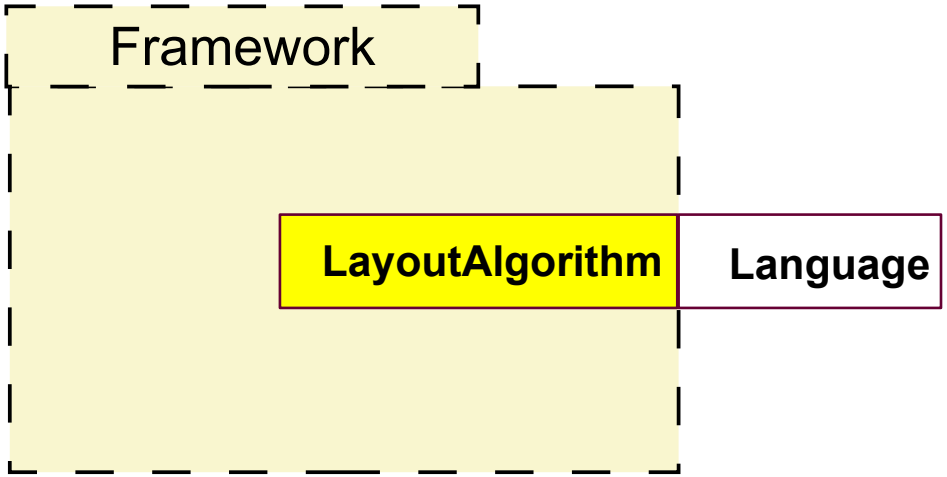


In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

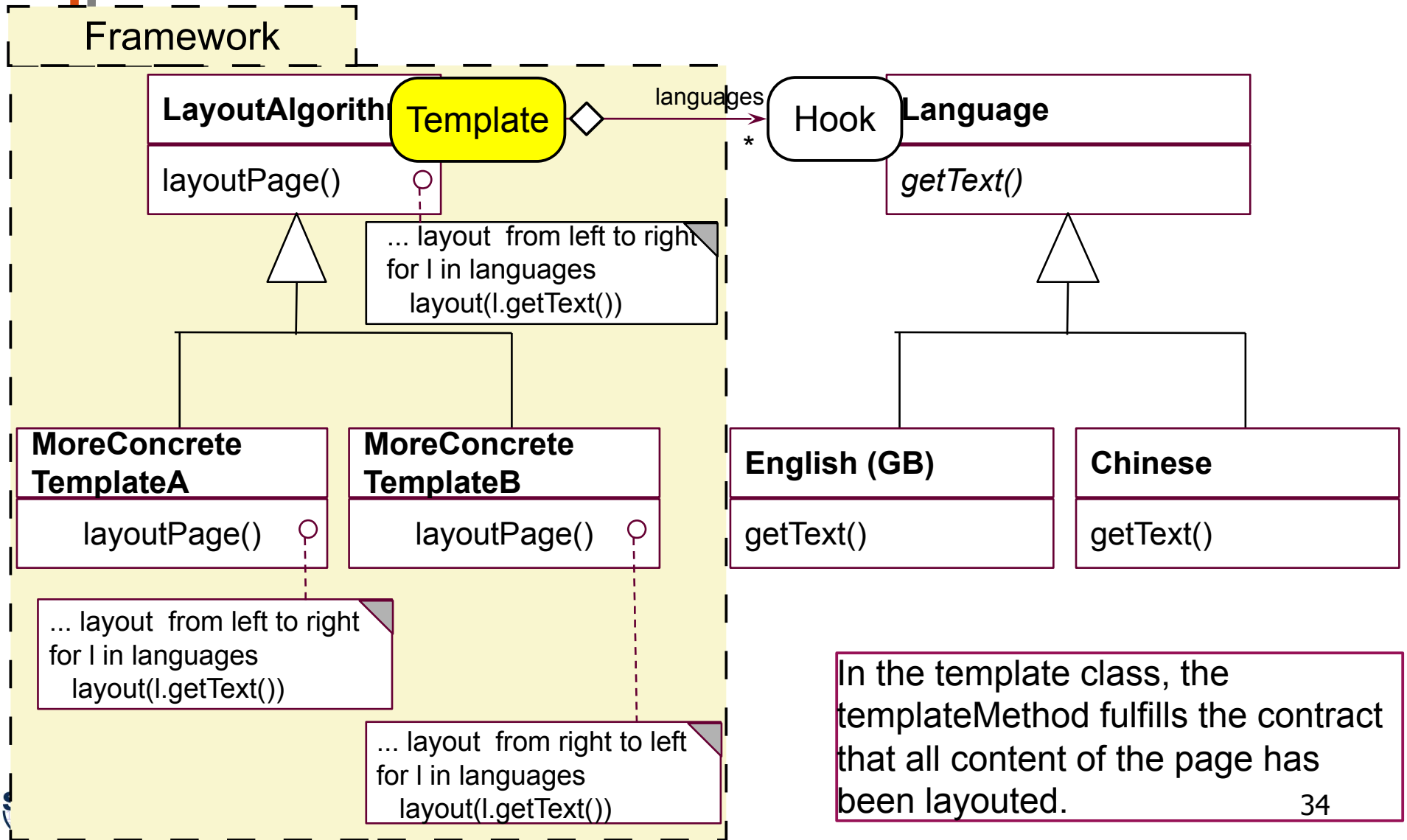
Internationalization as Dimensional Class Hierarchy with 1-T--H



- may be abbreviated to:



Multiple Internationalization as Dimensional Class Hierarchy with n-T--H

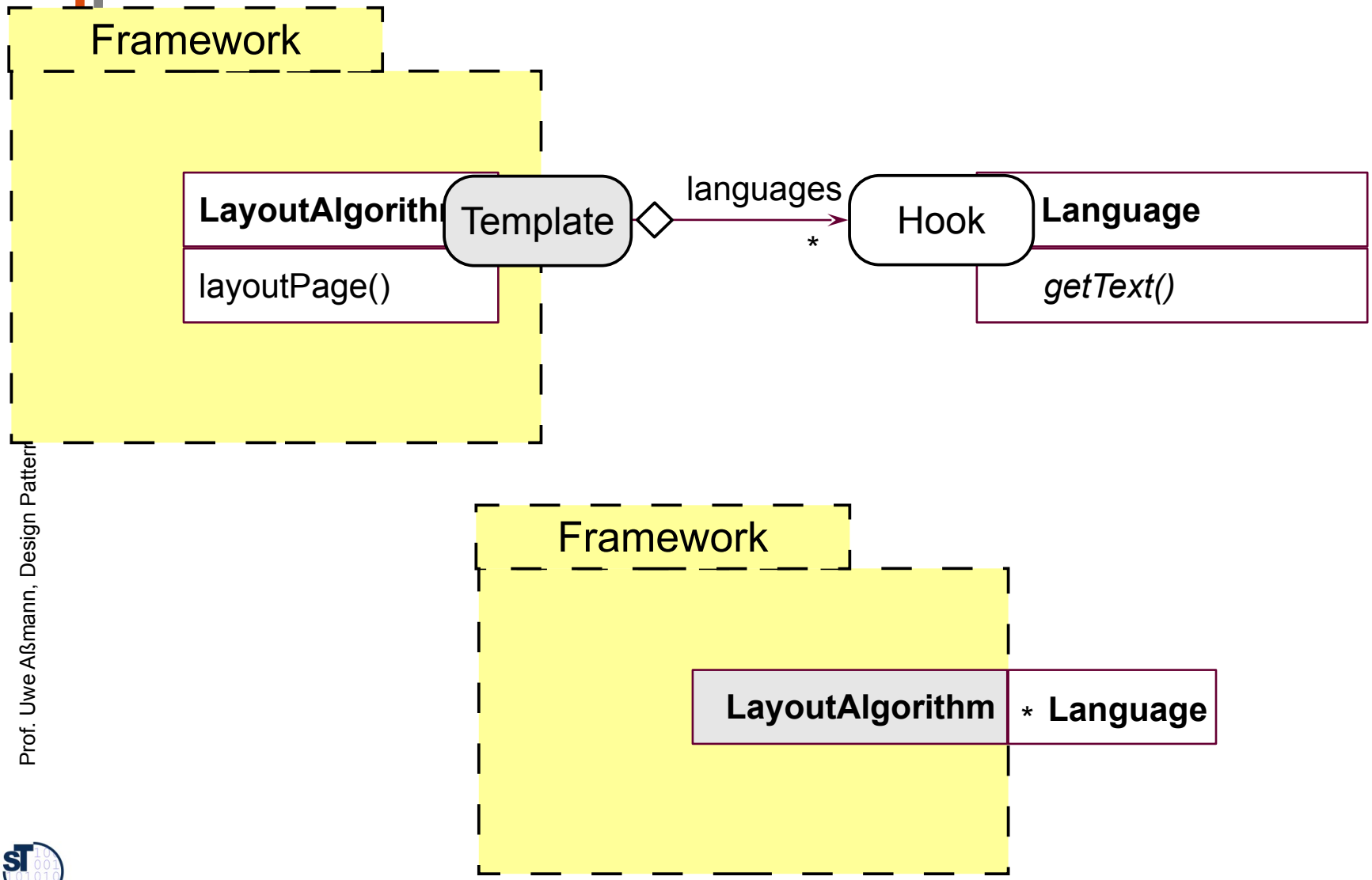


In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

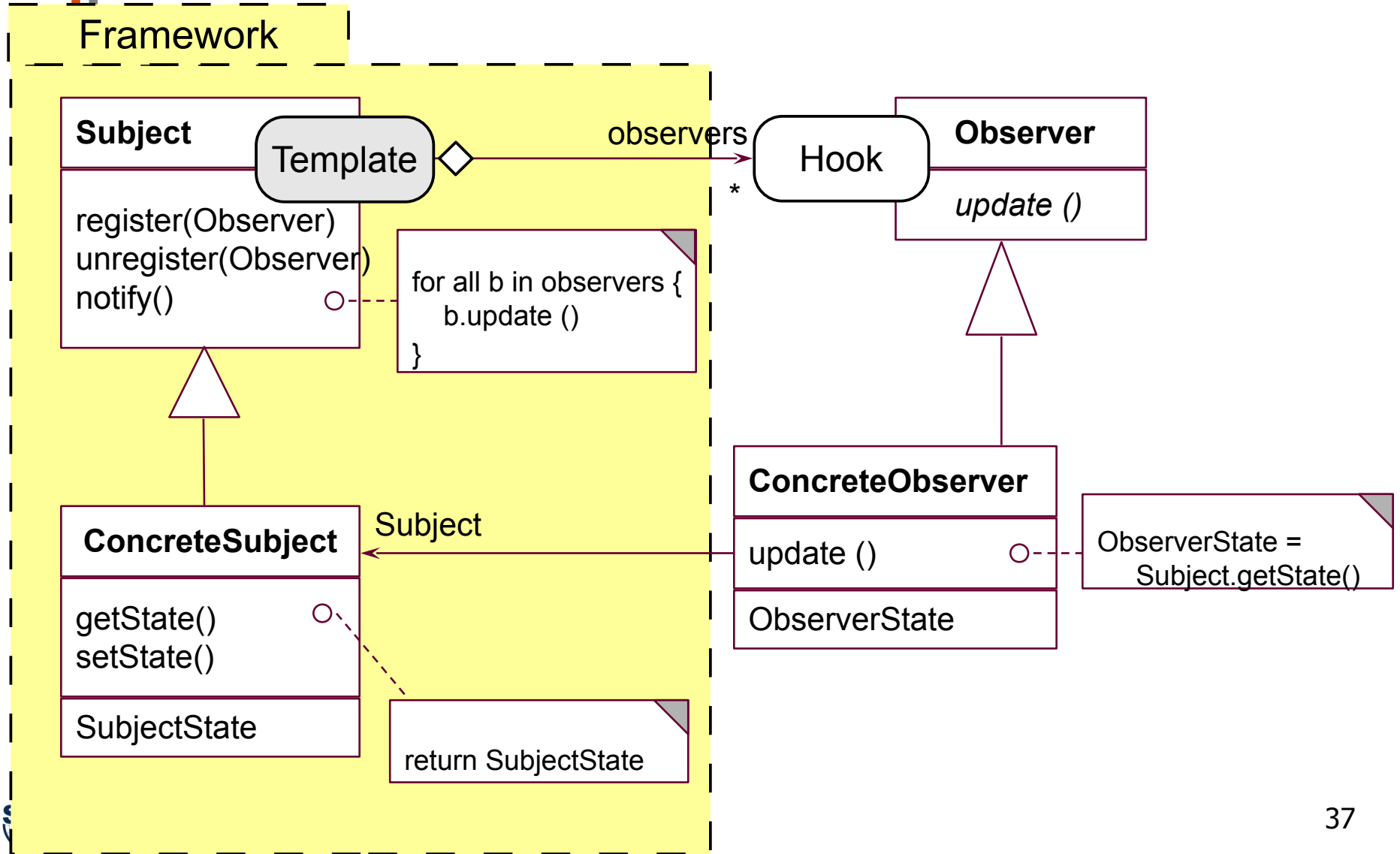
Multiple Internationalization as Dimensional Class Hierarchy with n-T--H

- 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)

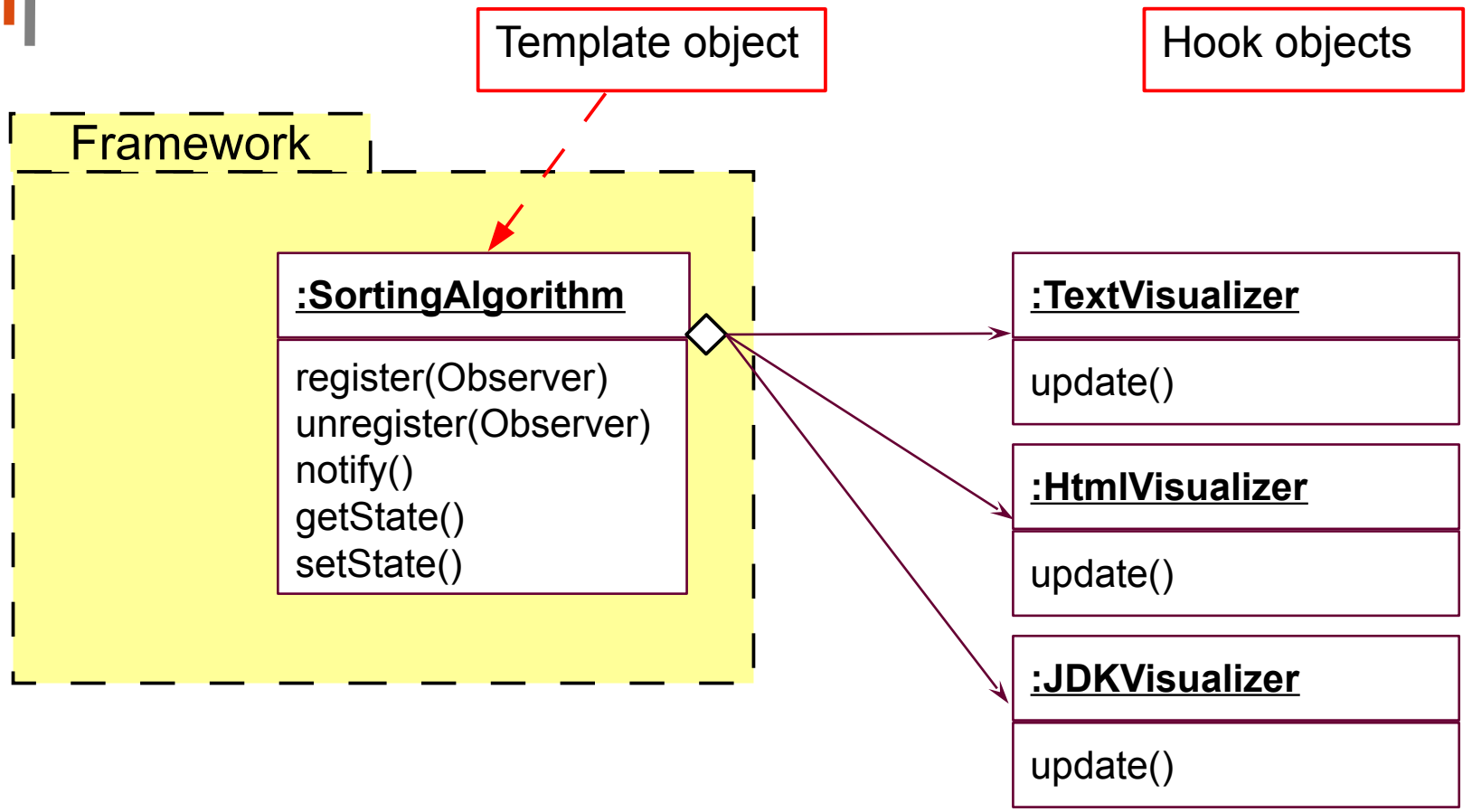
Multiple Internationalization as n-T—H Dimensional Hierarchy



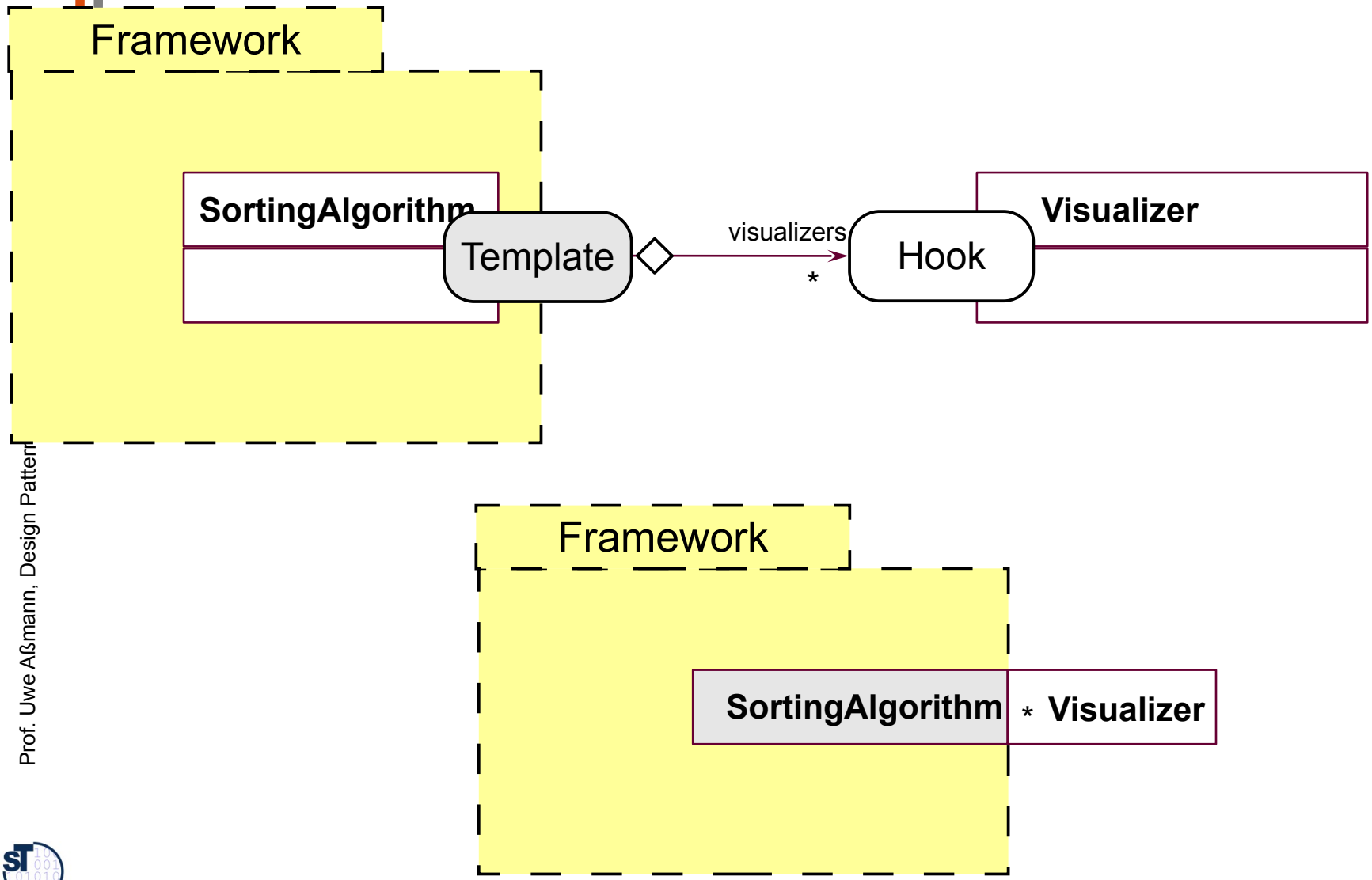
Observer as n-T—H of a Framework



Observer Runtime Scenario: Several Visualizers in Parallel



Observer-based Extensible Frameworks

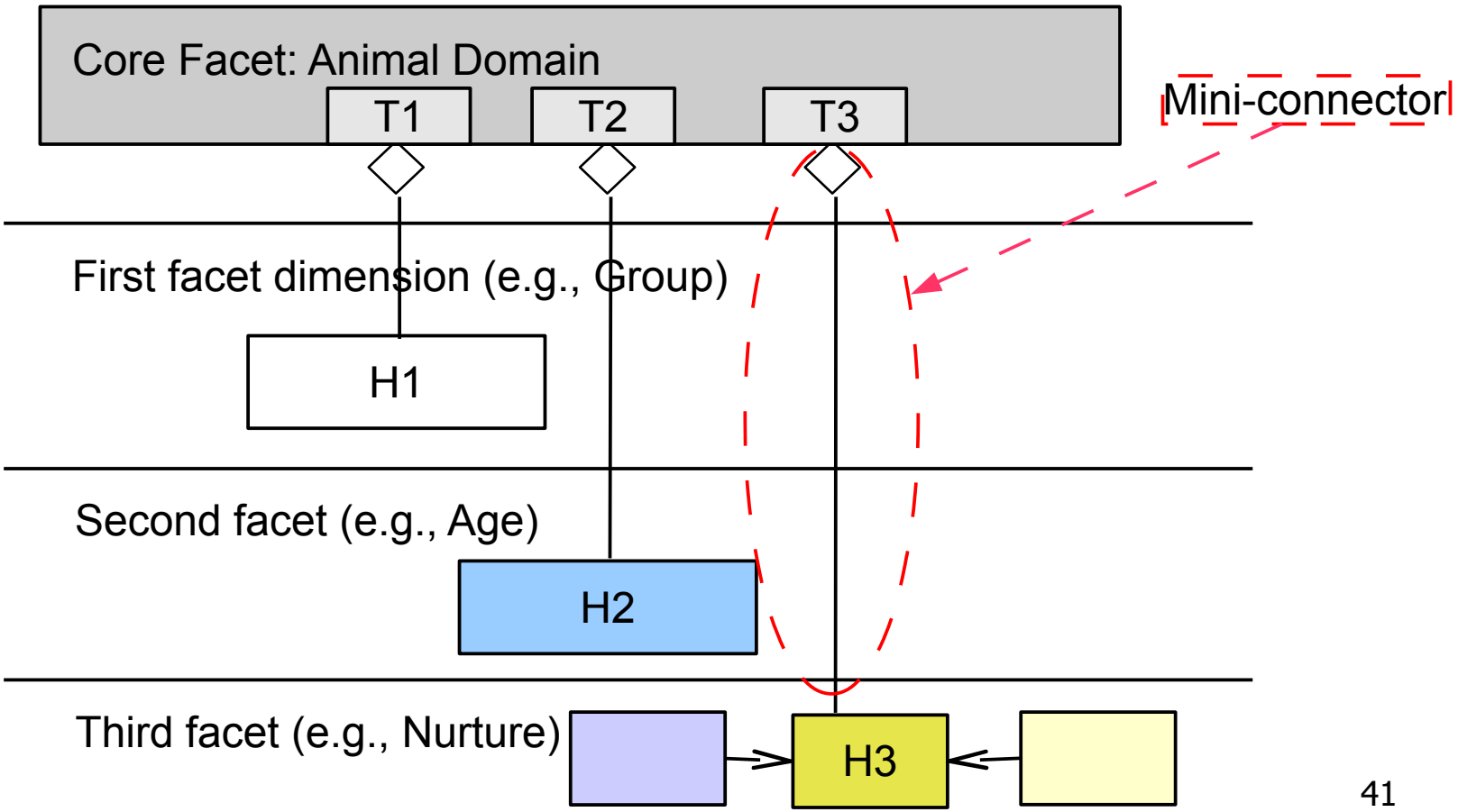


Observer

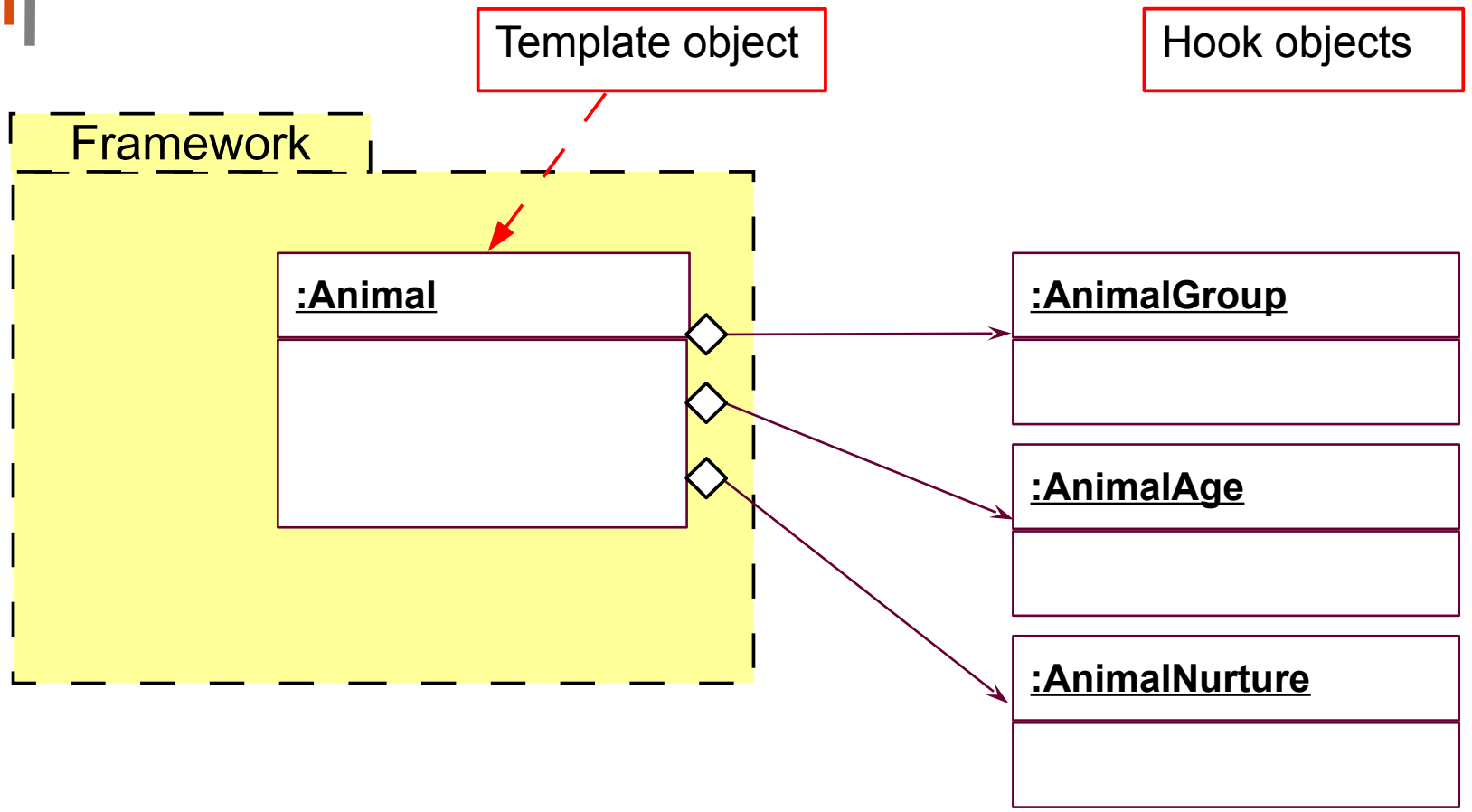
- The Observer pattern is used for extensibility
- With T&H, it becomes clear that Observers are a perfect way to achieve product lines with new feature extensions:
  - Model a critical template algorithm as Subject (template of the n-T--H)
  - Model an extension as a new Observer (hook of the n-T--H)

Bridge Frameworks Have T—H Hooks

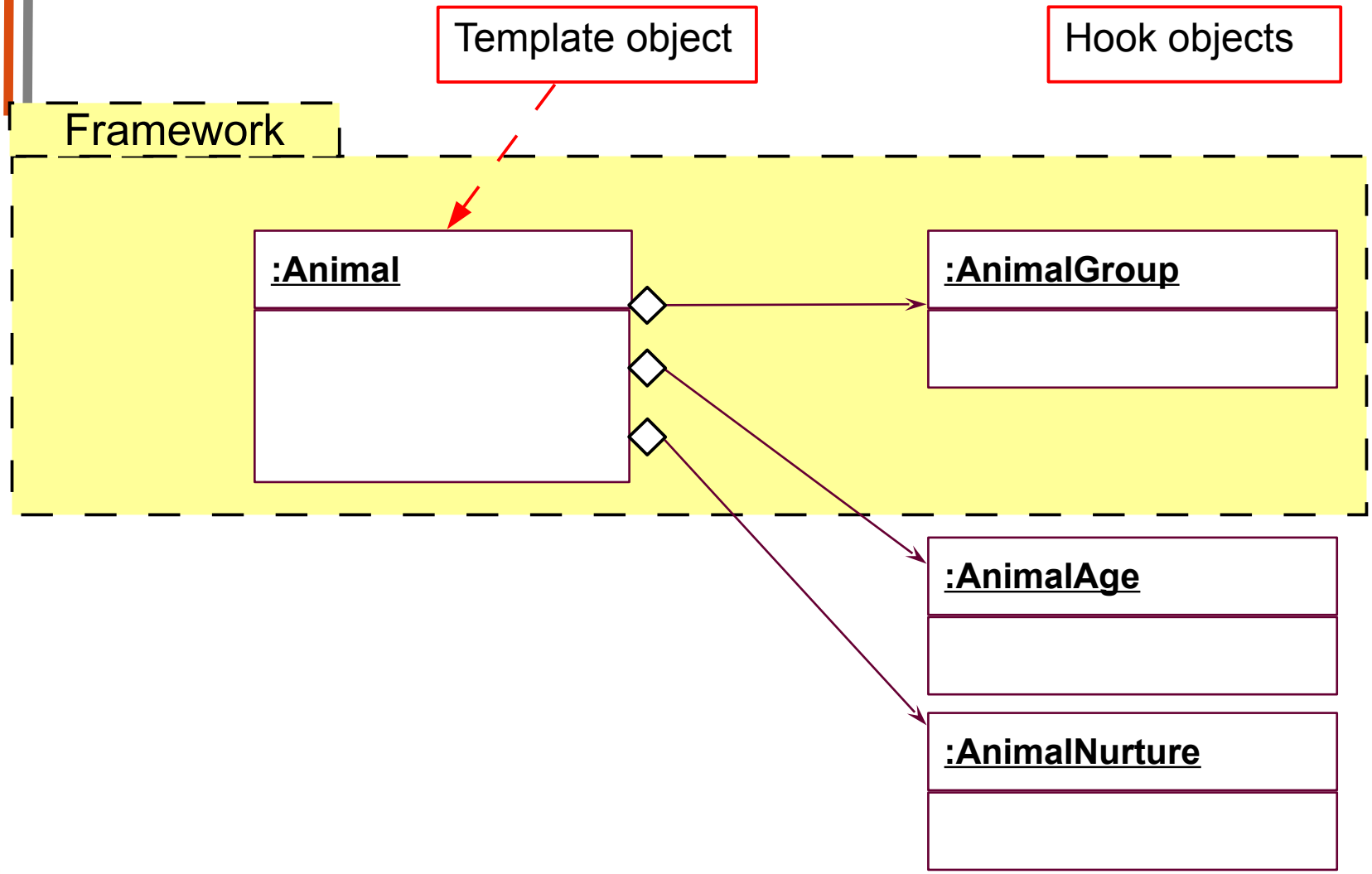
- Every dimension corresponds to a T—H hook
- Bridges, Strategy, Adapter can be used as mini-connectors



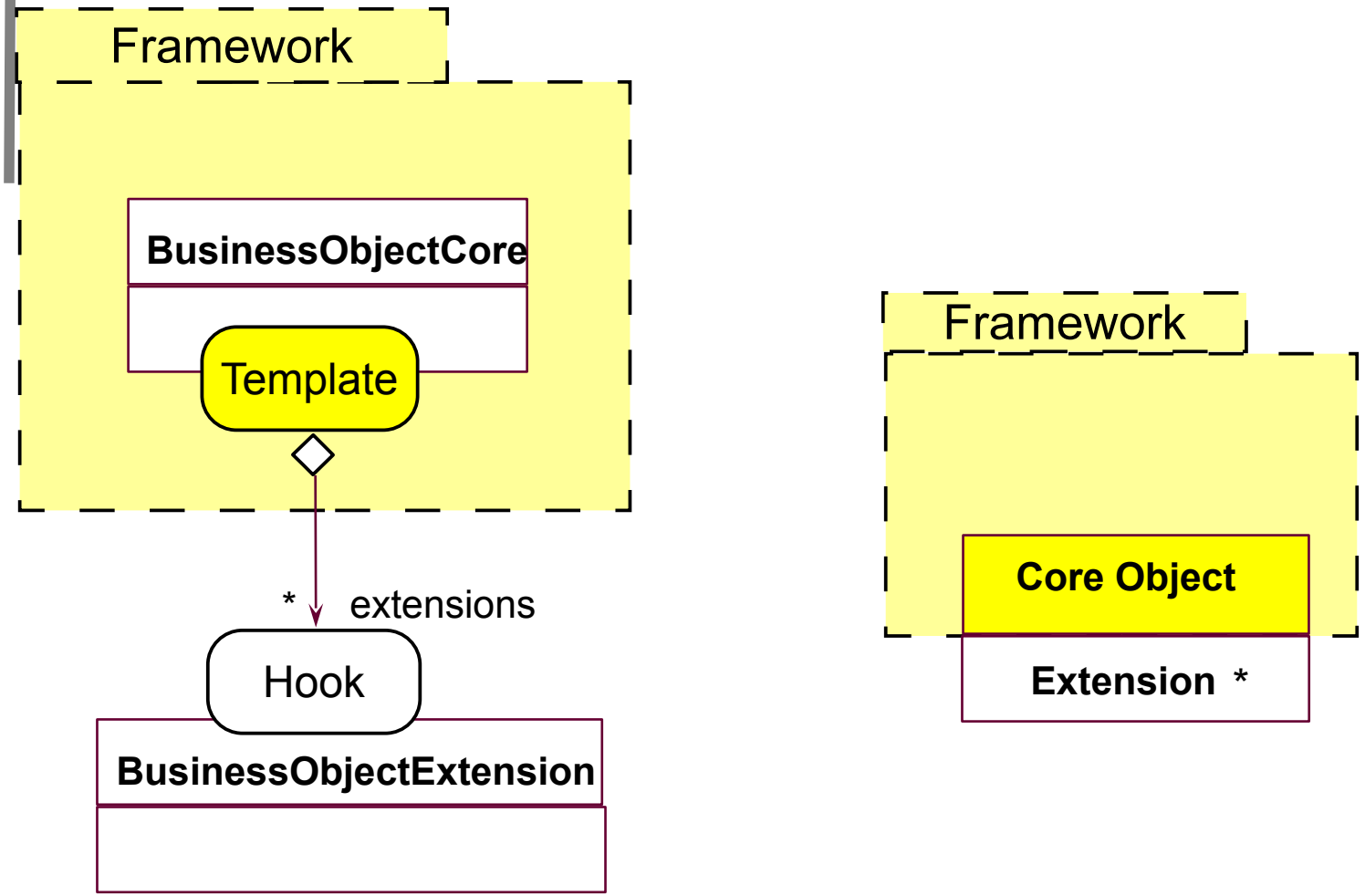
Bridge Framework Runtime Scenario



Bridge Framework Runtime Scenario, with dimension 1 in Framework



Extensible Bridge Framework with n-T--H



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

T—H Patterns Result in Blackbox Frameworks

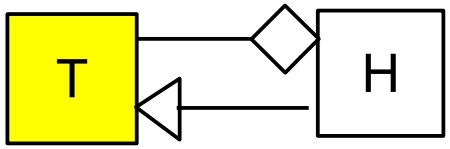
- The main relation between T and H is *delegation*.
- Hence, when overriding and instantiating H, the framework is untouched (*blackbox framework*)
- 1-T—H gives variability
- n-T—H gives extensibility

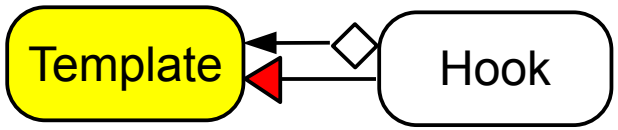
11.4 The H<=T Recursion Metapattern

H<=T Recursive Connection

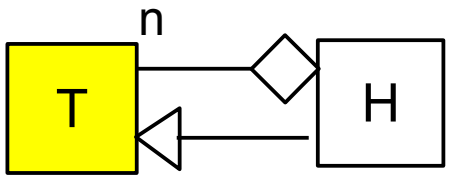
- T&H *recursive connection pattern* (H<=T framework hook, *deep extension pattern*)
  - with 1- or n-ObjectRecursion
  - H-class inherits from T; T is part of H
  - H is decorator of T (1:1) or a composed class in a composite pattern (1:n)

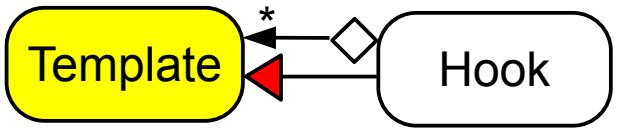
H<=T (deep list extension)
T part of H
H inherit from T
1-ObjectRecursion/Decorator





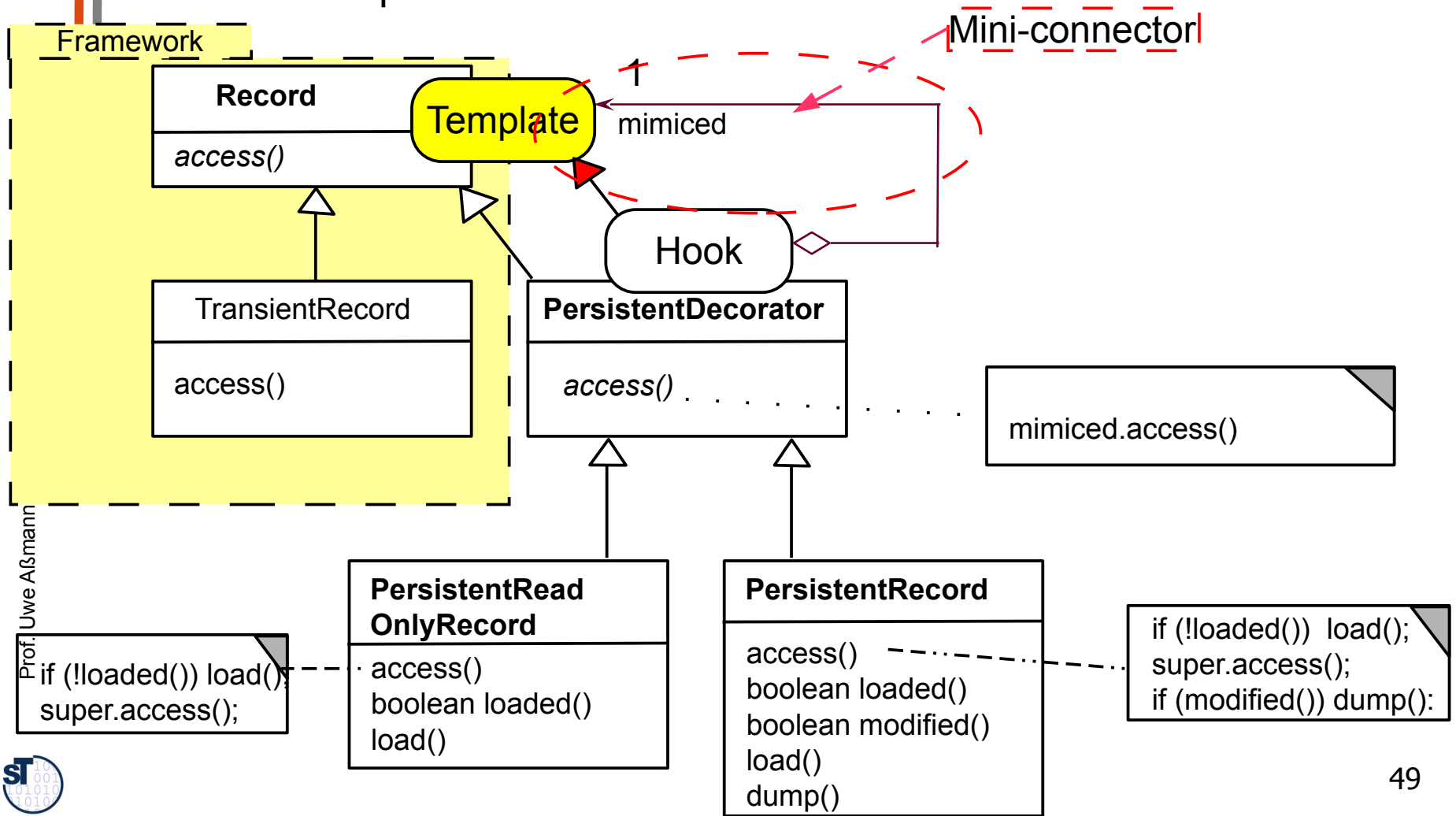
n-H<=T (deep graph extension)
H has n T parts
T inherit from H
n-ObjectRecursion/Composite





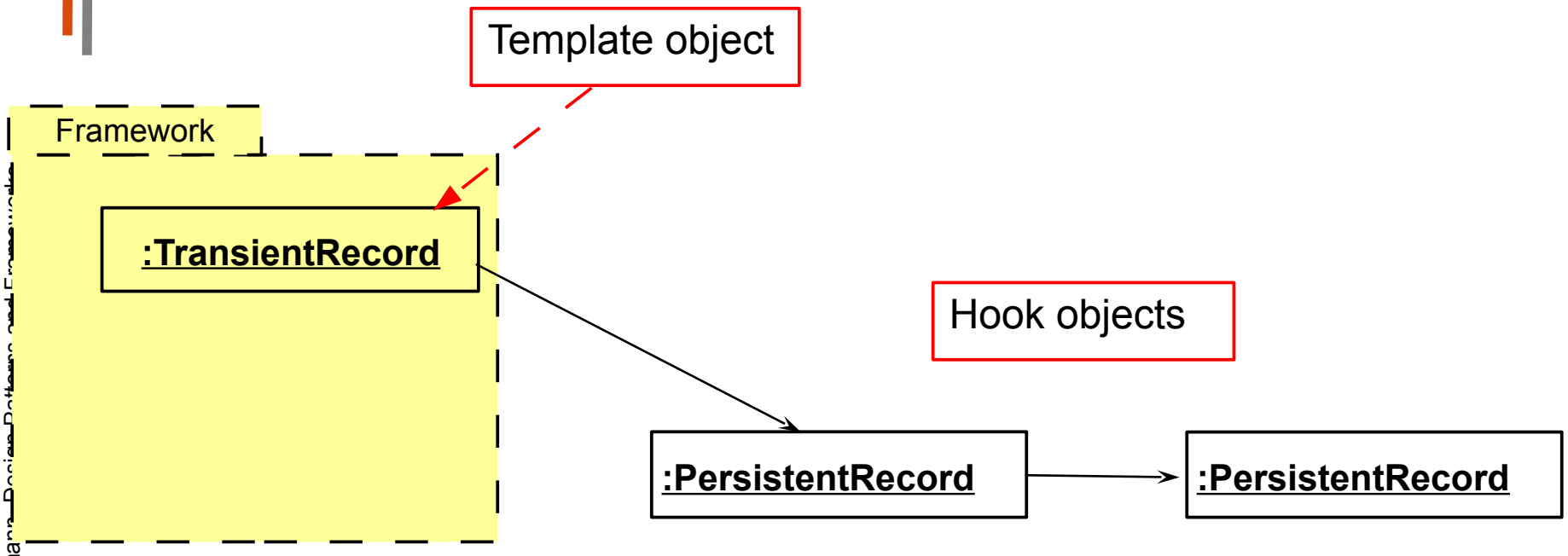
Decorator as 1-H<=T

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



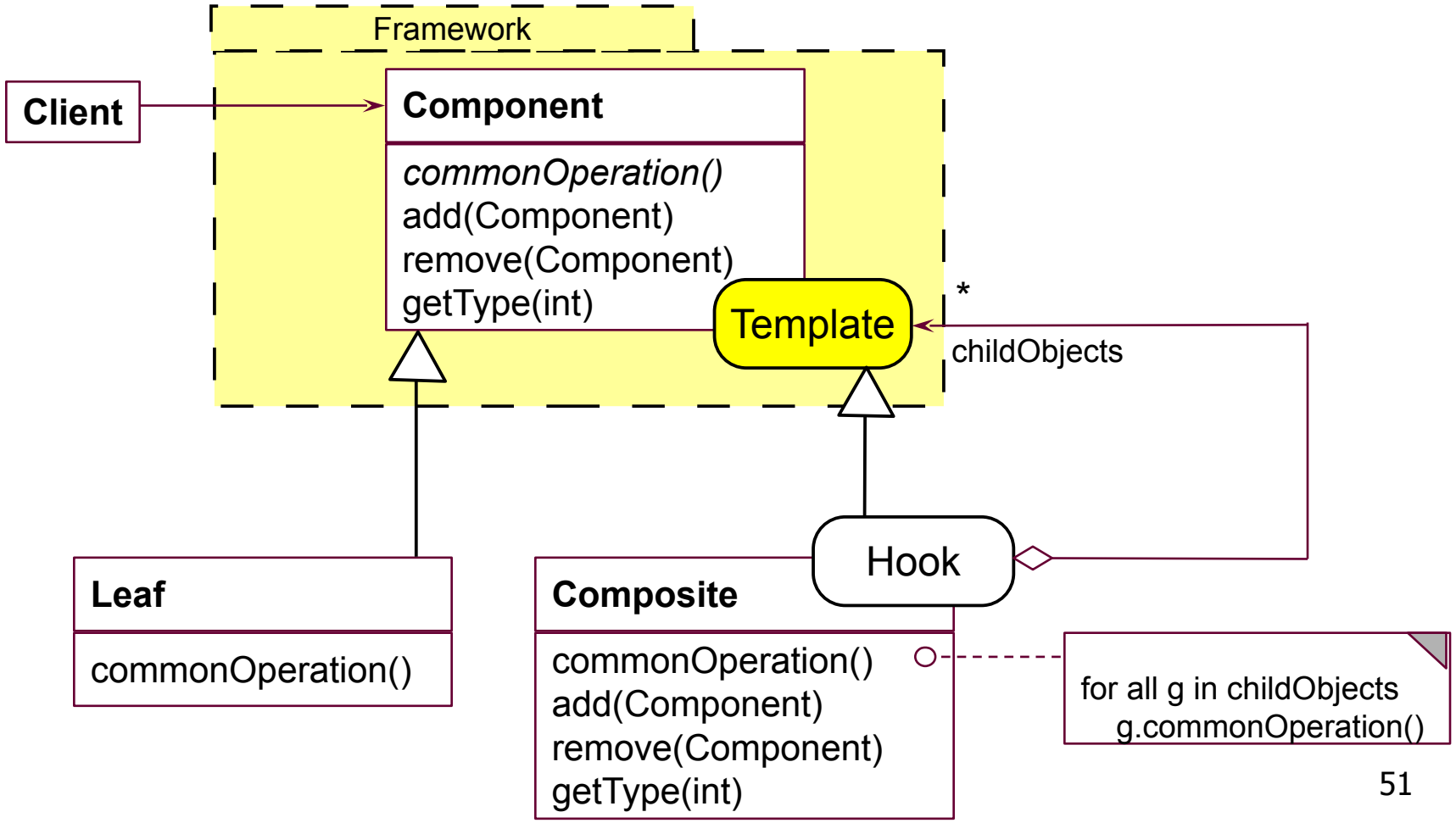
Decorator as Framework Hook Pattern

- Lists extend the framework



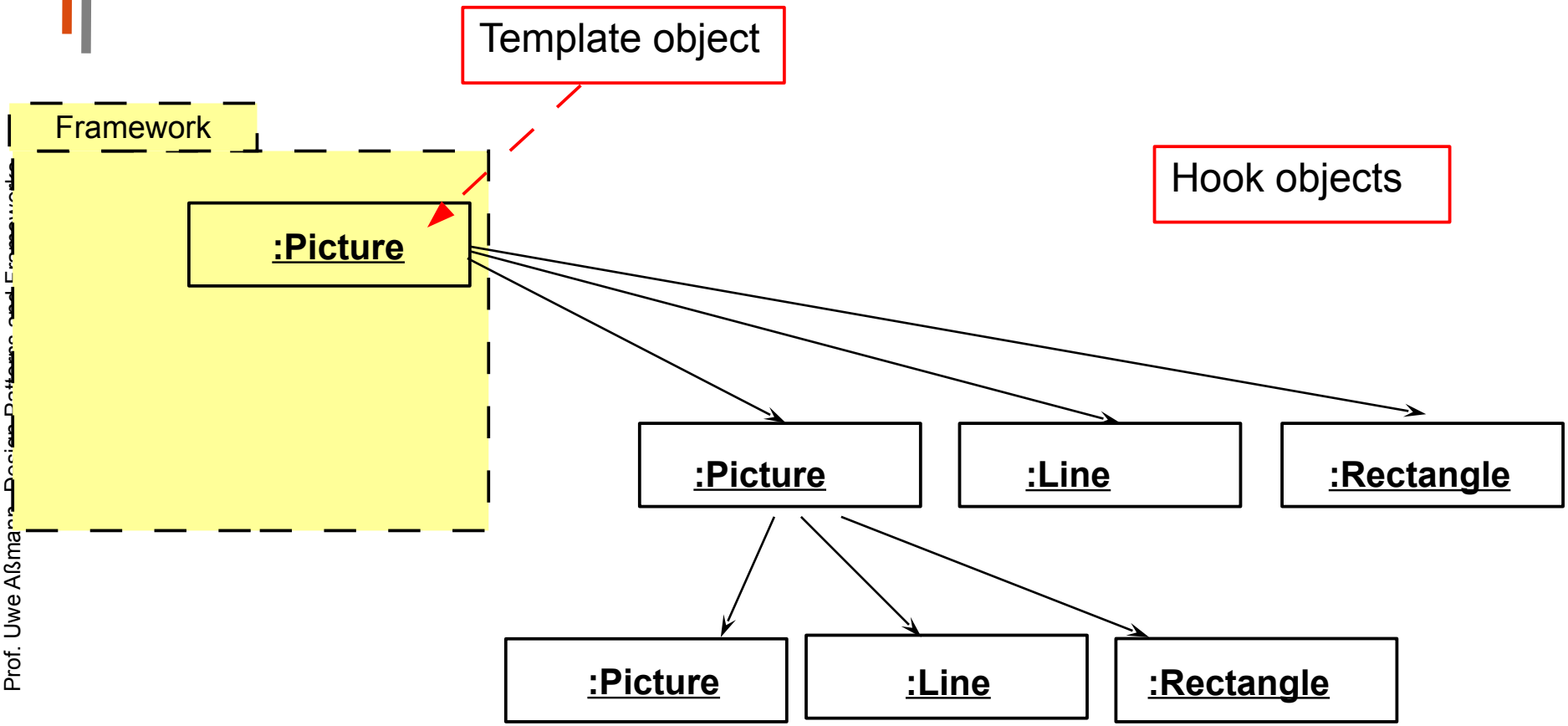
Composite as n-H<=T

- Composite is as instance of n-ObjectRecursion and n-H<=T



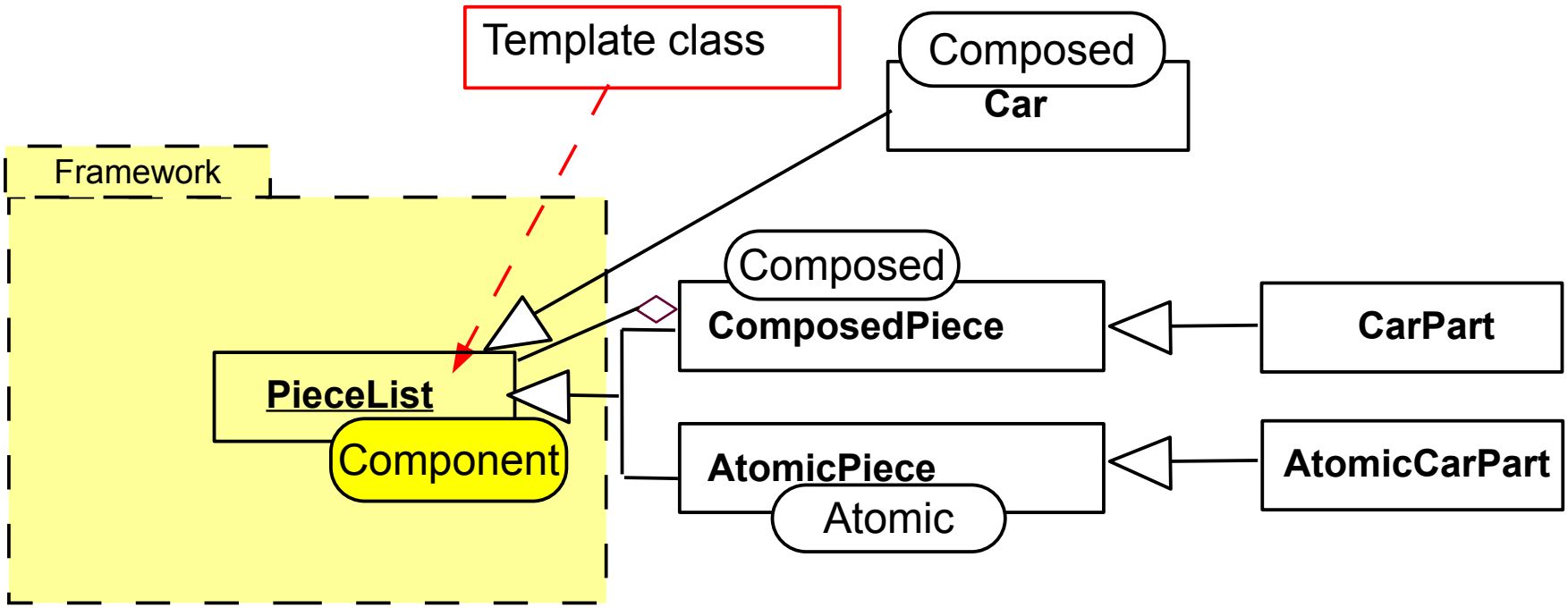
Composite as Framework Hook Pattern

- Part/Whole hierarchies extend the framework



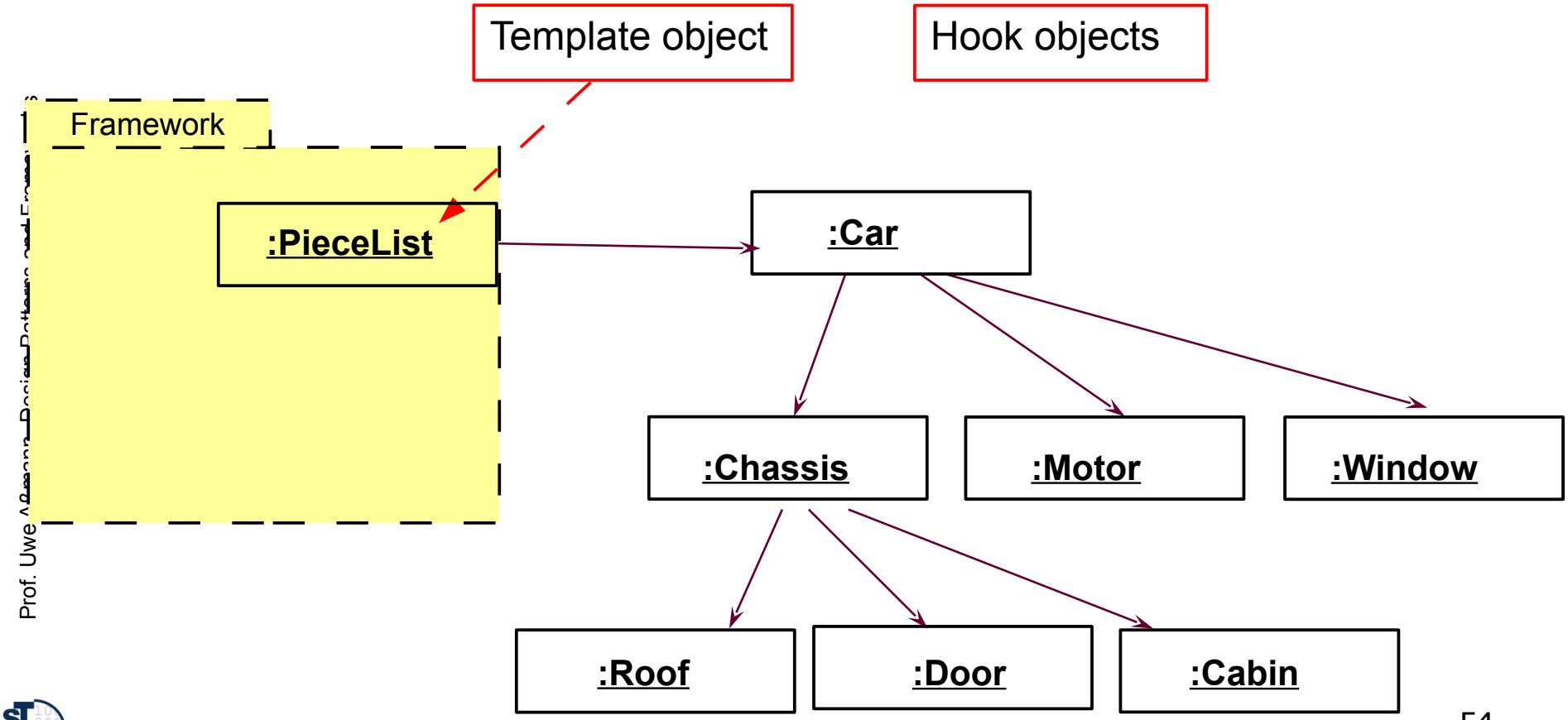
Production Data Systems

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



Production Data Systems

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

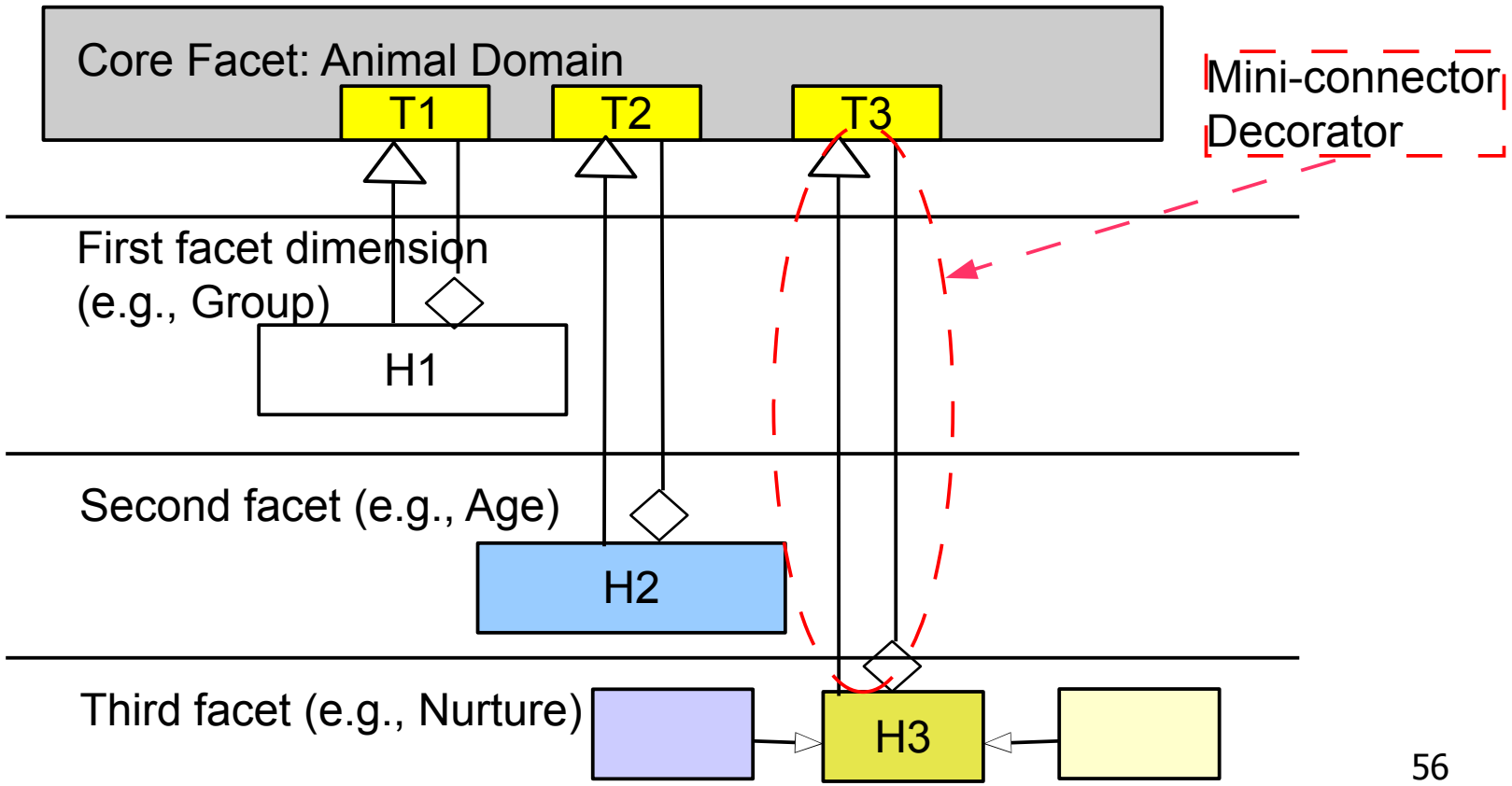


H<=T

- 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 !!

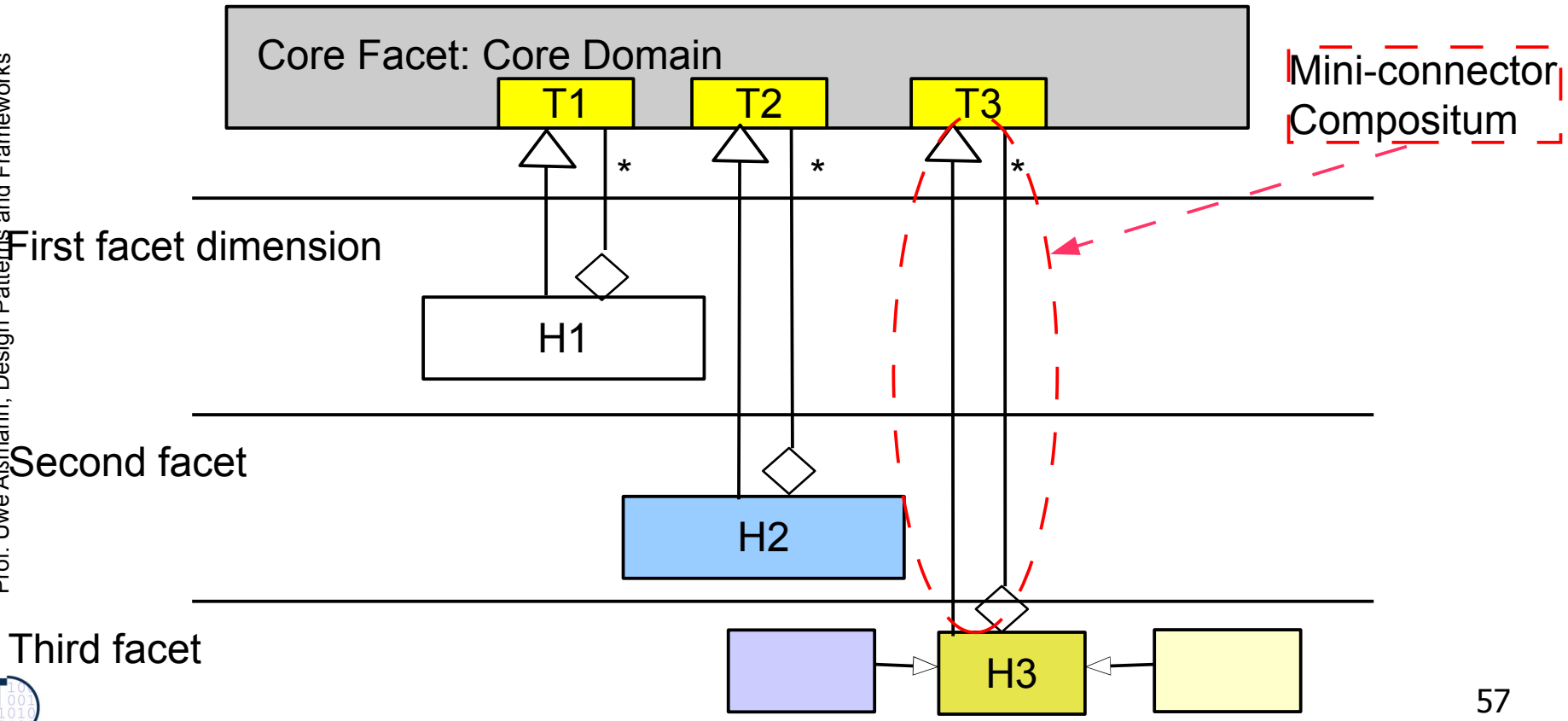
Bridge Frameworks Can Be Done with H<=T (Bridge H<=T Framework)

- 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)

- Composite as mini-connector

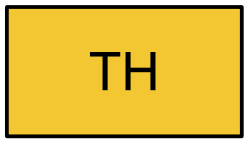


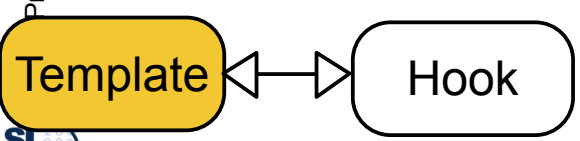
11.5 The TH Unification Metapattern

TH

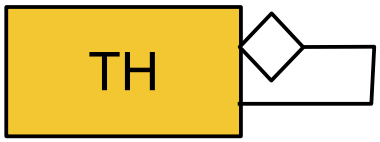
- Unified T&H pattern (TH framework hook)
  - T-class == H-class

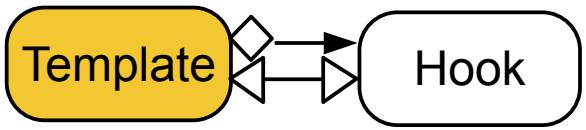
TH
T == H
TH part of TH
“funny” Decorator



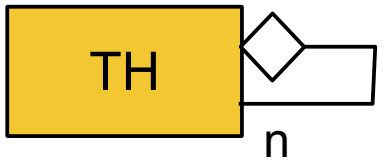


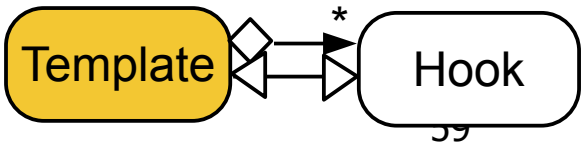
1-TH (deep list extension)
T == H
TH part of TH
“funny” Decorator





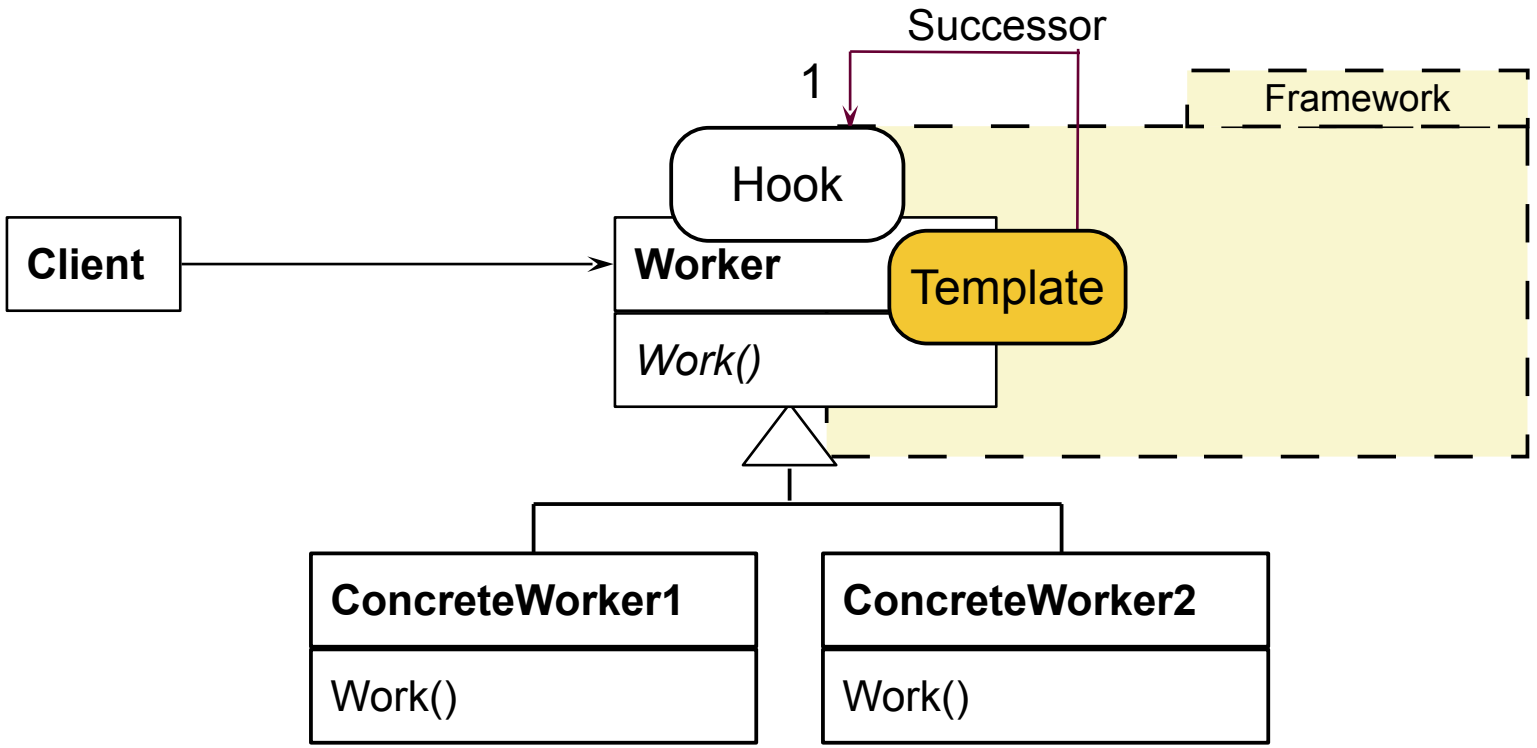
n-TH (deep tree extension)
T == H
TH has n TH parts
“funny” 1:n-Composite



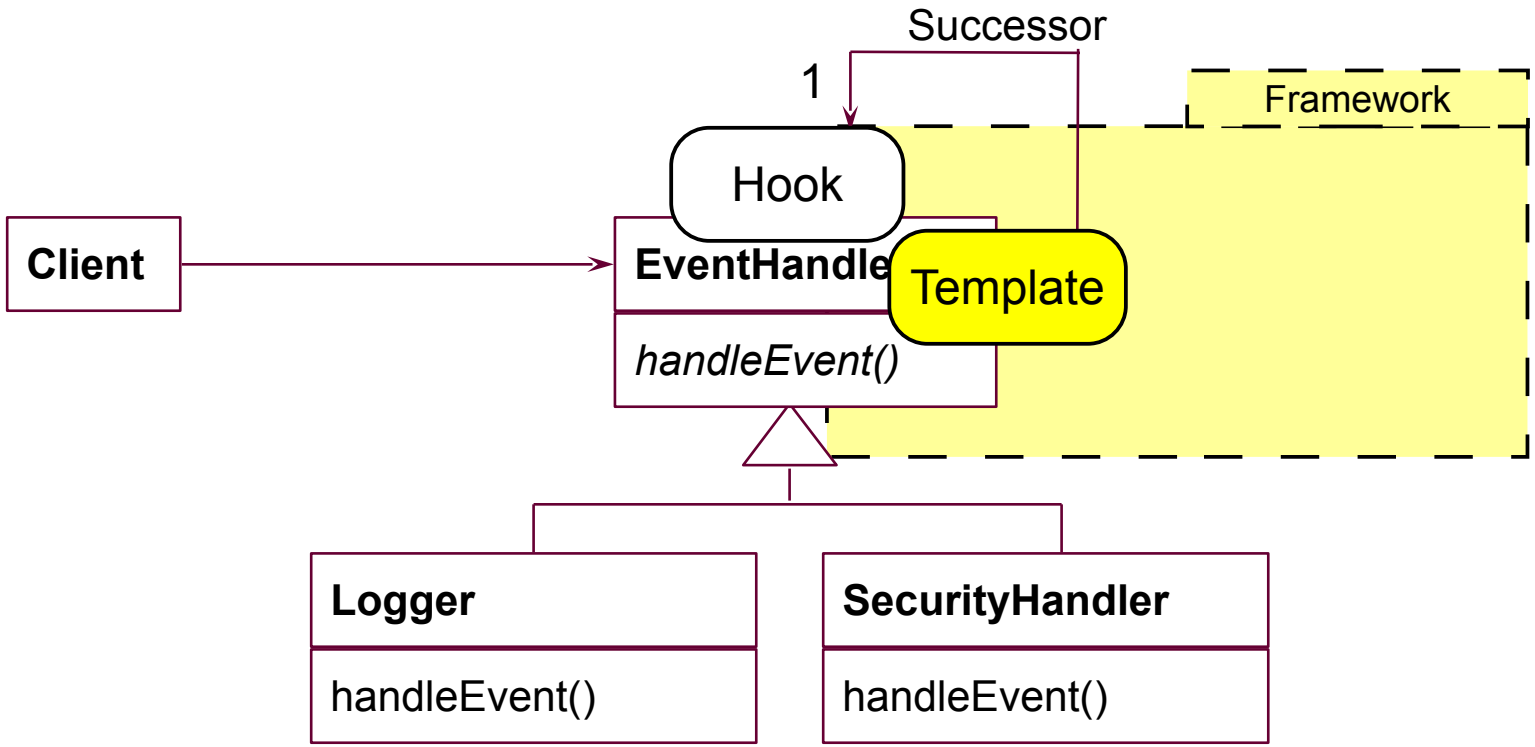


ChainOfResponsibility as 1-TH

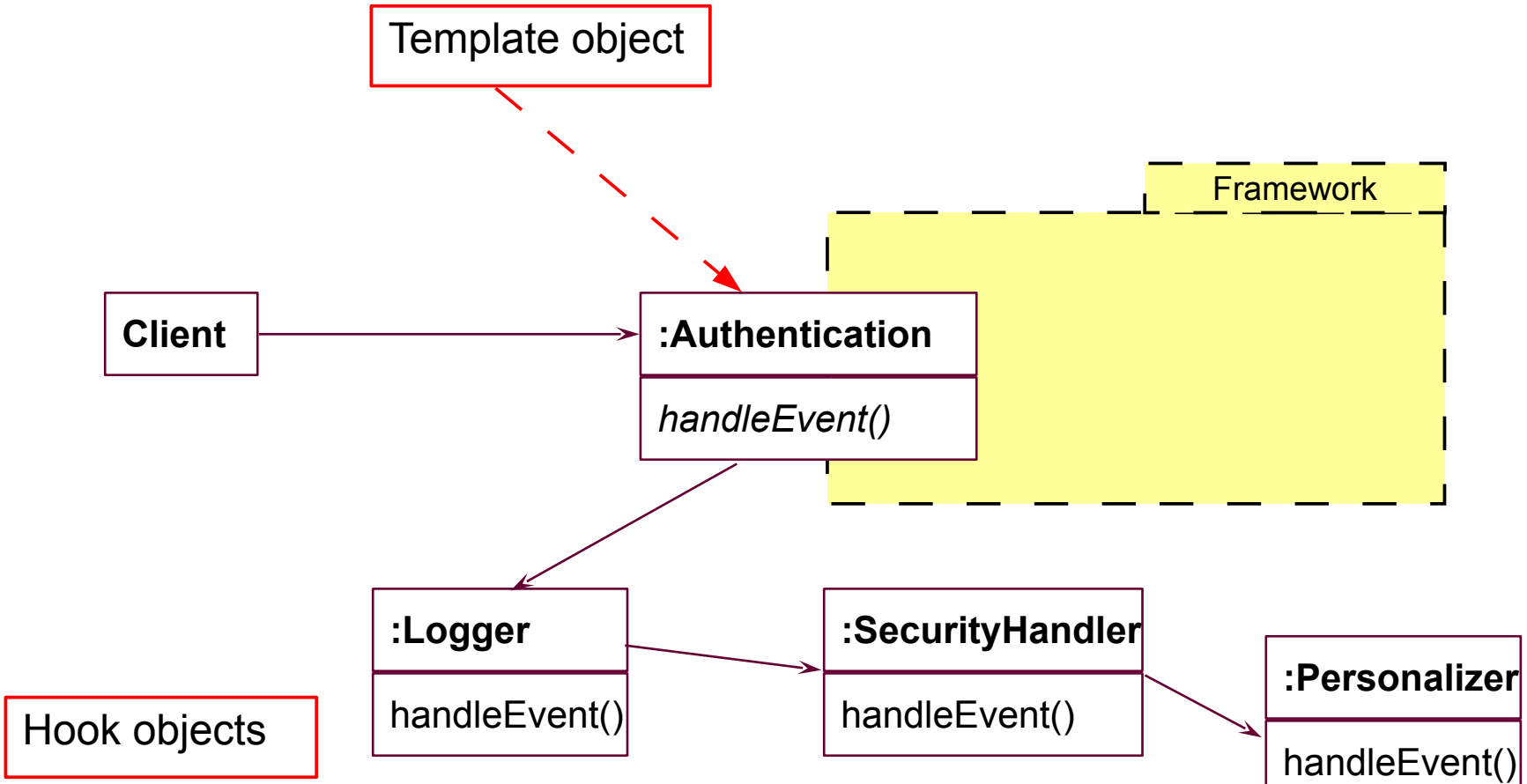
- A Chain is recursing on the abstract super class, i.e.,
  - All classes in the inheritance tree know they hide some other class (unlike the ObjectRecursion)



Event Handlers



Event Handlers: Object Diagram

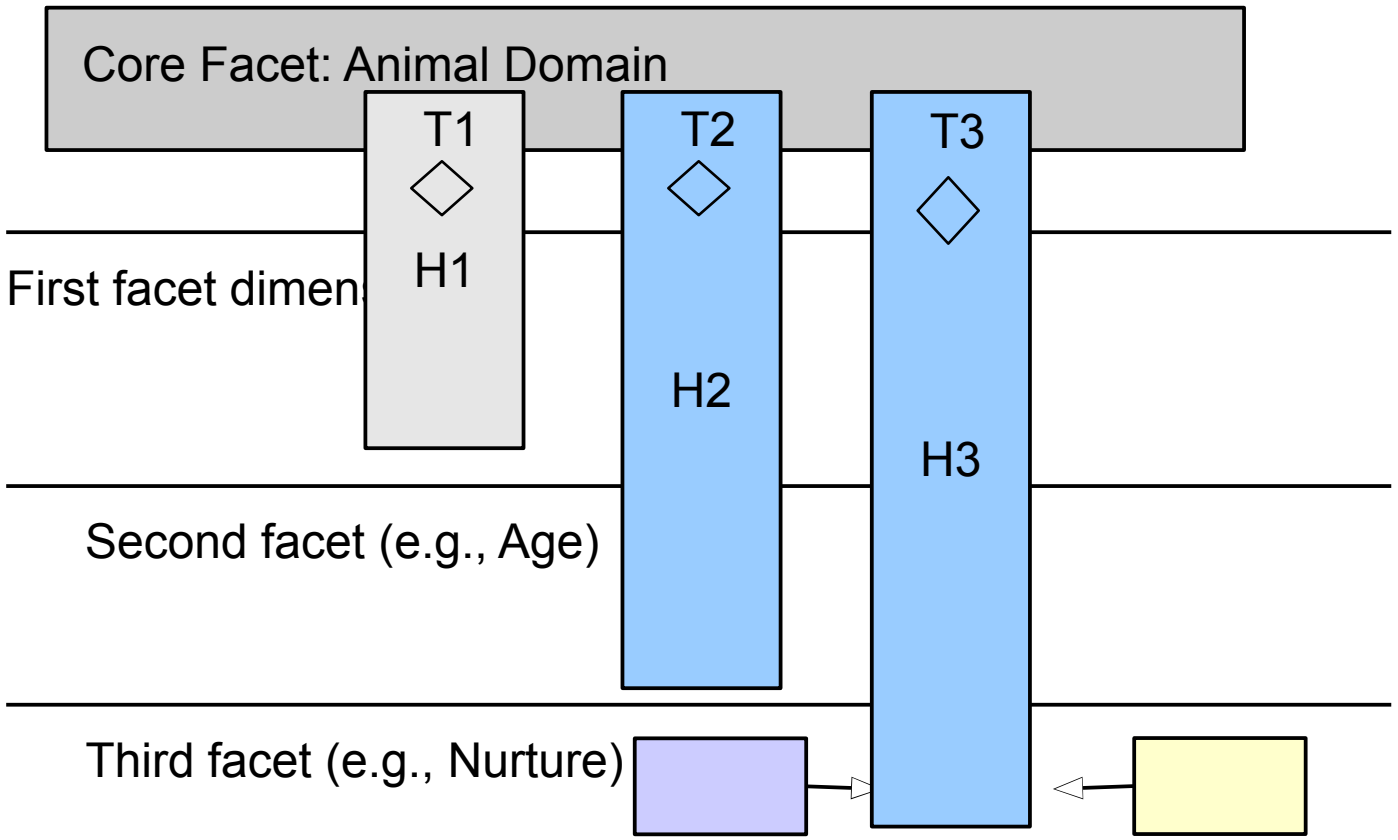


Why TH Unification Makes Sense

- 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

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

- A dimension may correspond to a H<=T hook
- Chain can be used as mini-connector

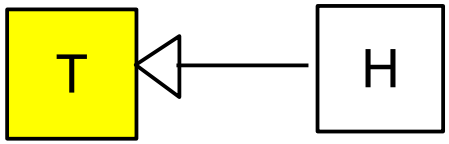


11.6 The H<T Whitebox Inheritance Metapattern

H<T

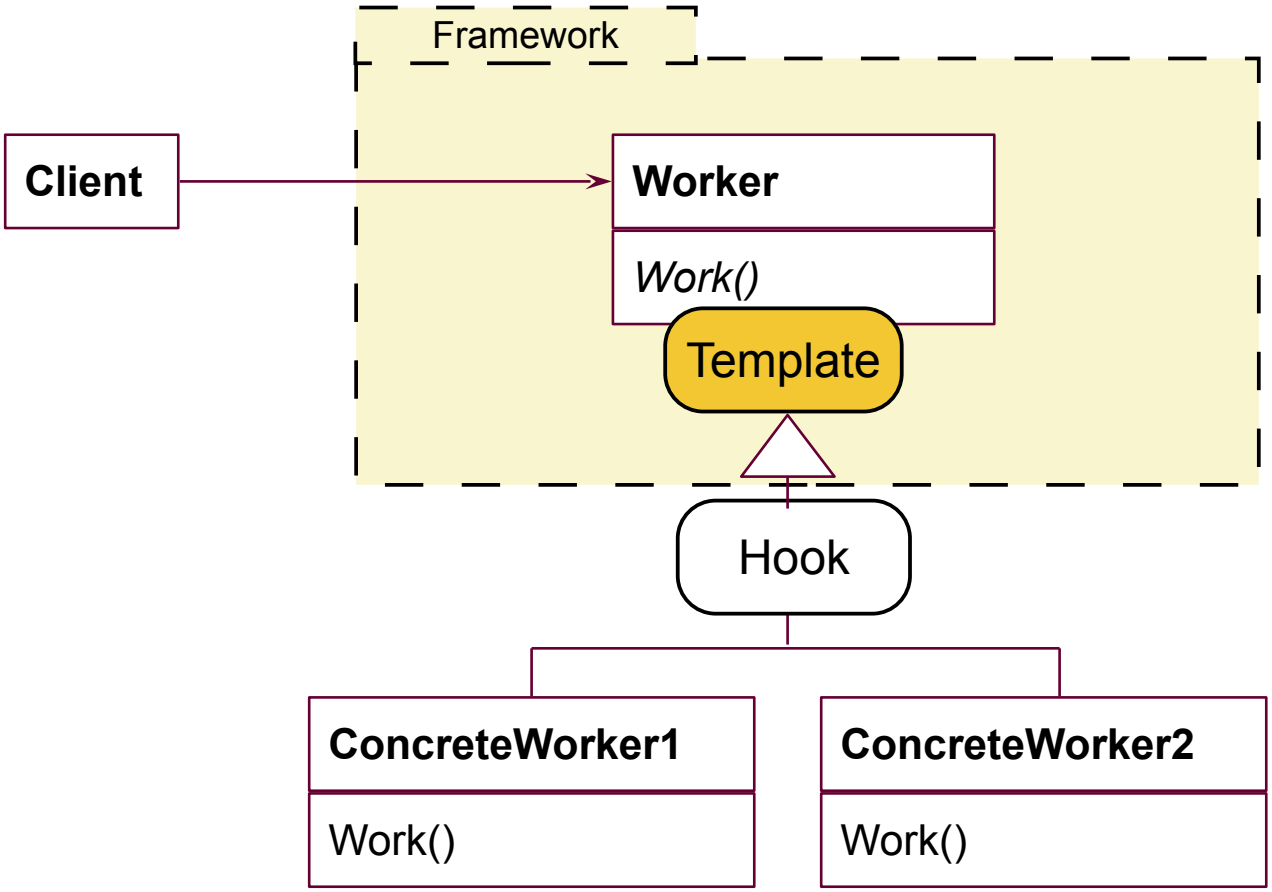
- If H inherits from T, H<T framework port (whitebox framework pattern)
  - Whitebox reuse of T in the framework, while deriving H in the application
  - (not of Pree, earlier known)
- If a hook class inherits from a template class, it inherits the skeleton algorithm
  - Template methods in the template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

H<T



Whitebox Framework with H<T Framework Hook

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



Summary of T&H Patterns and Framework Hooks

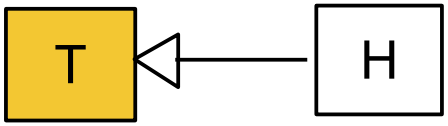
Cardinalities and Extensibility of Framework Hooks

- 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

H<T
H inherit from T
whitebox

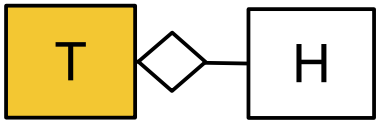


Unification

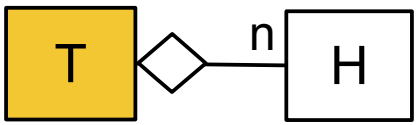
TH
T == H

Aggregation/Association

T--H
H part of T
T is core class of
complex object

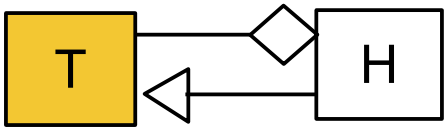


n-T--H
T has n H parts
T is core class of
complex object

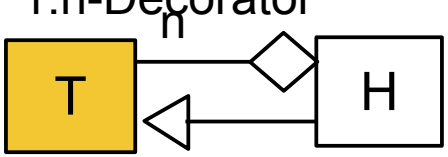


Recursion

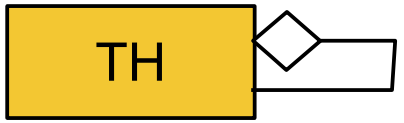
H<=T
T part of H
H inherit from T
Decorator



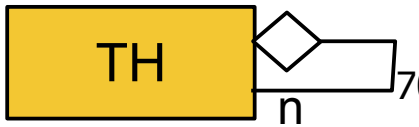
n-H<=T
H has n T parts
H inherit from T
1:n-Decorator



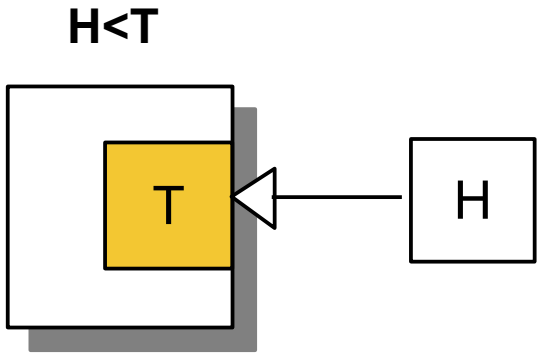
1-TH
T == H
TH part of TH
“funny” Decorator

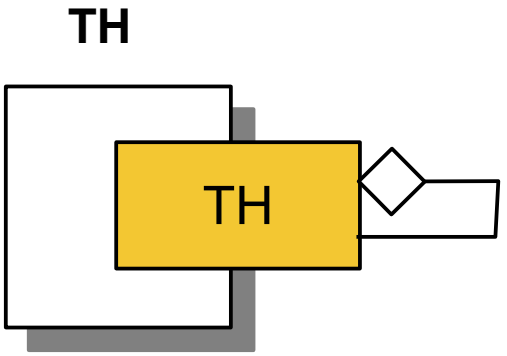


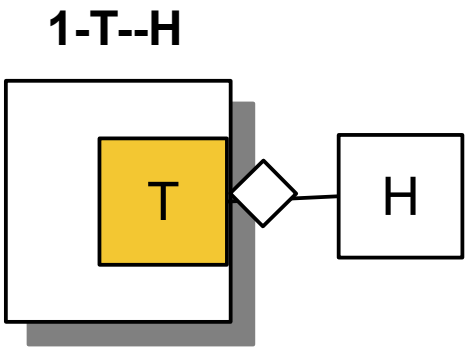
n-TH
T == H
TH has n TH parts
“funny” 1:n-Composite

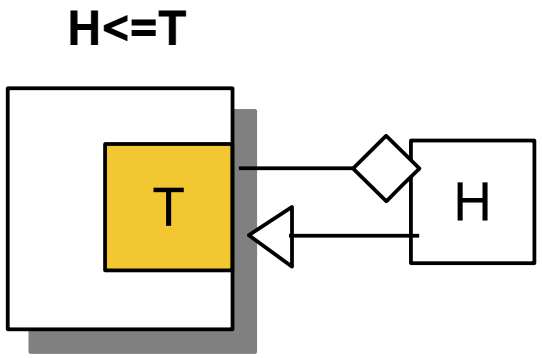


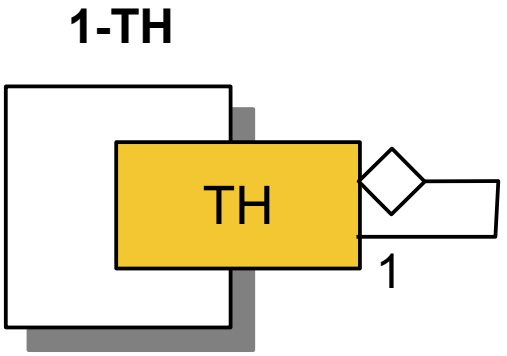
Deriving a Simple Notation for Framework Hooks

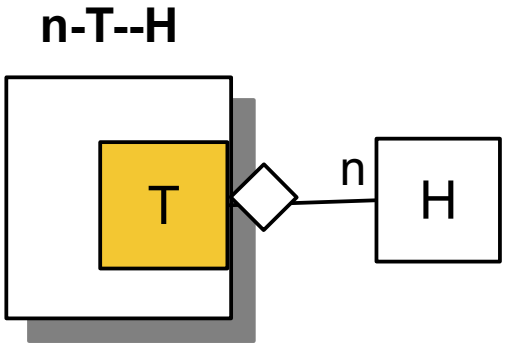


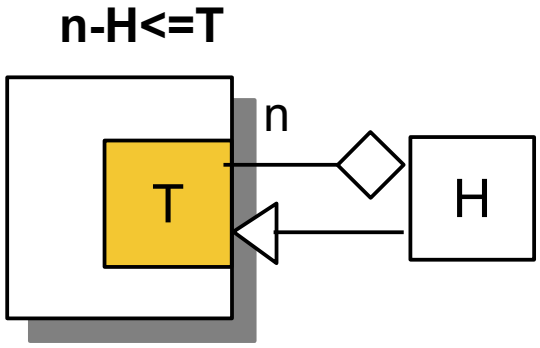


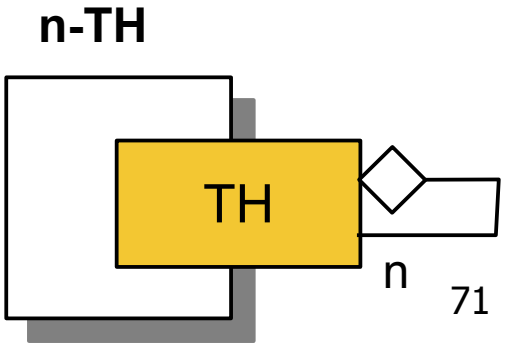




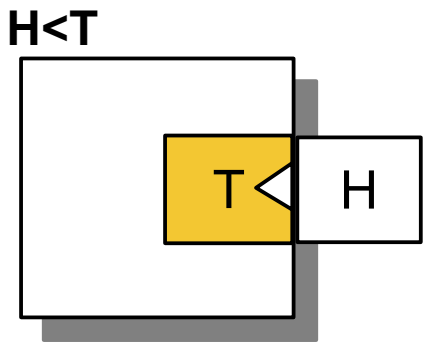


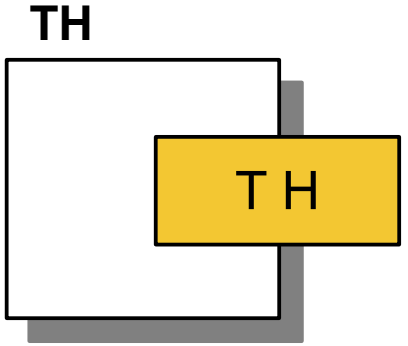


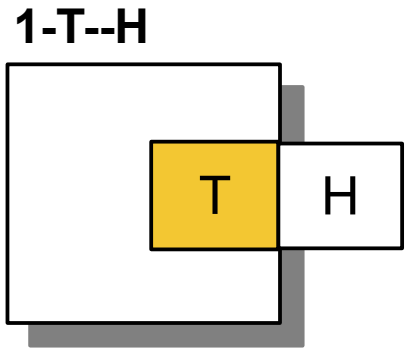


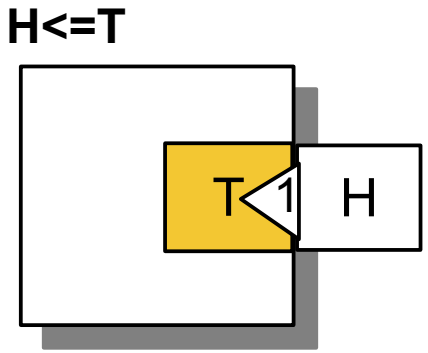


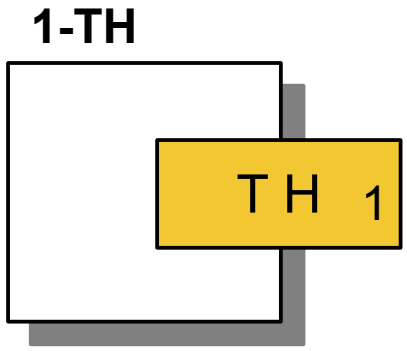
Short-Hand Notation for Framework Hooks

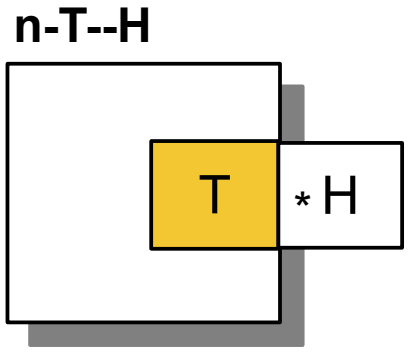


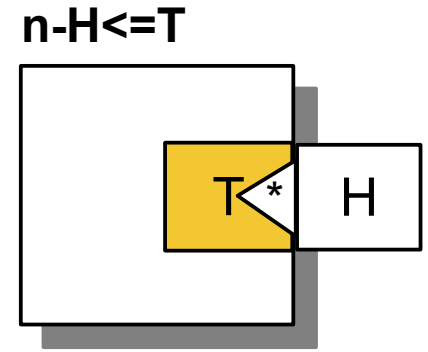


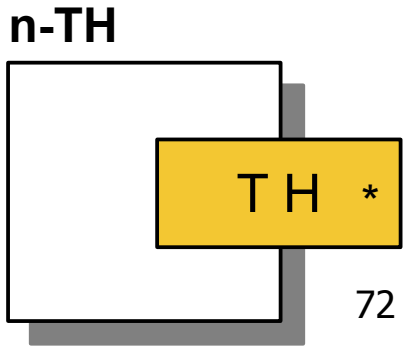












11.7 T&H in Frameworks

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 stable
- 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

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

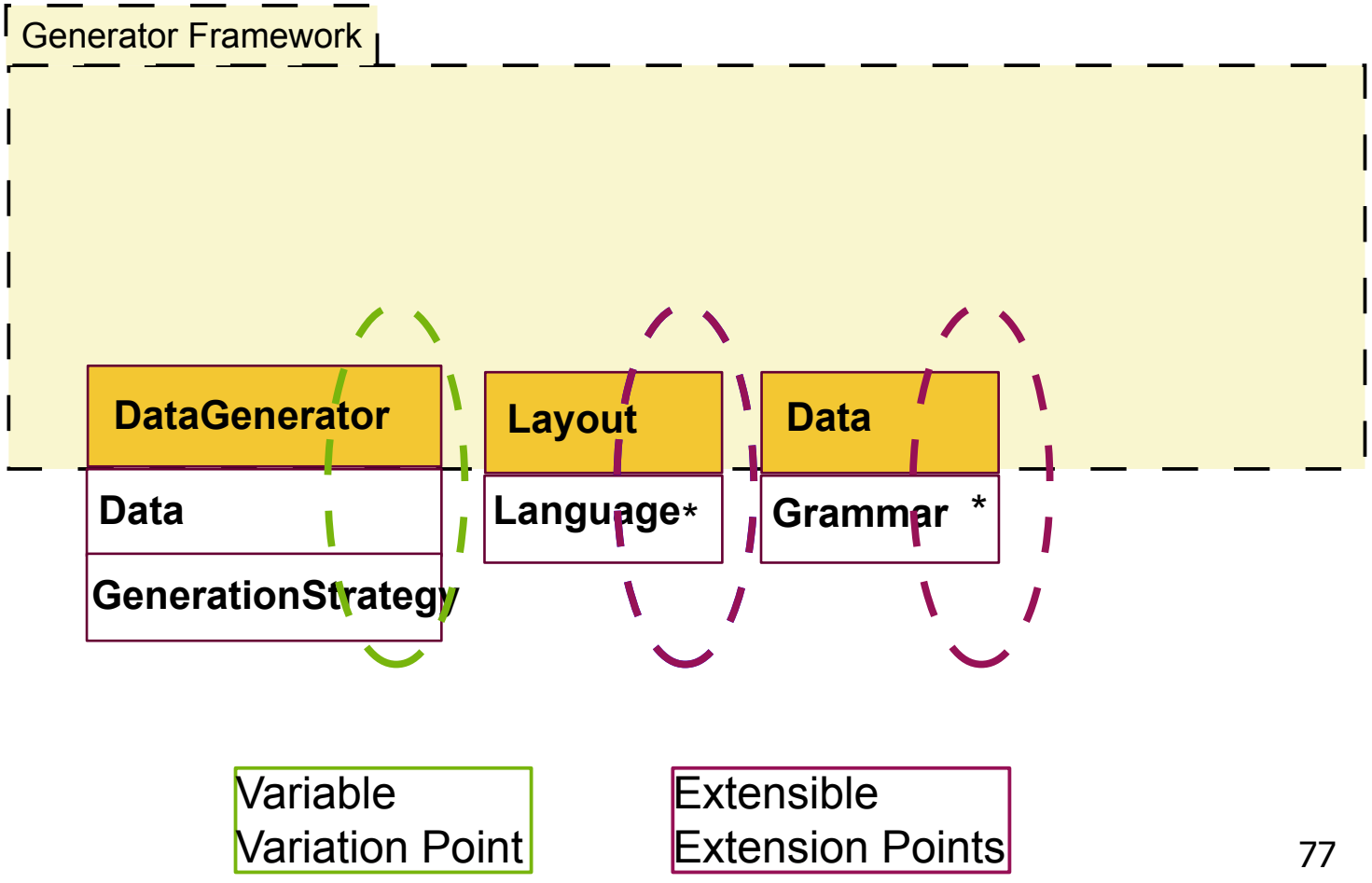
Pree's Second Law of Framework Instantiation

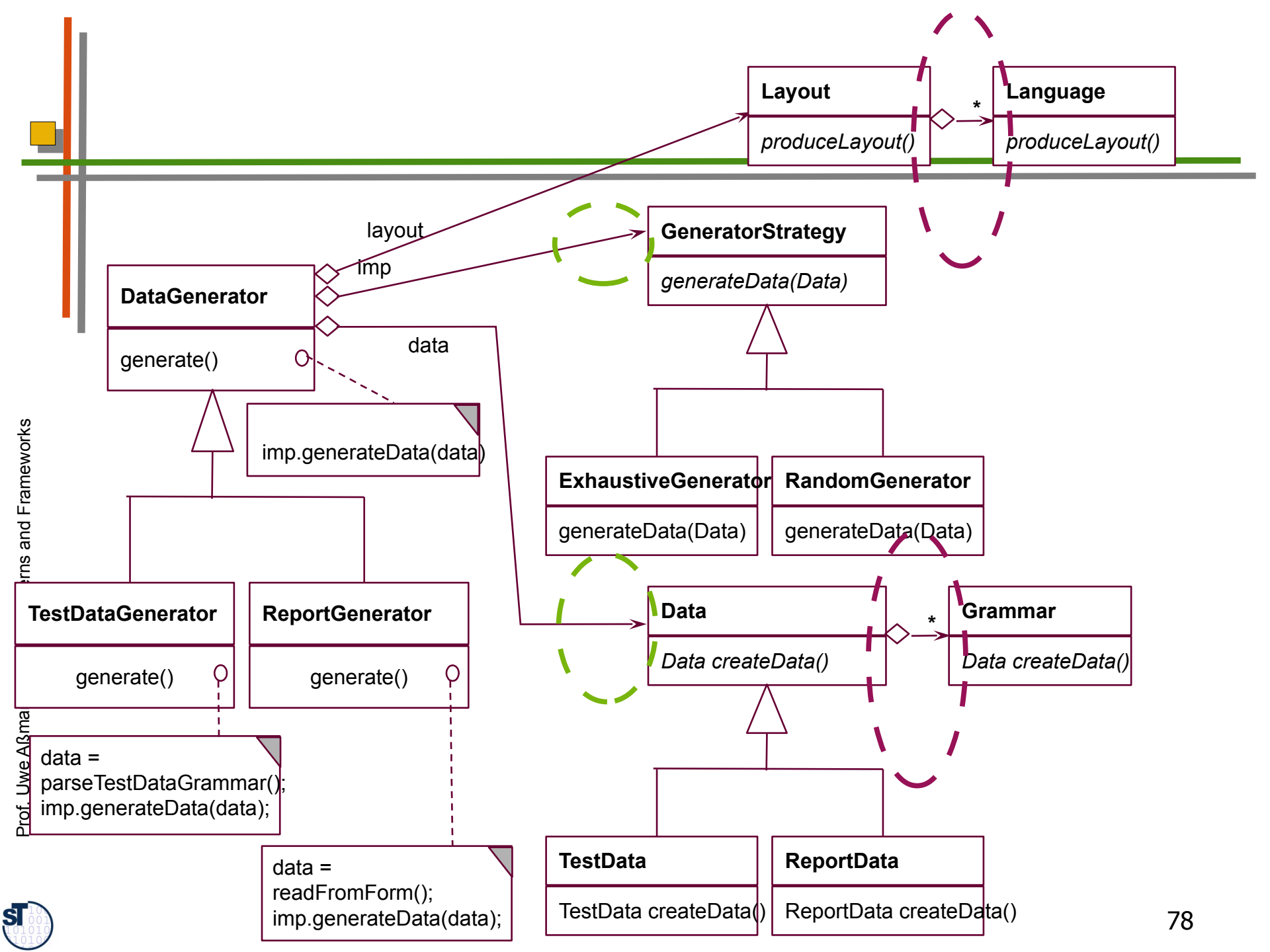
- Extensibility-based framework hooks define *framework extension points*
  - If you *do not want to constrain* the uses of a framework to a fixed set of variations, use extensibility patterns for framework hooks (n-TH patterns)

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

A Multi-lingual dimensional Data Generator

- One framework hook may have several bridge dimensions

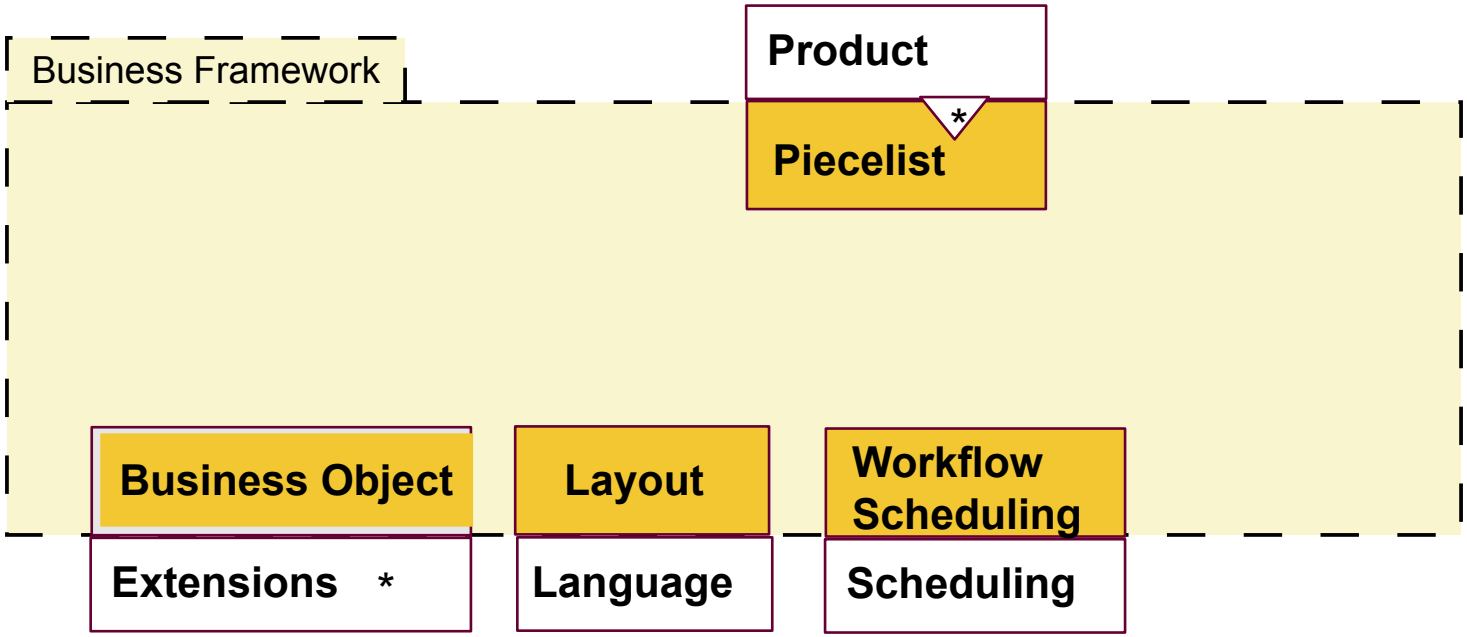



Layout
produceLayout()
*
Language
produceLayout()
layout
imp
GeneratorStrategy
generateData(Data)
DataGenerator
generate()
data
imp.generateData(data)
ExhaustiveGenerator
generateData(Data)
RandomGenerator
generateData(Data)
TestDataGenerator
generate()
ReportGenerator
generate()
Data
Data createData()
*
Grammar
Data createData()
data =
parseTestDataGrammar();
imp.generateData(data);
data =
readFromForm();
imp.generateData(data);
TestData
TestData createData()
ReportData
ReportData createData()

Framework Instantiation Market

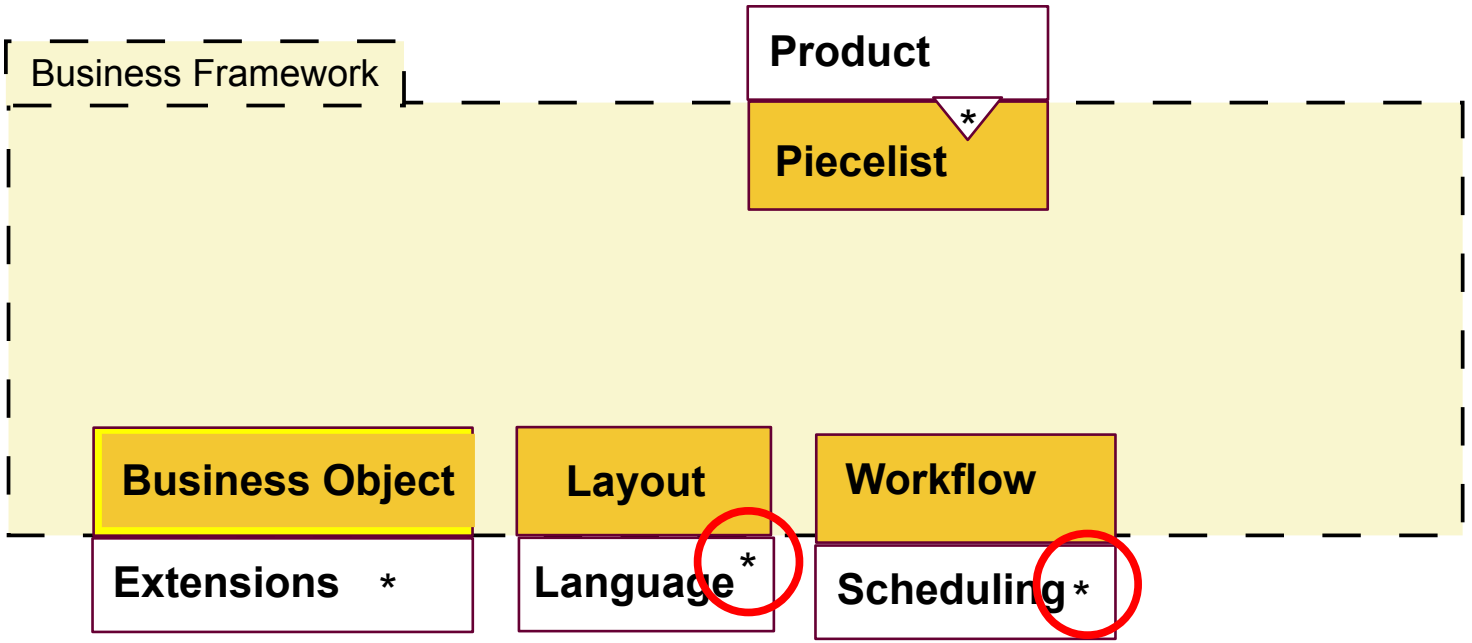
- Today, frameworks are the most important software technology for product lines in large companies
- Instantiating big frameworks is very hard
  - Requires special *instantiation consultancy,* which is a big market
  - SAP Germany has a marker for instantiation companies of their framework!
  - If you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

A Multi-lingual Business Framework



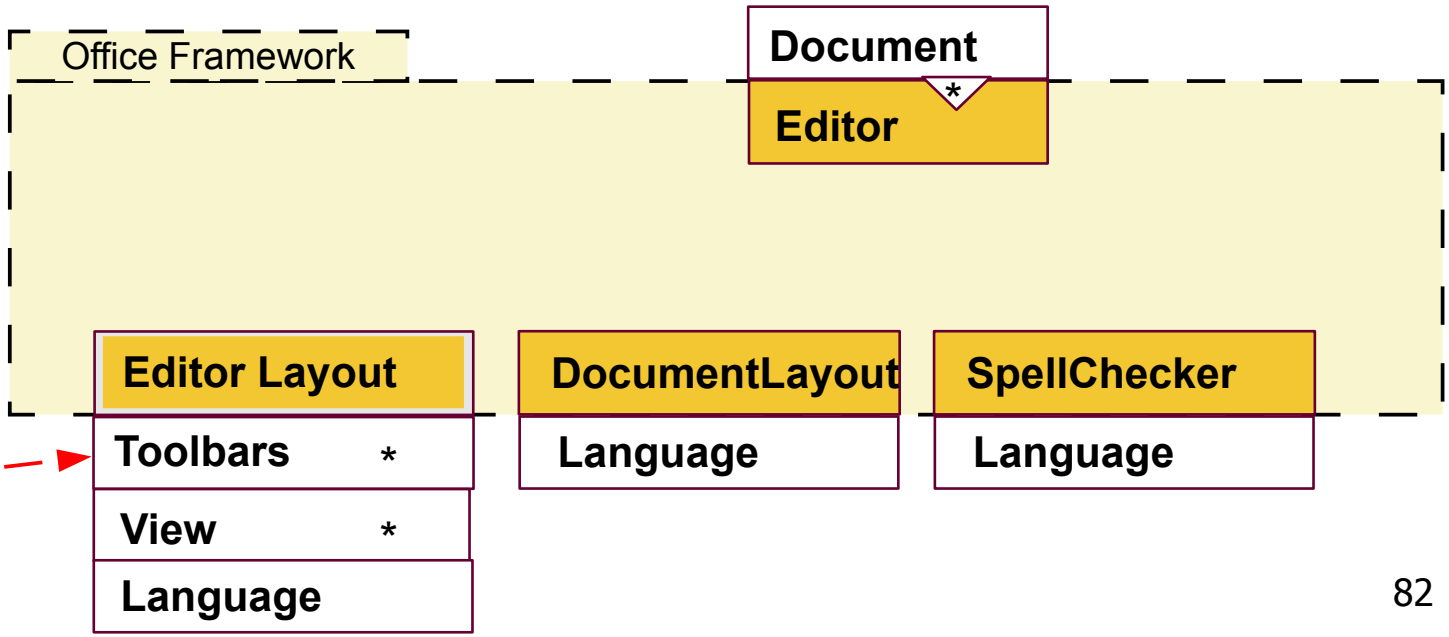
A Business Framework with Several Languages Simultaneously

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



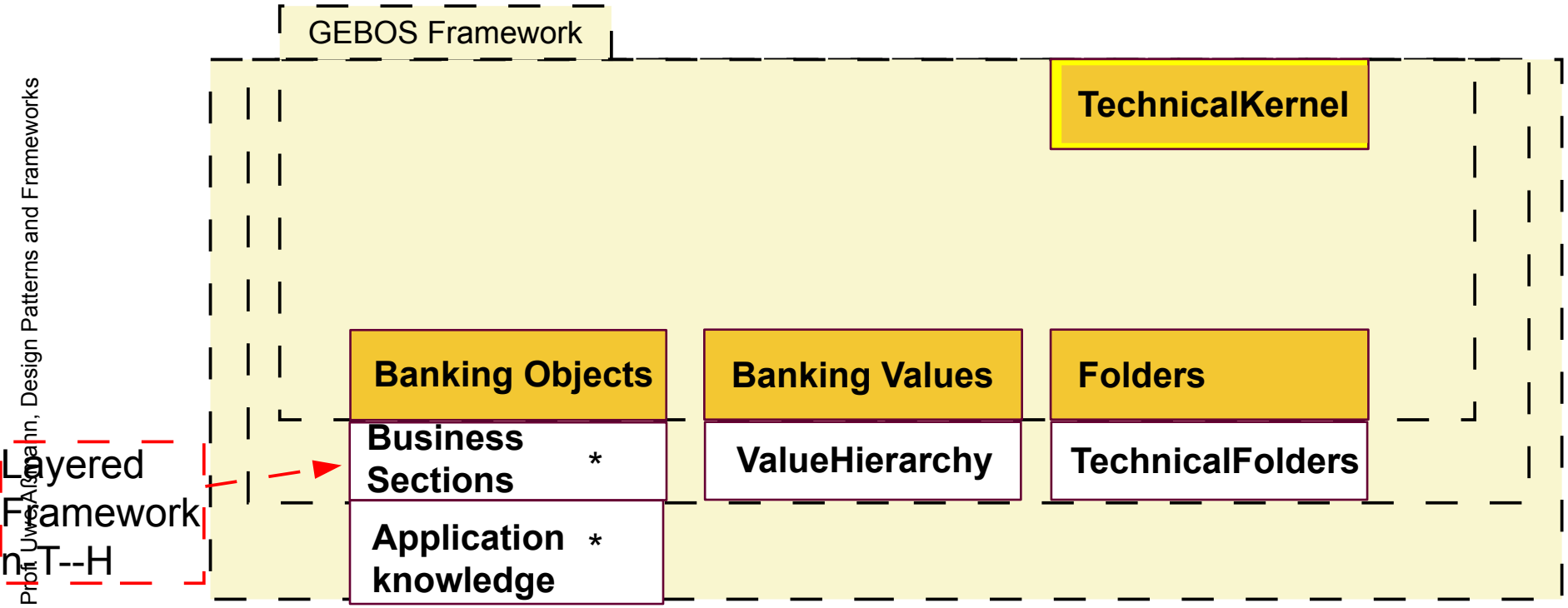
OpenOffice

- 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

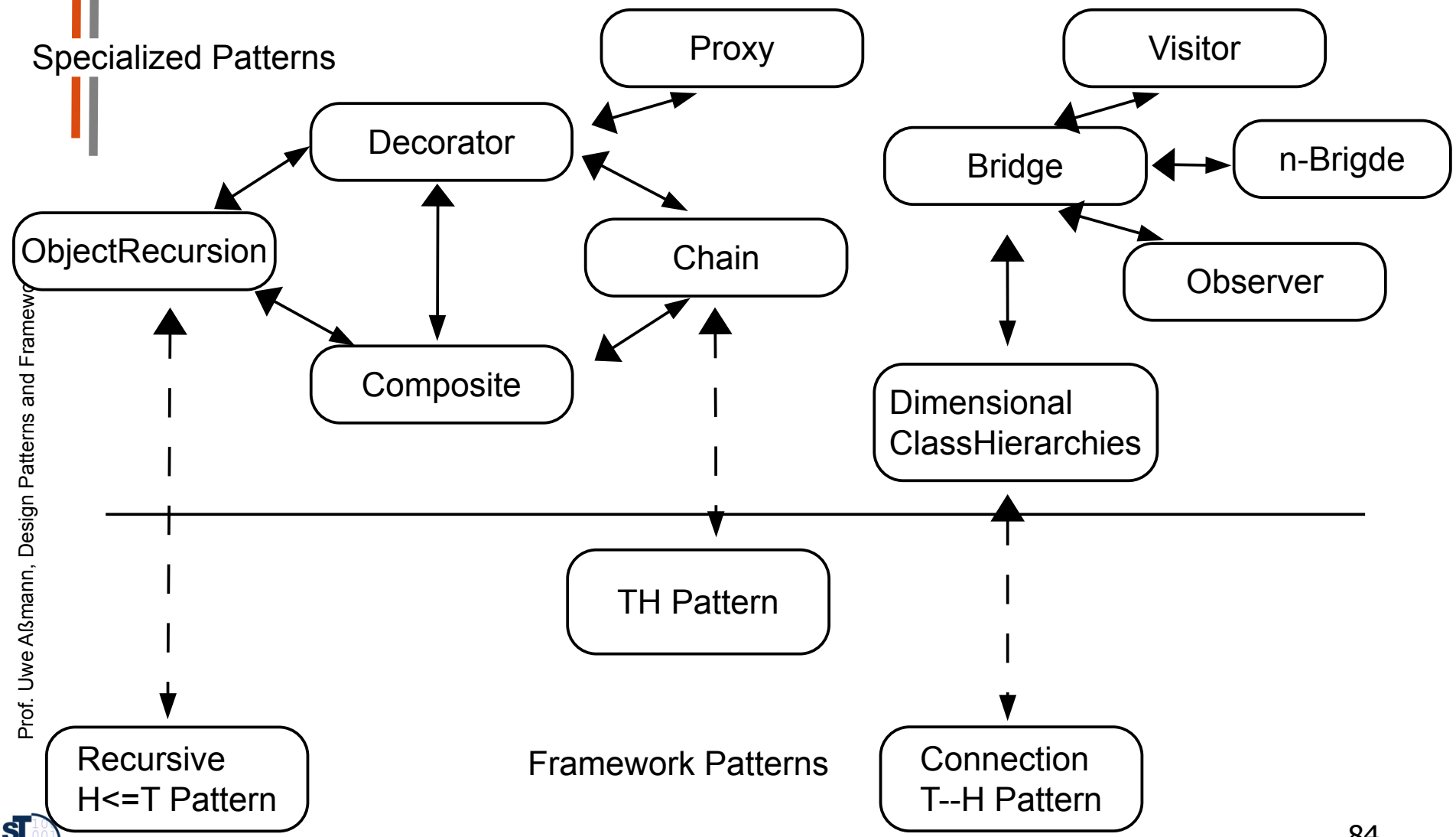


GEBOS Banking Layered Framework

- 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 overlayed 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<=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.

The End