11. Frameworks and Patterns - Framework Variation Patterns

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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. www.softwareresearch.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.

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

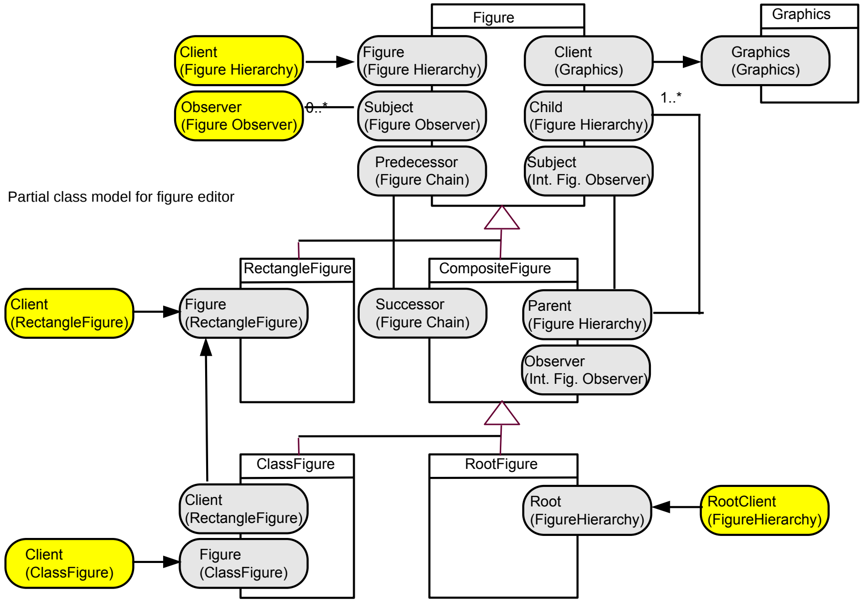
- Historically, design patterns were discovered during framework development
  - Smalltalk MVC [Goldberg, Reenskaug]
  - ET++ [Gamma]
  - Interviews [Vlissides]
- Design patterns are building blocks of frameworks
  - Framework developers vary and extend classes of the framework
- Design patterns are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

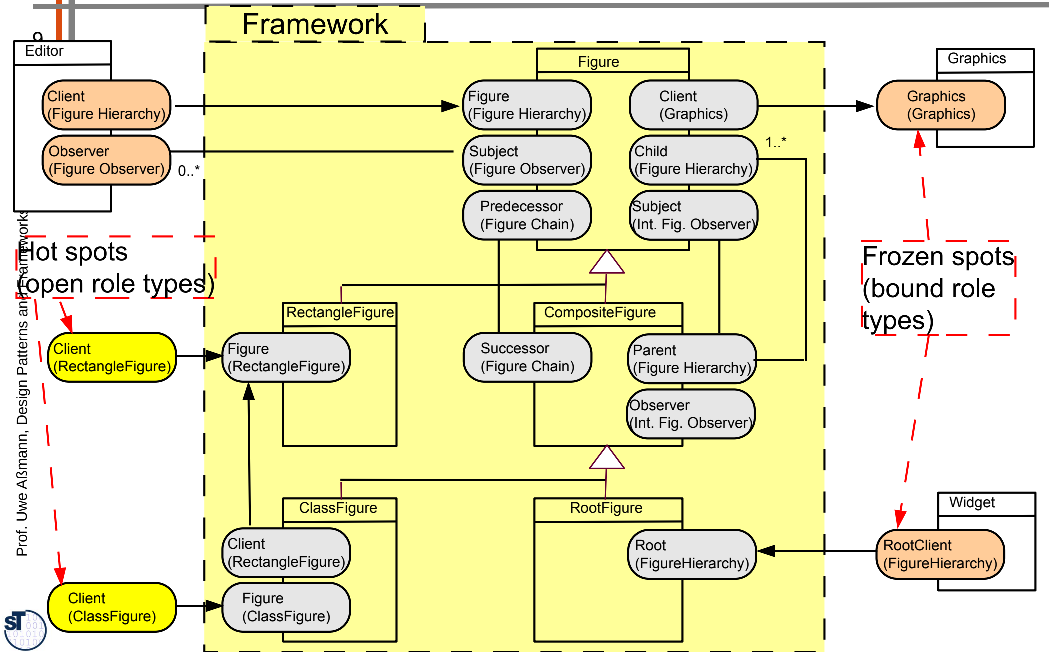
- The most simple form of framework instantiation is Riehle/Gross' *open role instantiation* based on association
  - Here, frameworks are class models with “open” role hot spots
  - *Open role hooks (free, unbound abilities)* are role types that have not yet been assigned to classes
- The hot spots 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,* role 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

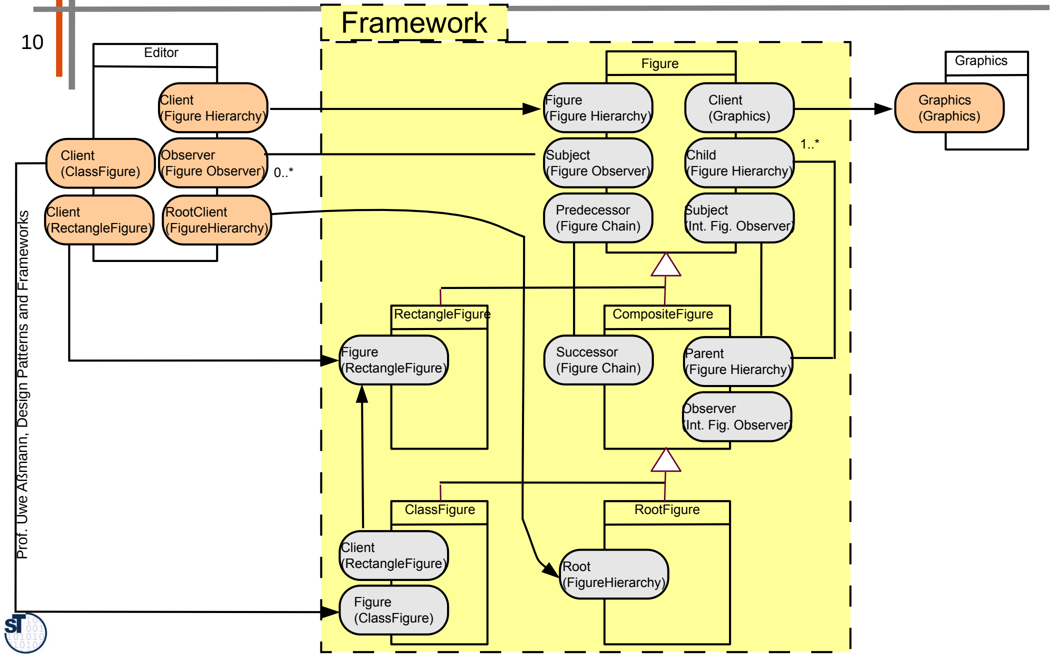


Partial class model for figure editor

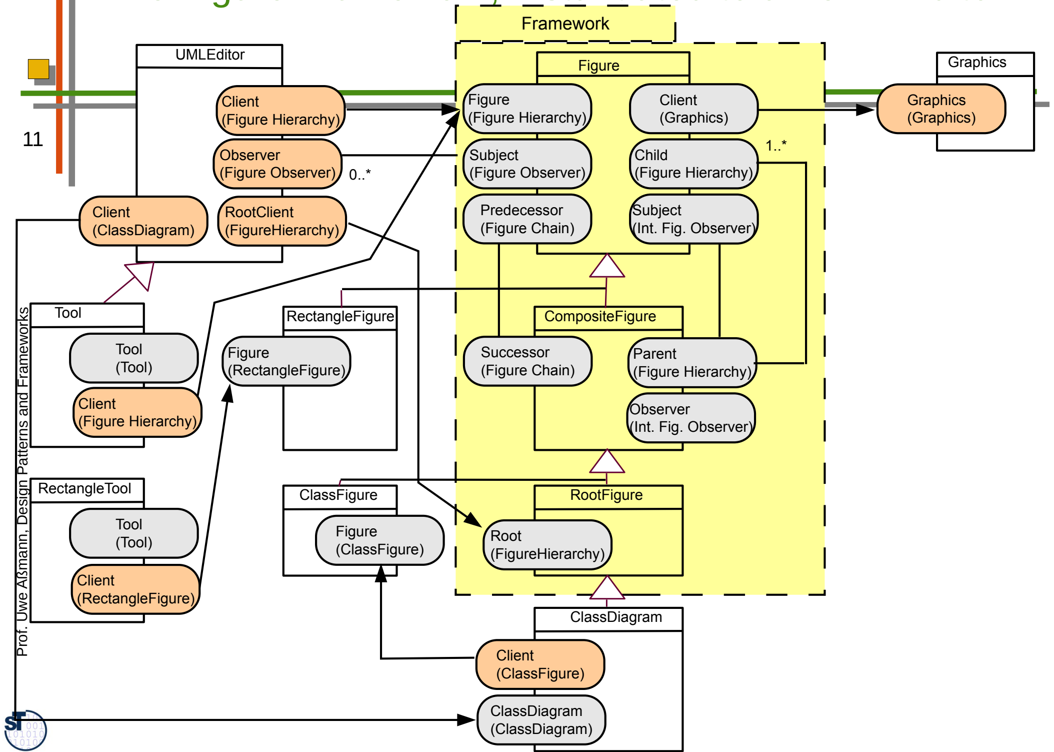
The Figure Framework, Partially Instantiated



The Figure Framework, Fully Instantiated to an Editor



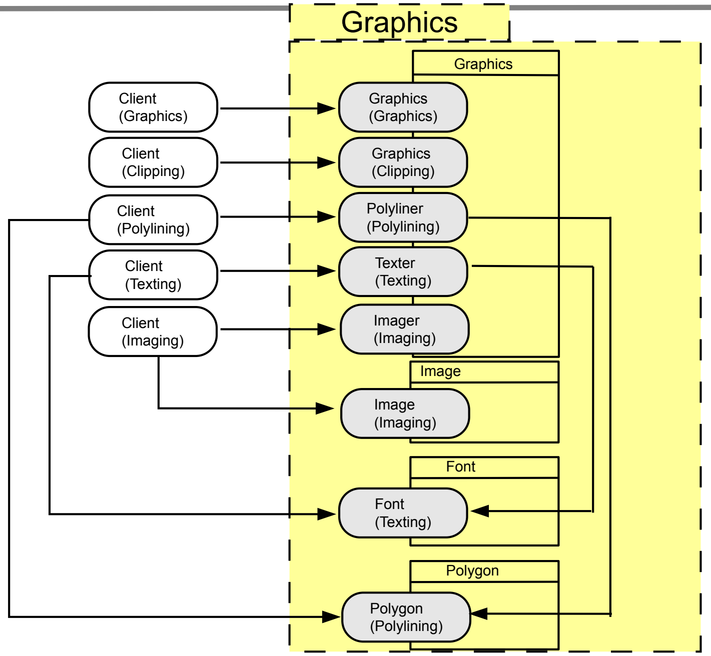
The Figure Framework, Instantiated to an UML Editor



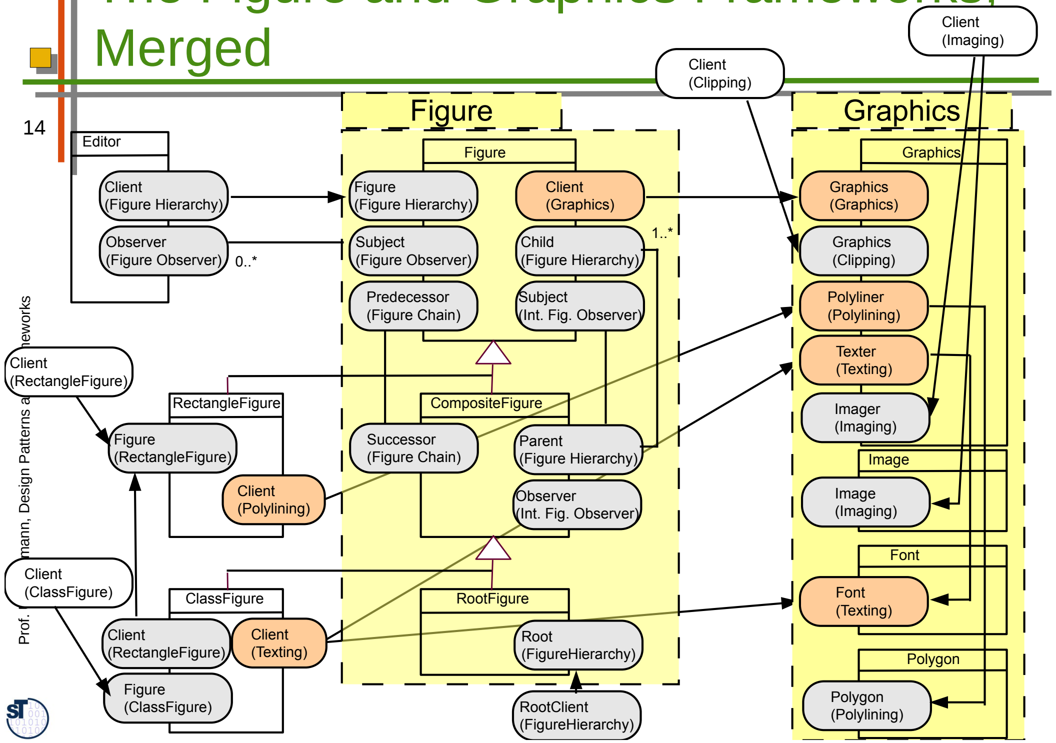
Merging of Frameworks

- 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



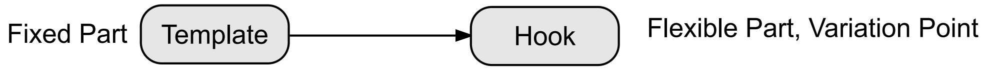
Limitations of Open Role Instantiation

- [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

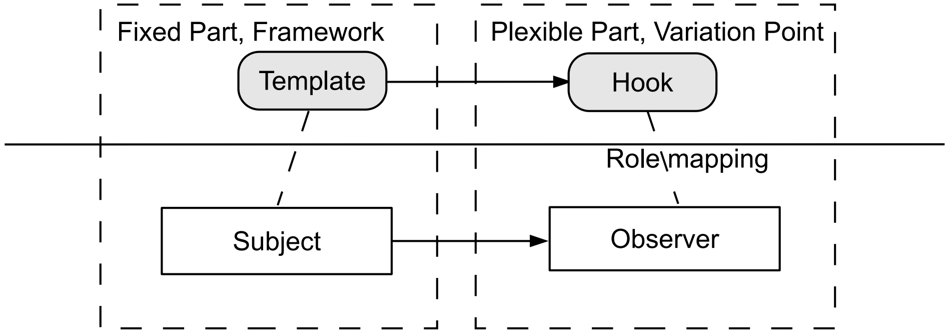
Pree's Framework Hook Patterns (Template&Hook Role Models)

- 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



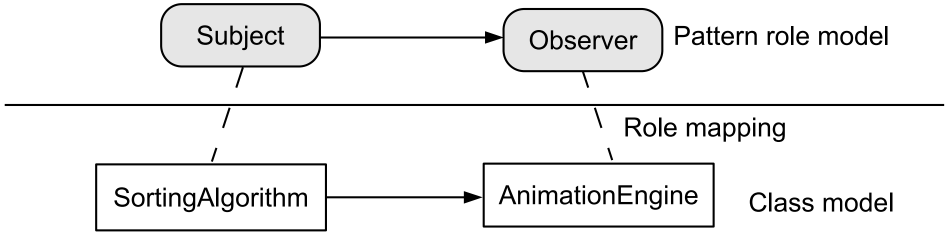
T&H Patterns and Standard Patterns

- 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.



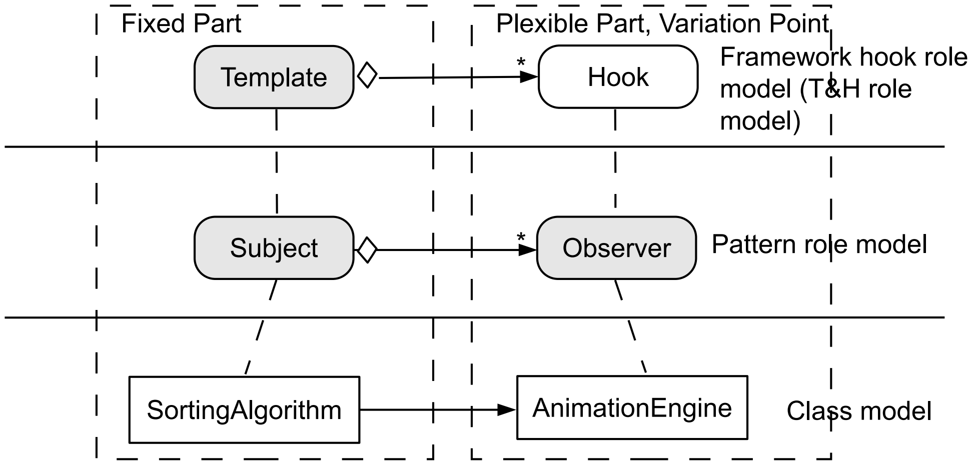
T&H in Standard Design Patterns

- 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)



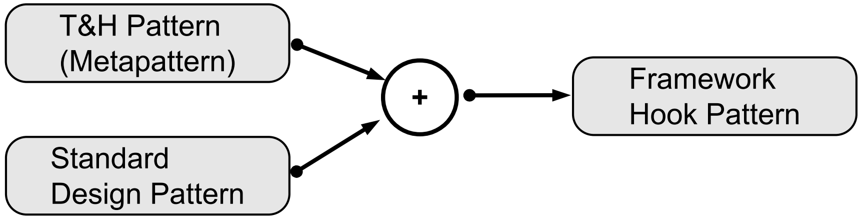
Why T&H Patterns Add More to Standard Patterns

- 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 overlayed 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**



T&H Pattern (Metapattern)

Standard Design Pattern

+

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

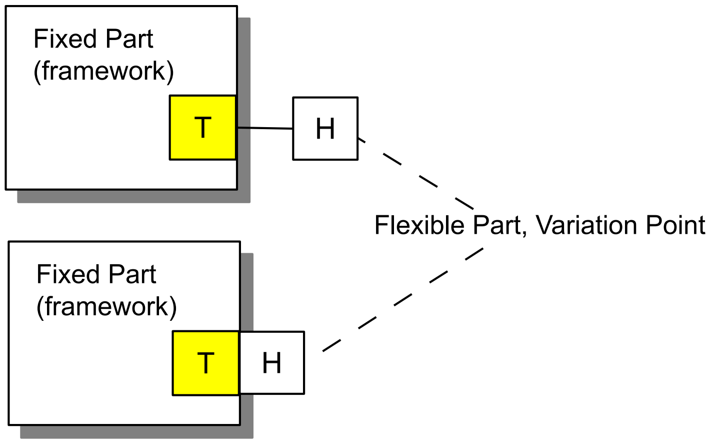
- Note: we mean in the following:
    - with the role *Template*, that the class of the role type belongs to the framework
    - with the role *Hook*, that the class of the role type belongs to the application
    - with the role *TemplateM(ethod)* that the role defines a template method, *calling* a 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

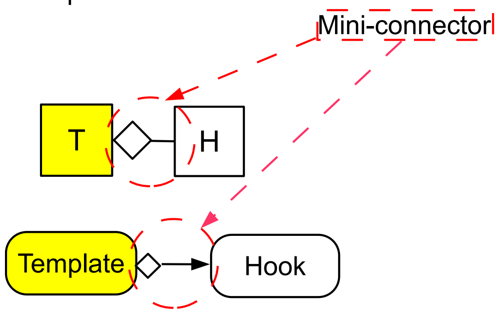


11.3 Delegation-Based Framework Hook Patterns

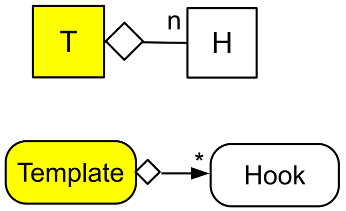
T—H Connection Pattern

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

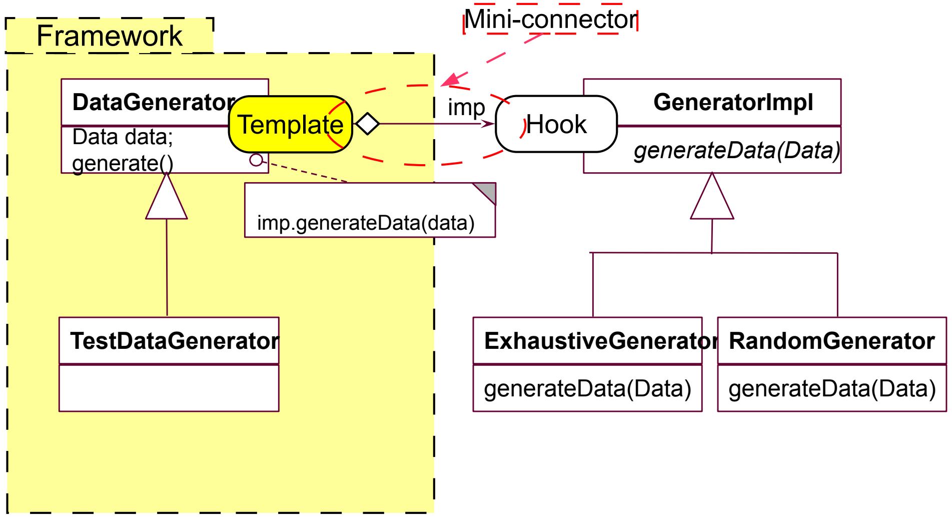


n-T—H (flat extension)
T has n H parts, n is dynamic

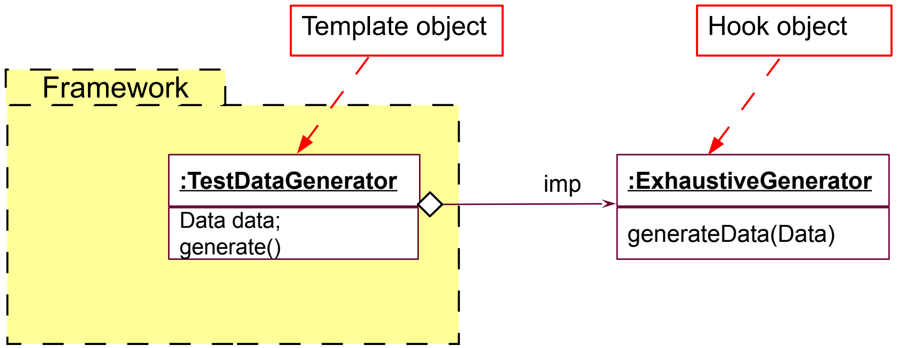


TemplateClass with 1-T--H

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

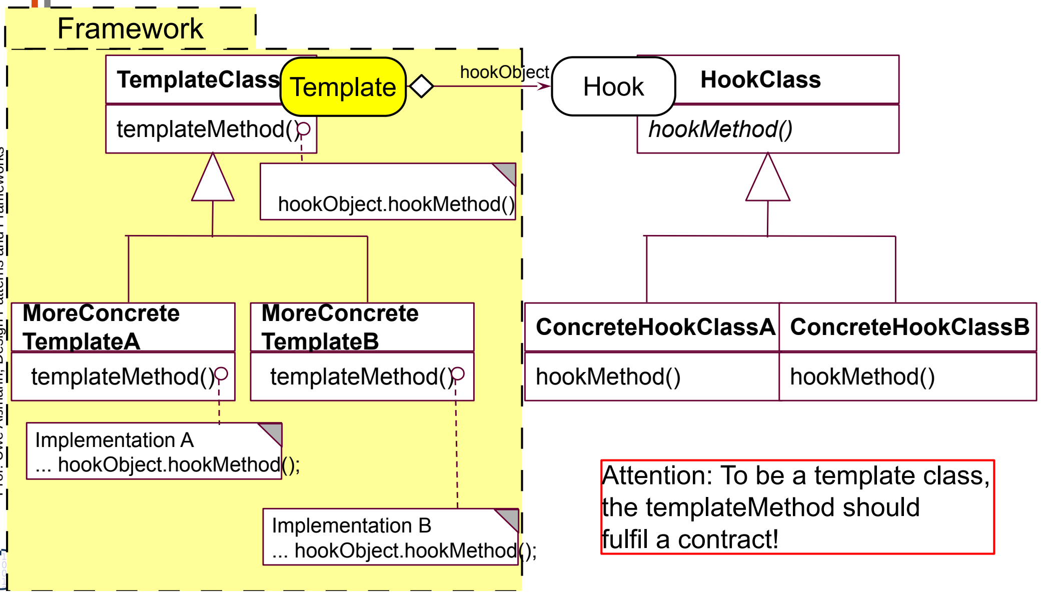


TemplateClass Runtime Scenario



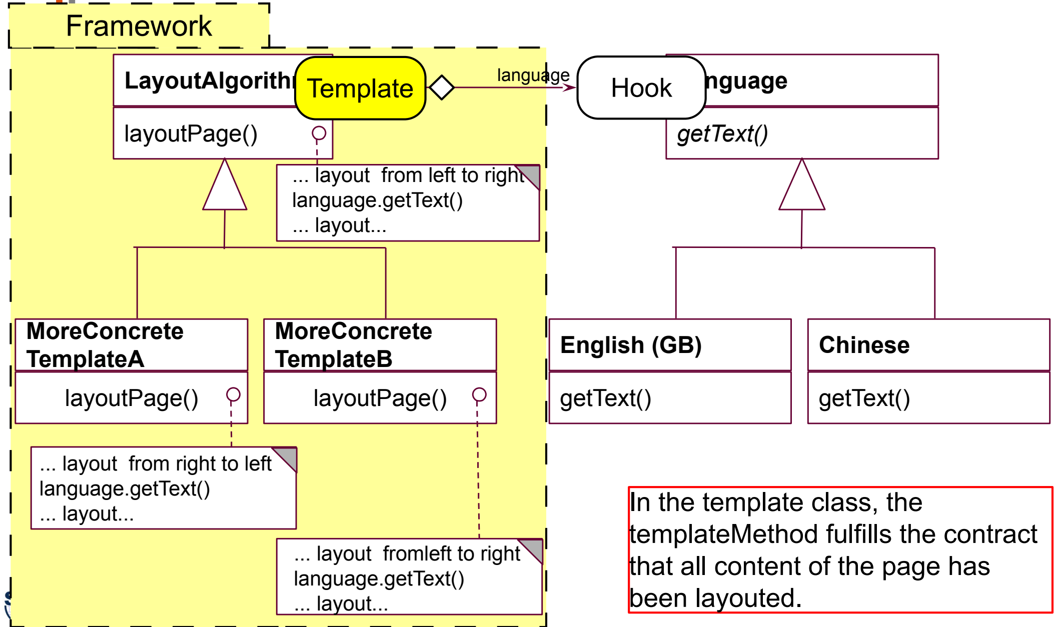
Dimensional Hierarchies with 1-T--H (Bridge with Template/Hook Constraint)

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



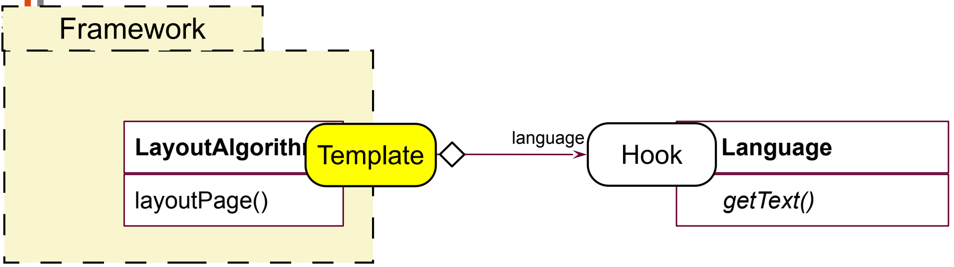
Attention: To be a template class, the templateMethod should fulfil a contract!

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

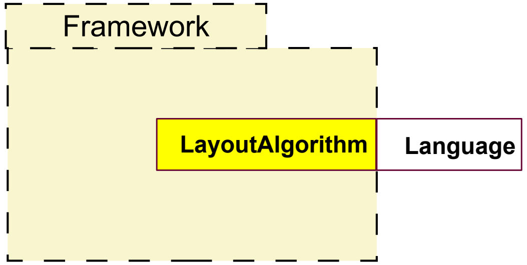


In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

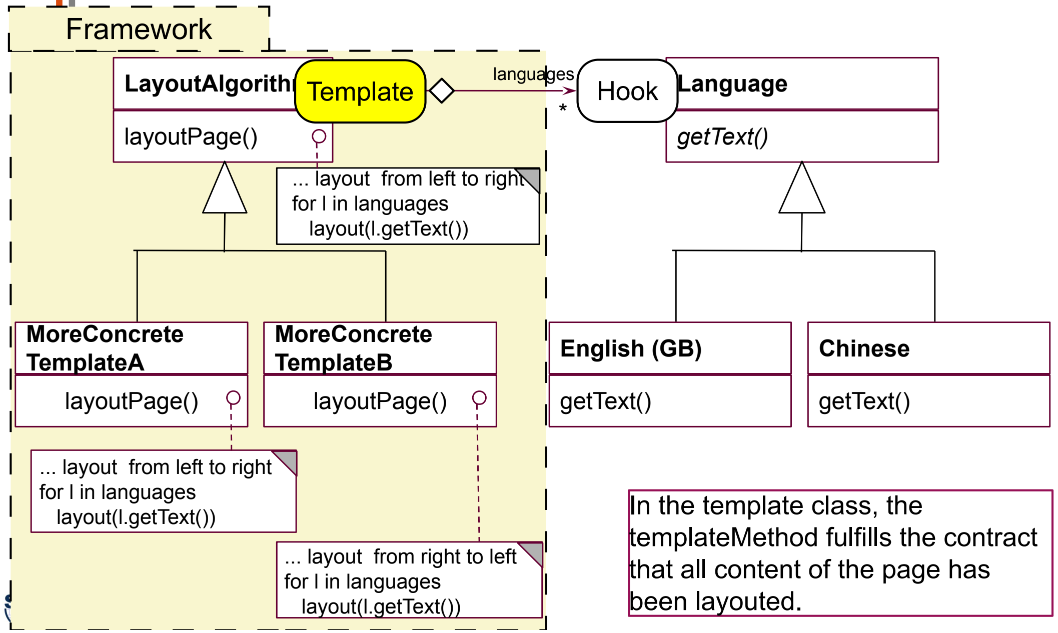
Internationalization as Dimensional Class Hierarchy with 1-T--H



- may be abbreviated to:



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

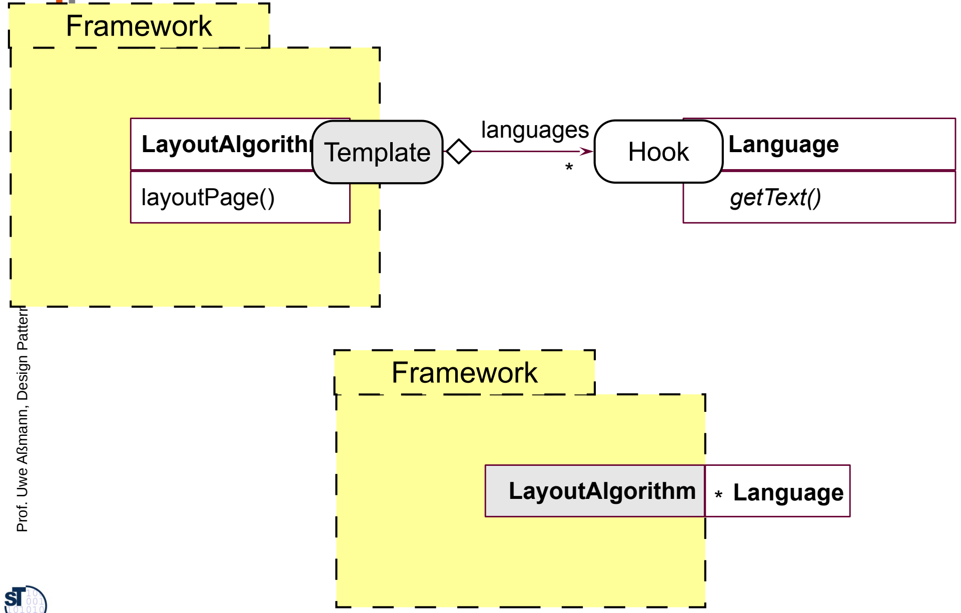


In the template class, the templateMethod fulfills the contract that all content of the page has been layouted.

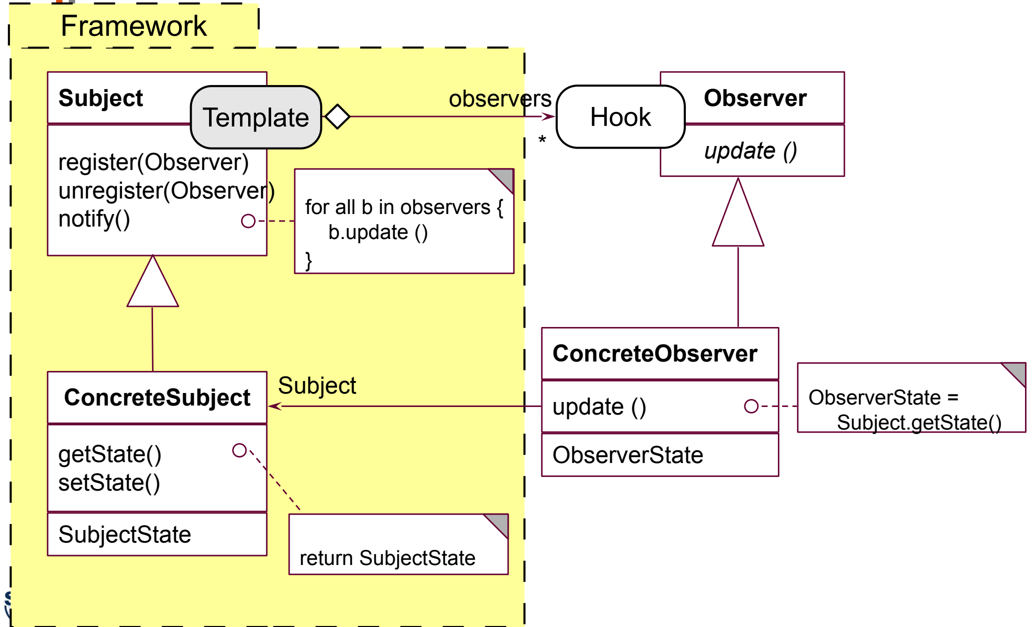
Multiple Internationalization as Dimensional Class Hierarchy with n-T--H

- 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)

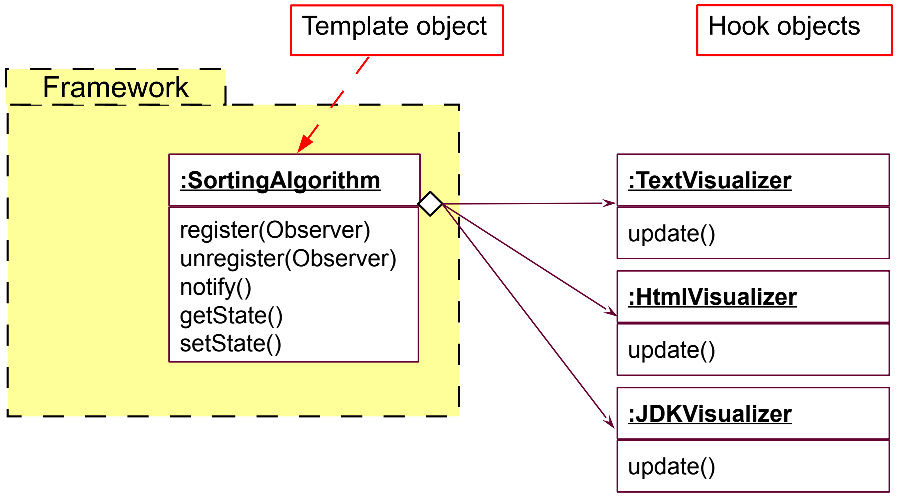
Multiple Internationalization as n-T—H Dimensional Hierarchy



Observer as n-T—H of a Framework



Observer Runtime Scenario: Several Visualizers in Parallel



Template object

Hook objects

Framework

:SortingAlgorithm

register(Observer)
unregister(Observer)
notify()
getState()
setState()

:TextVisualizer

update()

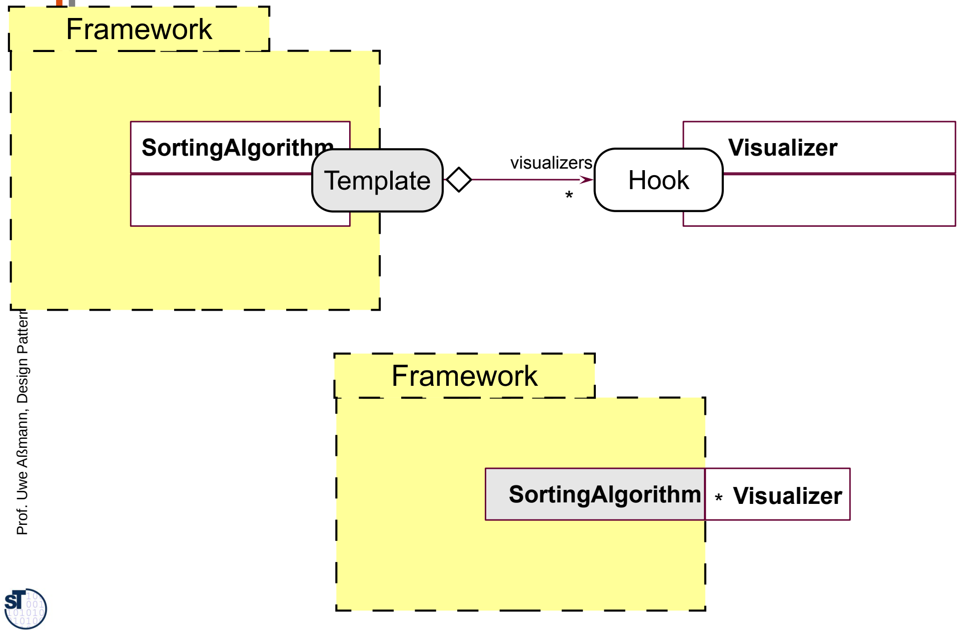
:HtmlVisualizer

update()

:JDKVisualizer

update()

Observer-based Extensible Frameworks



Framework

SortingAlgorithm

Template

visualizers

*

Hook

Visualizer

Framework

SortingAlgorithm

*

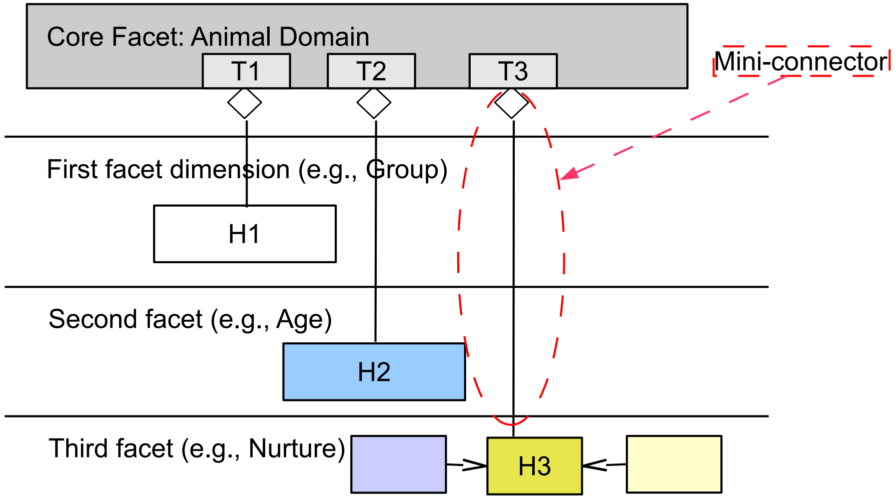
Visualizer

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



Core Facet: Animal Domain

T1

T2

T3

Mini-connector

First facet dimension (e.g., Group)

H1

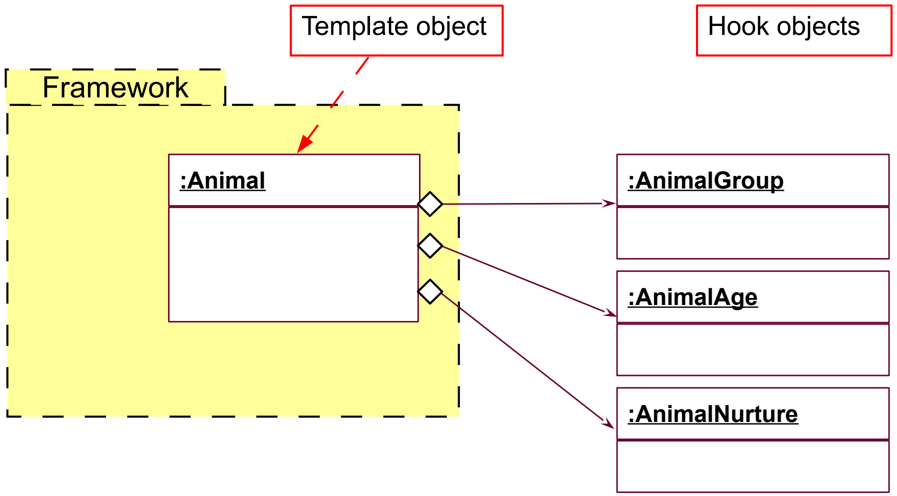
Second facet (e.g., Age)

H2

Third facet (e.g., Nurture)

H3

Bridge Framework Runtime Scenario



Template object

Hook objects

Framework

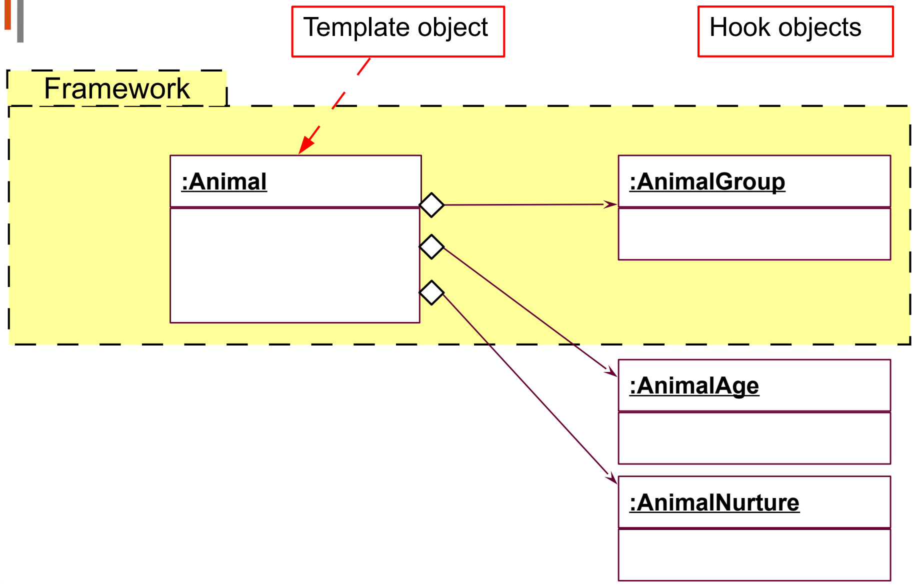
:Animal

:AnimalGroup

:AnimalAge

:AnimalNurture

Bridge Framework Runtime Scenario, with dimension 1 in Framework



Template object

Hook objects

Framework

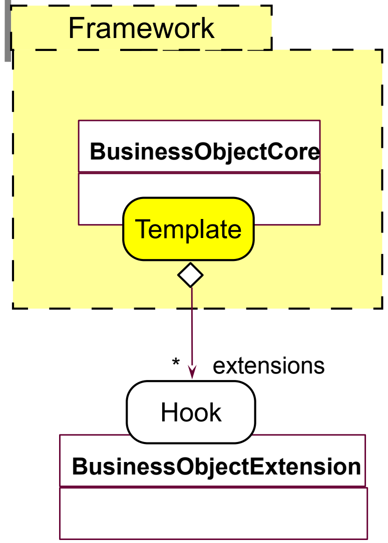
:Animal

:AnimalGroup

:AnimalAge

:AnimalNurture

Extensible Bridge Framework with n-T--H



Framework

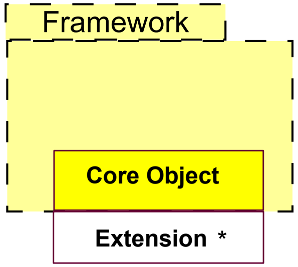
BusinessObjectCore

Template

* extensions

Hook

BusinessObjectExtension



Framework

Core Object

Extension *

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

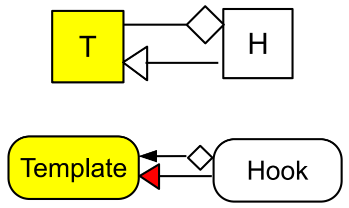
- The main relation between T and H is *delegation*.
- Hence, when overriding and instantiating H, the framework is untouched (*blackbox framework*)
- 1-T—H gives variability
- n-T—H gives extensibility

11.4 The H<=T Recursion Metapattern

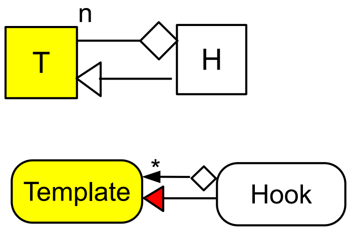
H<=T Recursive Connection

- 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

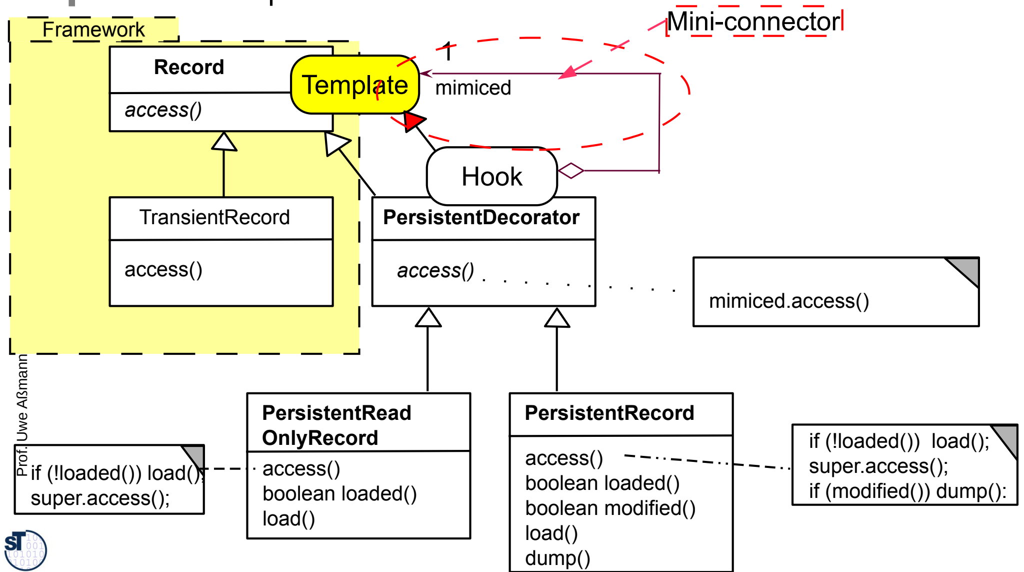


n-H<=T (deep graph extension)
H has n T parts
T inherit from H
n-ObjectRecursion/Composite



Decorator as 1-H<=T

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

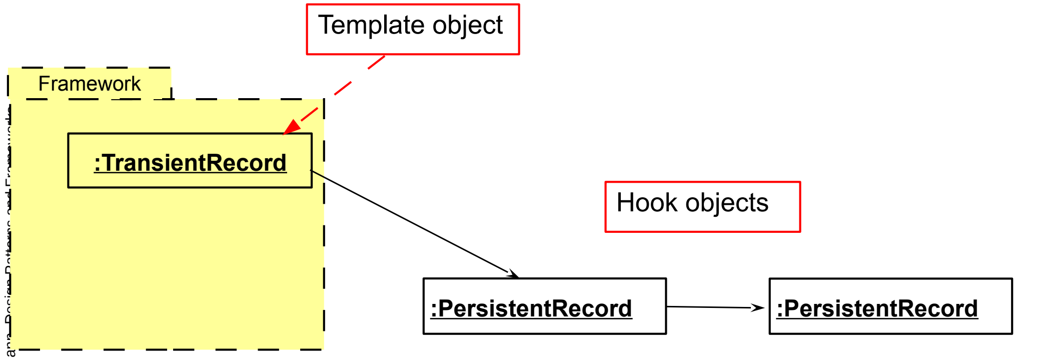


```
if (!loaded()) load();
super.access();
```

```
if (!loaded())  load();
super.access();
if (modified()) dump():
```

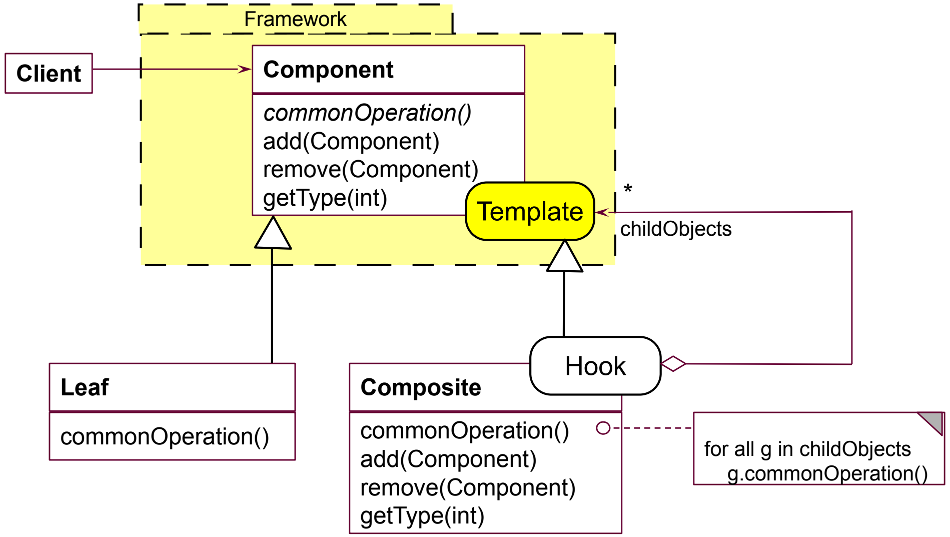
Decorator as Framework Hook Pattern

- Lists extend the framework



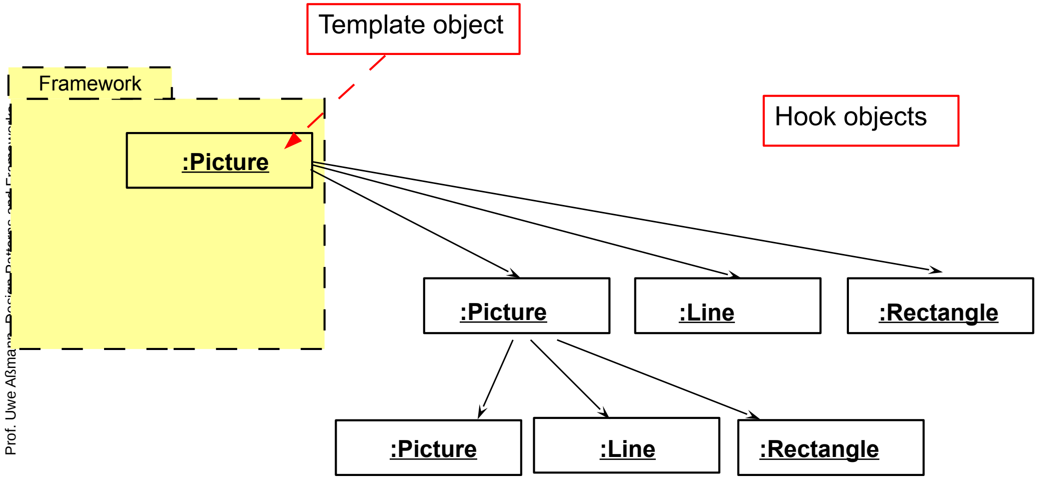
Composite as n-H<=T

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



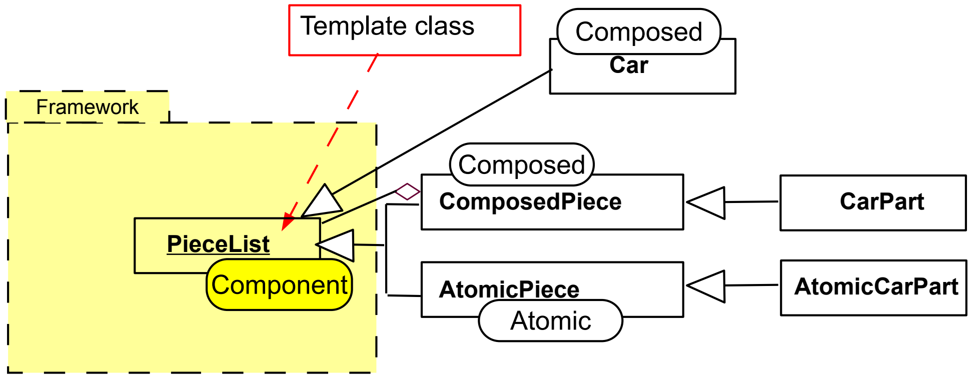
Composite as Framework Hook Pattern

- Part/Whole hierarchies extend the framework



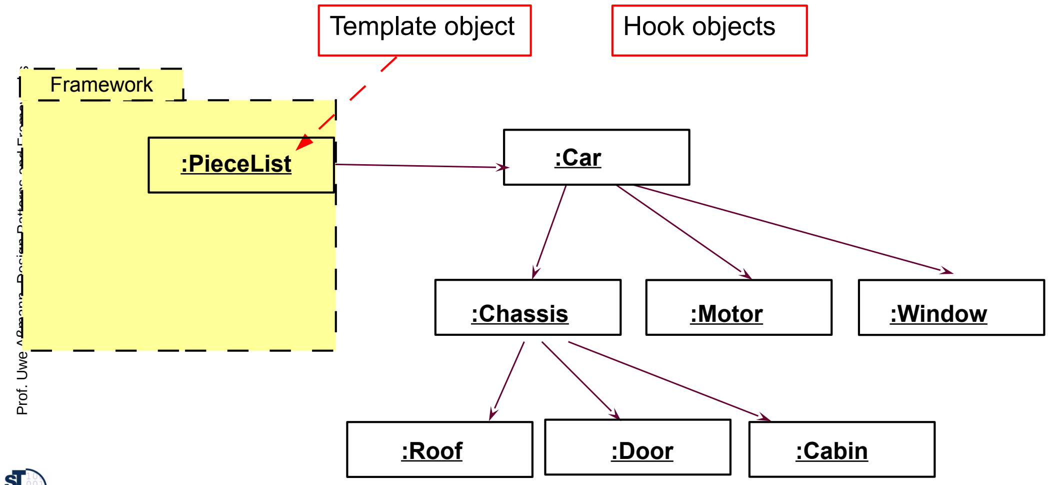
Production Data Systems

- 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

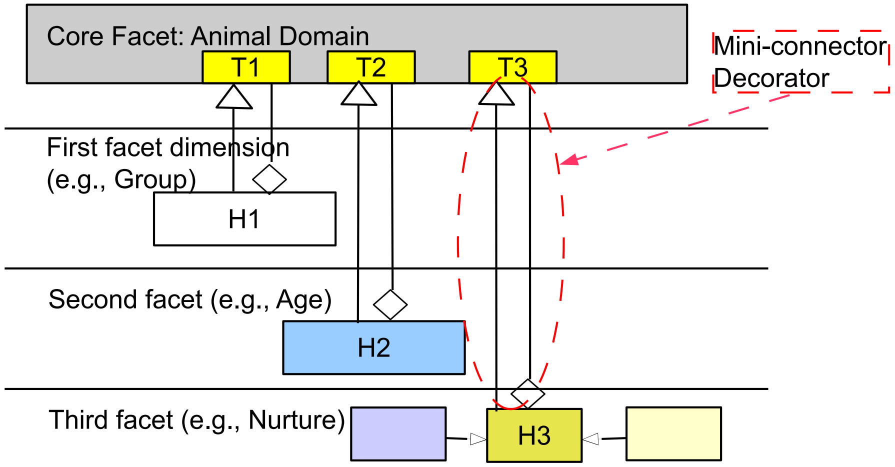


H<=T

- 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 !!

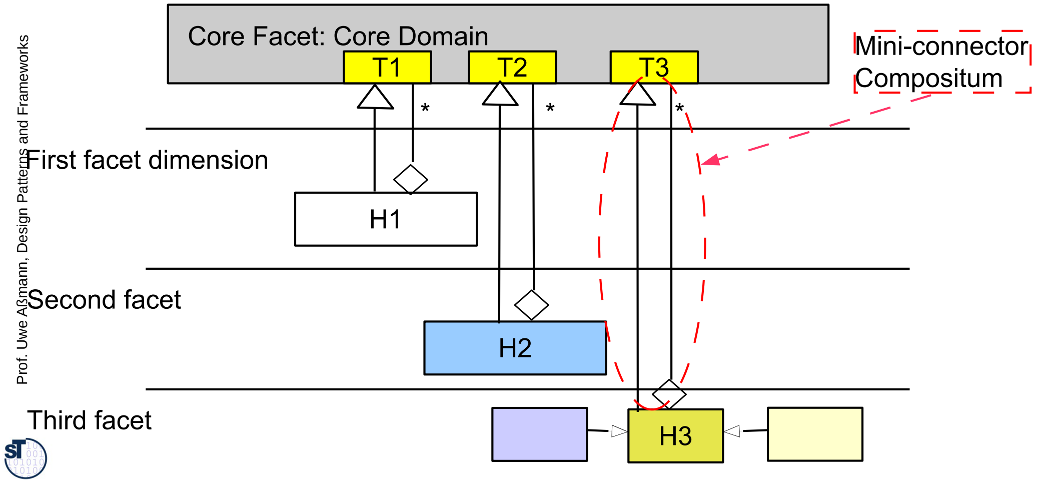
Bridge Frameworks Can Be Done with H<=T (Bridge H<=T Framework)

- 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

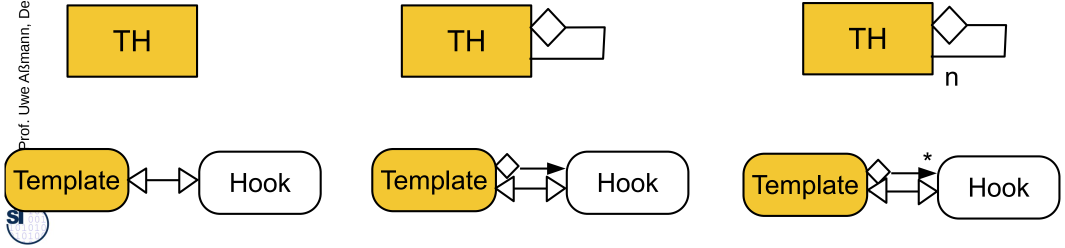
TH

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

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

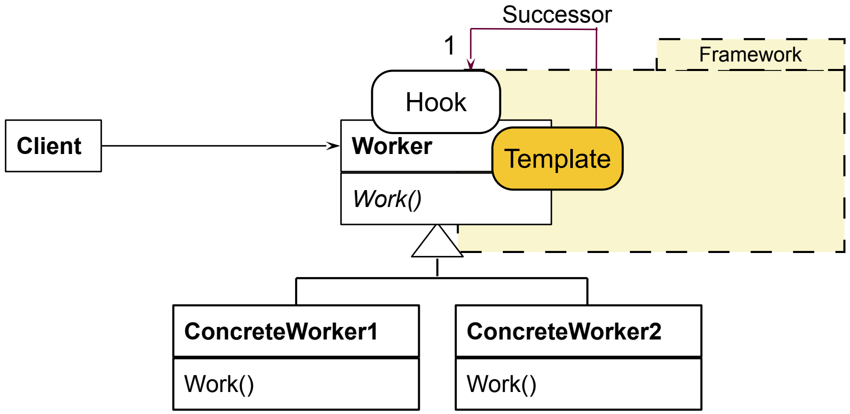
1-TH (deep list extension)
T == H
TH part of TH
“funny” Decorator

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

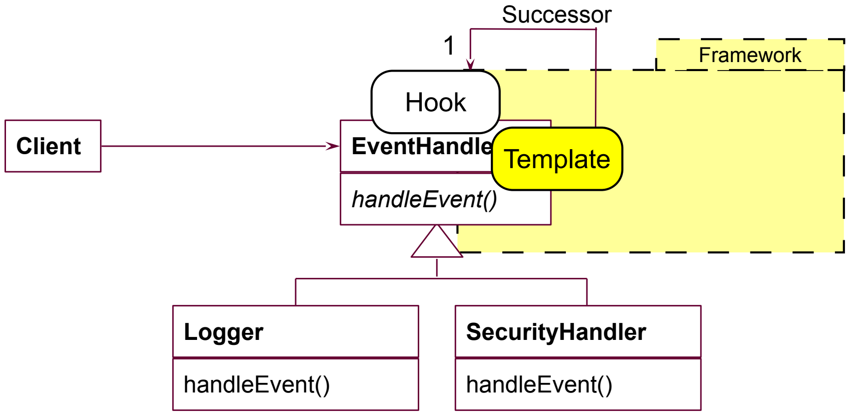


ChainOfResponsibility as 1-TH

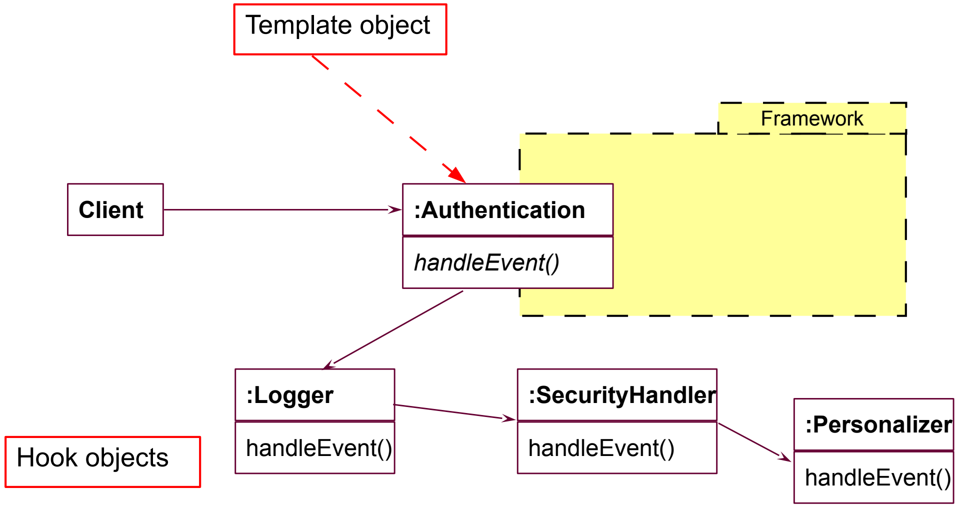
- A Chain is recursing on the abstract super class, i.e.,
  - All classes in the inheritance tree know they hide some other class (unlike the ObjectRecursion)



Event Handlers



Event Handlers: Object Diagram



Template object

Framework

Client

:Authentication

handleEvent()

:Logger

handleEvent()

:SecurityHandler

handleEvent()

:Personalizer

handleEvent()

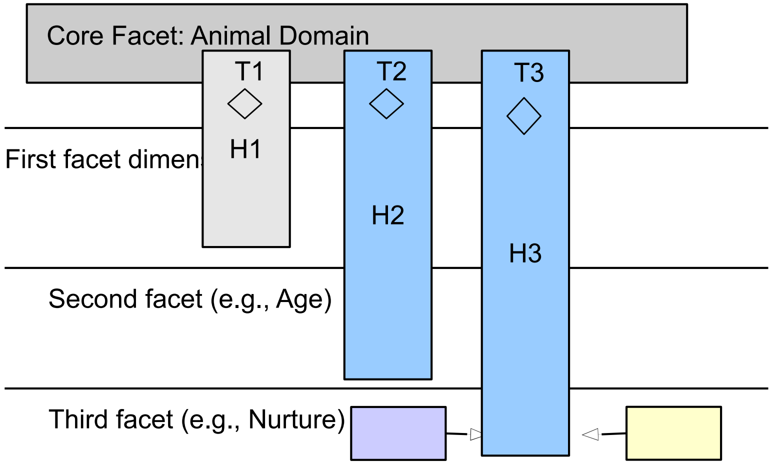
Hook objects

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



Core Facet: Animal Domain

T1

H1

T2

H2

T3

H3

First facet dimen

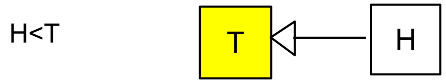
Second facet (e.g., Age)

Third facet (e.g., Nurture)

11.6 The H<T Whitebox Inheritance Metapattern

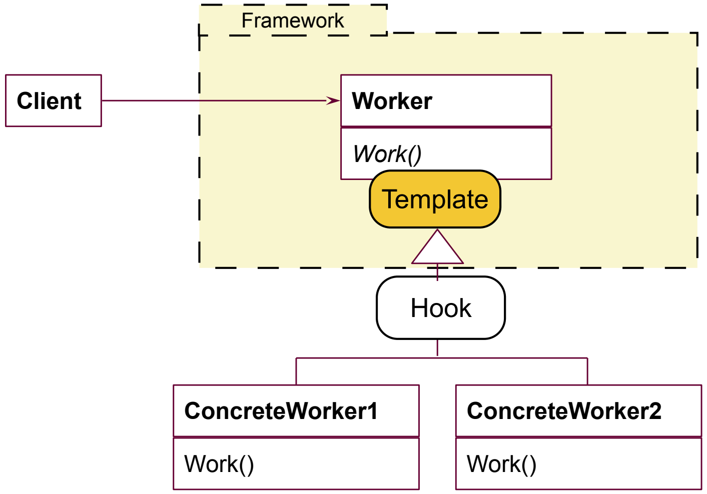
H<T

- 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



Whitebox Framework with H<T Framework Hook

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



Summary of T&H Patterns and Framework Hooks

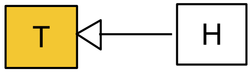
Cardinalities and Extensibility of Framework Hooks

- 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

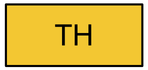
Inheritance

H<T
H inherit from T
whitebox



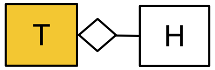
Unification

TH
T == H



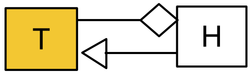
Aggregation/Association

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

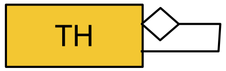


H<=T
T part of H
H inherit from T
Decorator

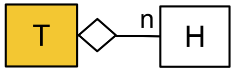
Recursion



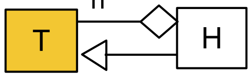
1-TH
T == H
TH part of TH
“funny” Decorator



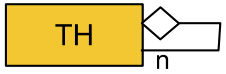
n-T--H
T has n H parts
T is core class of
complex object



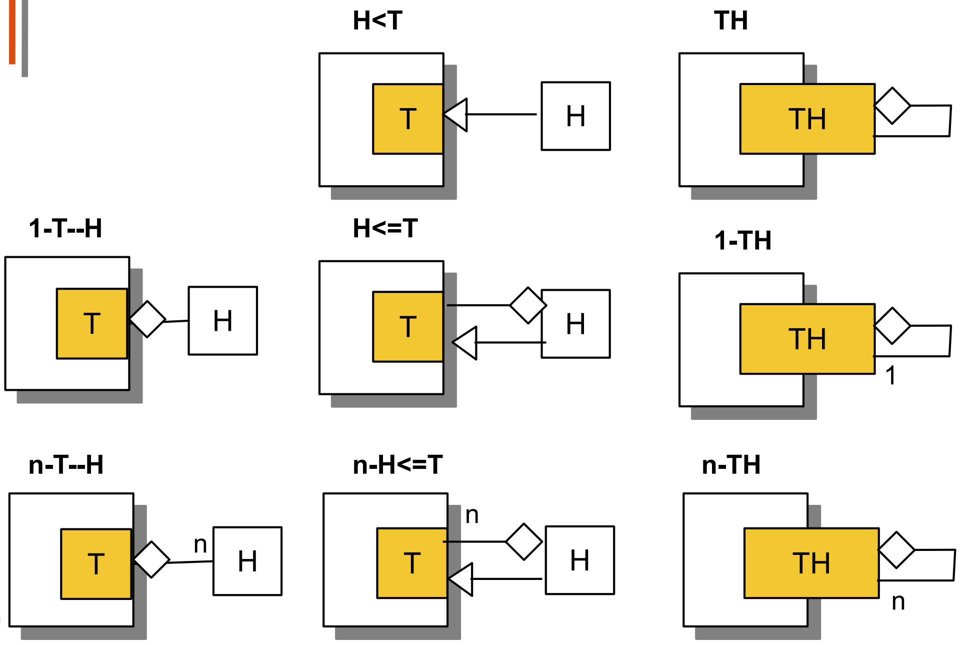
n-H<=T
H has n T parts
H inherit from T
1:n-Decorator



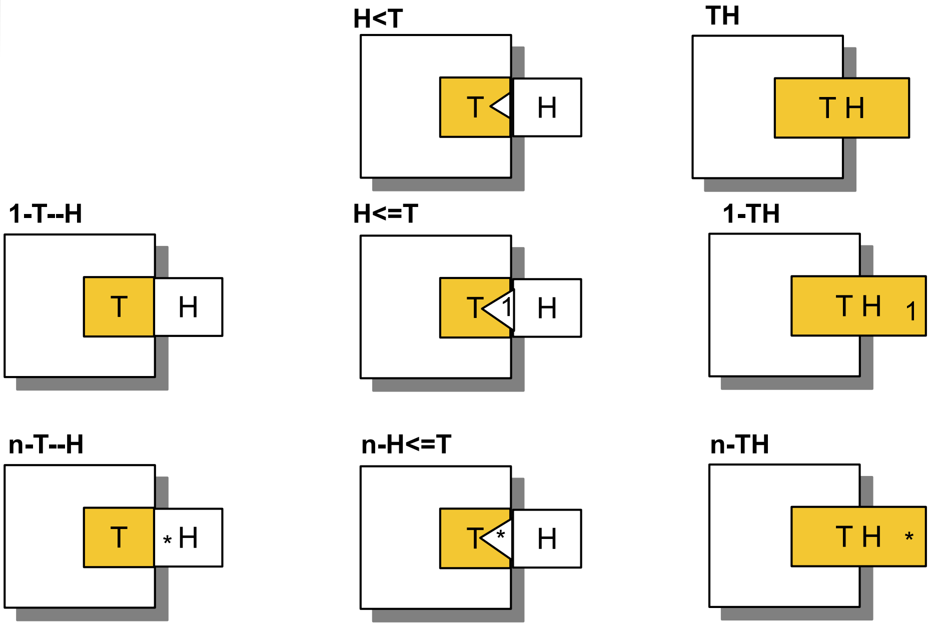
n-TH
T == H
TH has n TH parts
“funny” 1:n-Composite



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 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

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

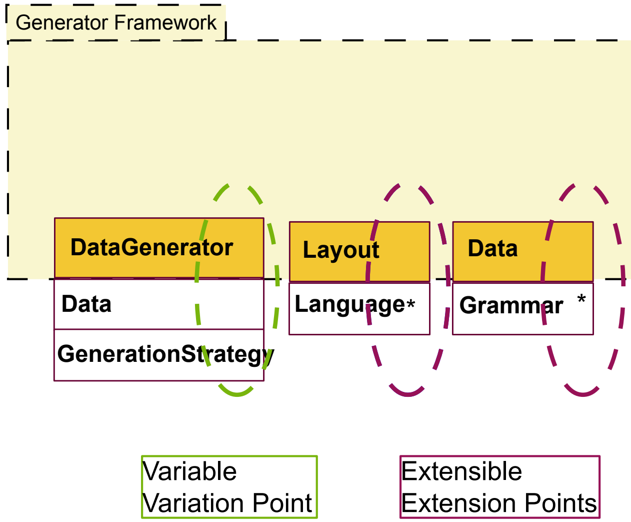
Pree's Second Law of Framework Instantiation

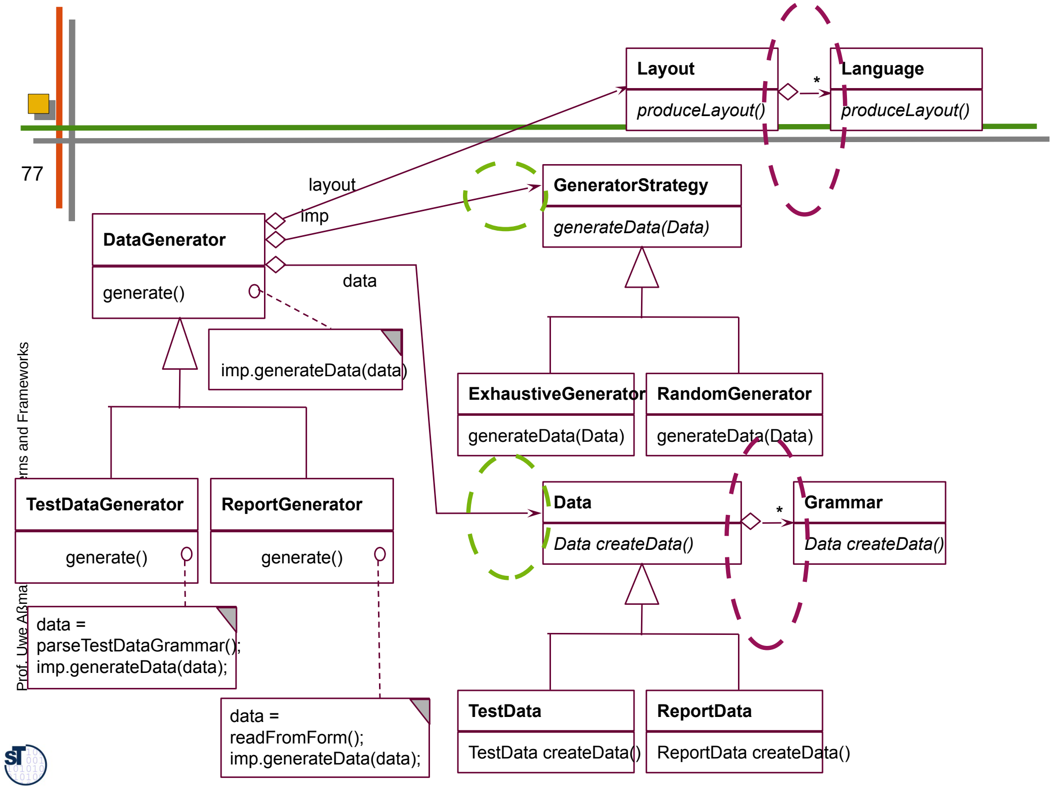
- Extensibility-based framework hooks define *framework extension points*
  - If you *do not want to constrain* the uses of a framework to a fixed set of variations, use extensibility patterns for framework hooks (n-TH patterns)

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

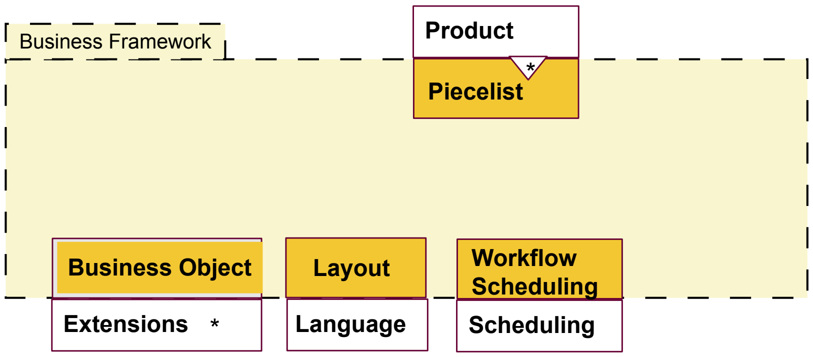




Framework Instantiation Market

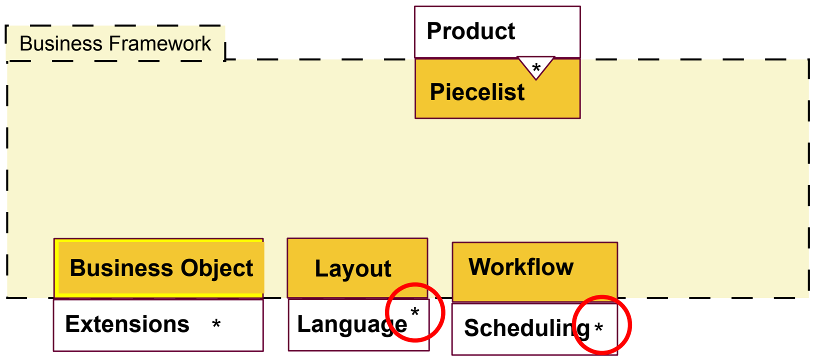
- Today, frameworks are the most important software technology for product lines in large companies
- Instantiating big frameworks is very hard
  - Requires special *instantiation consultancy*, which is a big market
  - SAP Germany has a marker for instantiation companies of their framework!
  - If you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

A Multi-lingual Business Framework



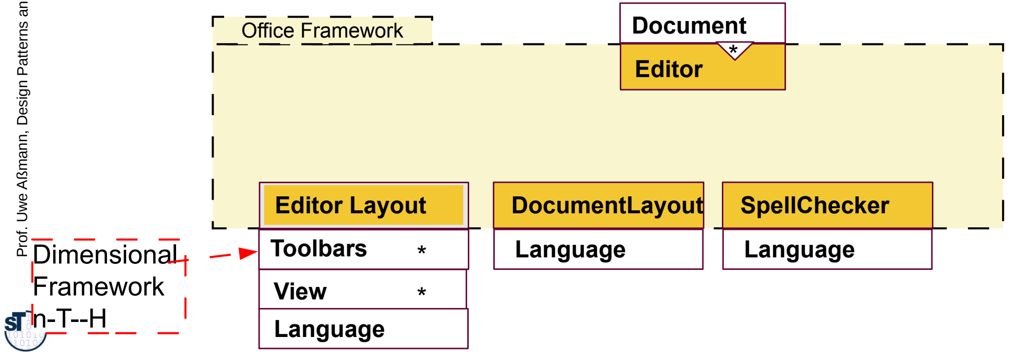
A Business Framework with Several Languages Simultaneously

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



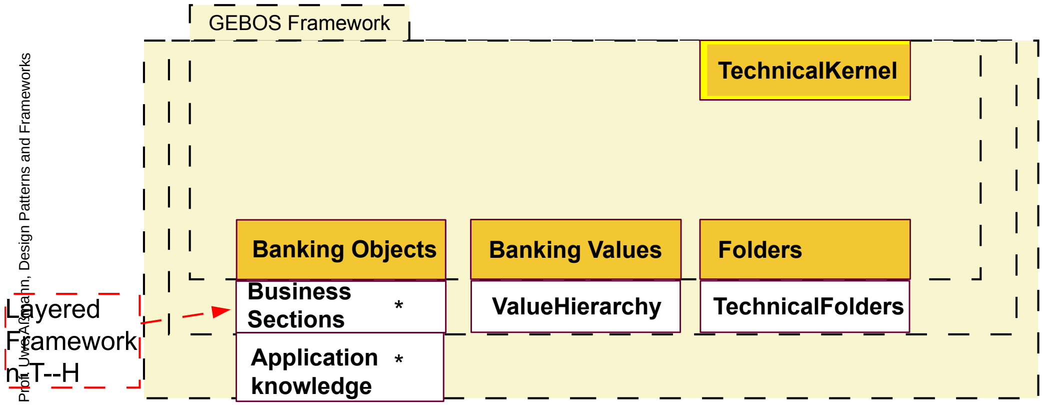
OpenOffice

- 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

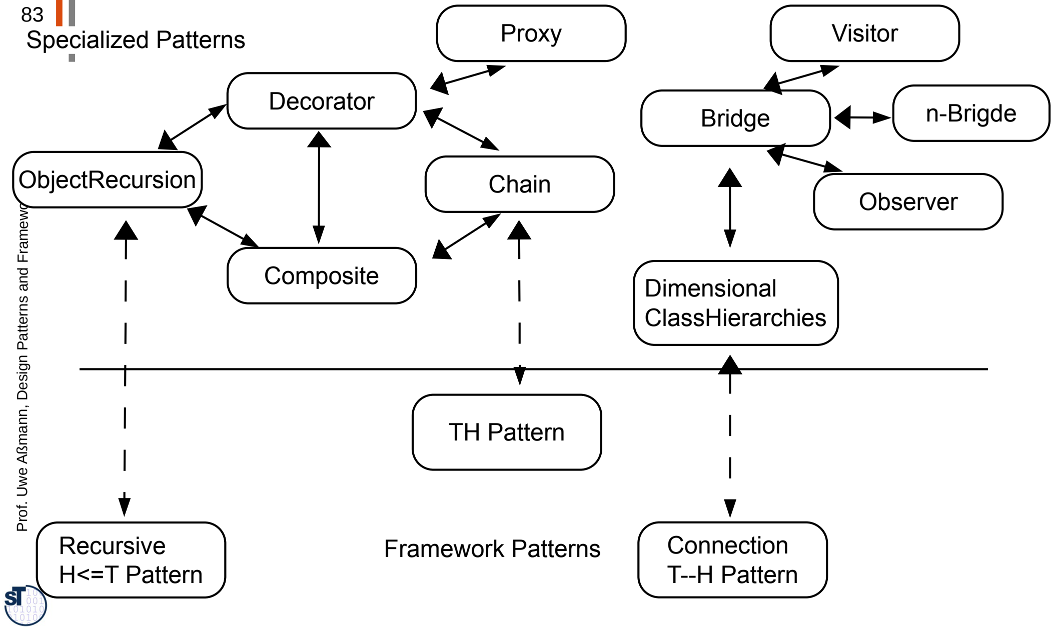


GEBOS Banking Layered Framework

- 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