

# 13) The Tools And Materials Architectural Style and Pattern Language (TAM)

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12-1.0, 12/15/12

- 1) Tools and Materials - the metaphor
- 2) Tool construction
- 3) The environment
- 1) Material constraints
- 4) TAM and layered frameworks



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## Literature

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- ▶ D. Riehle, H. Züllighoven. A Pattern Language for Tool Construction and Integration Based on the Tools&Materials Metaphor. PLOP I, 1995, Addison-Wesley.
- ▶ JWAM: Still available on Sourceforge  
<http://sourceforge.net/projects/jwamtoolconstr/>
  - A copy of jwam.org is in the Internet Archive, also literature
  - [http://web.archive.org/web/20041009212341/www.jwam.org/engl/produkt/e\\_literature.htm](http://web.archive.org/web/20041009212341/www.jwam.org/engl/produkt/e_literature.htm)
  - Thanks to Moritz Bart!

# Literature

3

- ▶ D. Riehle, H. Züllighoven. A Pattern Language for Tool Construction and Integration Based on the Tools&Materials Metaphor. PLOP I, 1995, Addison-Wesley.
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  - Thanks to Moritz Bart!



# Secondary Literature

4

- ▶ Heinz Züllighoven et.al. The object-oriented construction handbook. Morgan Kaufmann Publishers, 2004. The TAM explained in detail.
- ▶ In German: Heinz Züllighoven et.al. Das objektorientierte Konstruktionshandbuch – nach dem Werkzeug und Material-Ansatz. Dpunkt-Verlag, Heidelberg, 1998.
- ▶ D. Riehle. Framework Design – A Role Modeling Approach. PhD thesis 13509, ETH Zürich, 2000. Available at <http://www.riehle.org>.



# Exam Questions (Examples)

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- ▶ What are the central metaphors of the Tools-and-Materials architectural style?
- ▶ Explain tool-material collaboration. Which roles do role models play?
- ▶ How are tools structured?
- ▶ How is TAM arranged as a layered framework?



# Why Do People Prefer to Use Certain Software Systems?

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- ▶ People should feel that they are competent to do certain tasks
- ▶ No fixed workflow, but flexible arrangements with tools
  - Domain office software, interactive software
- ▶ People should decide on how to organize their work and environment
- ▶ People want to work incrementally, in piecemeal growth



# 13.1 Elements of “Tools and Materials”

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## 13.1 The Central T&M Metaphor

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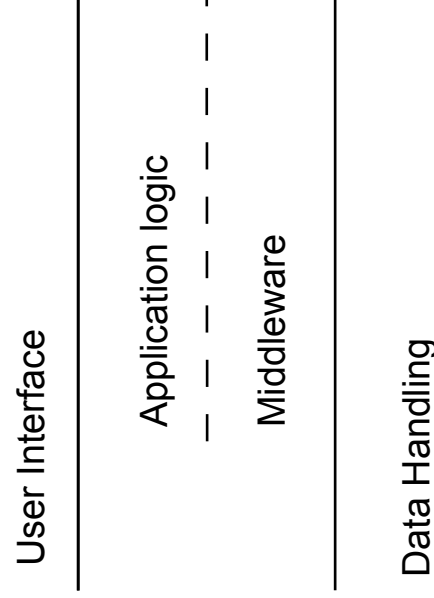
- ▶ Tools and Materials pattern language T&M
  - Werkzeug und Material (WAM)
  - Craftsmanship: Craftsmen use tools to work on material
- ▶ People use tools in their everyday work: Tools are means of work
  - People use tools to work on material
- ▶ T&M-collaboration: Tools and materials are in relation
- ▶ Environment: Craftsmen work in an environment



# And 3-Tier Architectures?

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- ▶ Another popular architectural style for interactive applications is 3-tier architecture
- ▶ However, the 3-tiers are so coarse-grained that they do not really help for interactive applications
- ▶ T&M is much more detailed



Data Handling



# Material

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- ▶ Passive entities, either values or objects
  - Ex.: Forms laid out on a desktop, entries in a database, items in a worklist
- ▶ Prepared and offered for the work to be done
- ▶ Transformed and modified during the work
- ▶ Not directly accessible, only via tools

- ▶ Values (e.g., Dates, Money)
  - Without time and position
  - Abstract, without identity
  - Equality is on value
  - A value is defined or undefined, but immutable
  - Cannot be used in a shared way
  - Structured (then every subvalue has 1 reference), such as documents
  - are domain-specific, such as business values (value objects)

- ▶ Objects (e.g., Persons, technical objects, Bills, Orders)
  - With time and position
  - Concrete, with identity
  - Equality is on names
  - Mutable; identity does not change
  - Shared by references
  - Structured (a subvalue may have several references)



# Tools

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- ▶ Active entities
  - Tools are means of work. They embody the experience of how to efficiently work with material
  - Present a view on the material.
  - Often visible on the desktop as wizards, active forms,...
  - Tools give feedback to the user
  - Tools have a state
- ▶ If well-designed, they are transparent, light-weight, and orthogonal
  - However, they should not disappear, since users need to look at a tool if they are worried
- ▶ Examples:
  - Browser – Contents of a folder
  - Interpreter – Code and data
  - Calendar - Calendar data
  - Form editor - Form



# Tools vs. Material

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- ▶ To say, what is a tool and what the material, depends a lot on the concrete task (interpretation freedom)
  - Pencil -- paper
  - Pencil sharpener - pencil
- ▶ Tools can be structured
  - Supertools and subtools, according to tasks and subtasks
  - e.g., Calendar = AppointmentLister + AppointmentEditor
- ▶ We work with different tools on the same material
- ▶ In implementations, tools are a often realized as a variant of the Command/Objectifier reified actions
  - They have a function `execute()`



# Tools and Materials as Special Role Model

- ▶ The tool is active, has control
- ▶ The material is passive and hands out data

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## (Work-)Environment

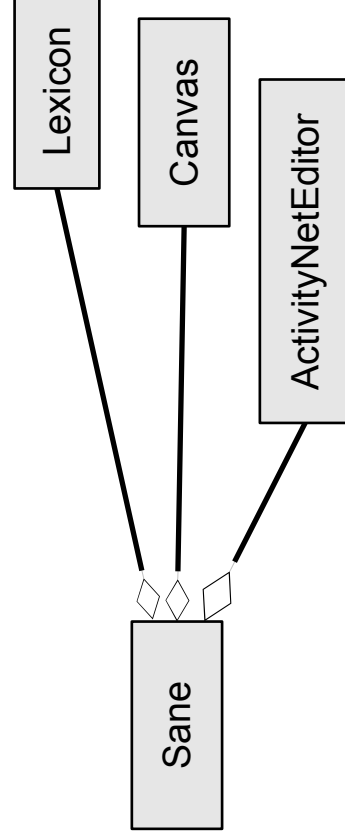
- ▶ The (Work-)Environment to organize the tools, materials, and T&M-collaborations
  - Tools can be created from the environment by tool factories (Factory pattern)
  - Materials can be created from the environment by material factories
  - Corresponds to the metaphors of a workshop or desktop
- ▶ Environment for planning, working, arranging, space
  - Several logical dimensions to arrange things

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# Running Example: TORA Tools

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- ▶ Tool for Task oriented requirements analysis (TORA)
  - Editor SANE for activity nets in requirements analysis
- ▶ TORA has subtools
  - Glossary browser *Lexicon* to manage glossaries about requirement specifications
  - *Canvas* for the editor's graphical objects. Manipulates the editor's visible materials (Graphical objects, GraphObj):
    - Edit shapes, icons, representation
    - Annotate activity nets
  - *ActivityNetEditor* for logical materials ActivityObj
    - An ActivityObj may have several visual representations (GraphObj)



## 13.2 Tool Construction

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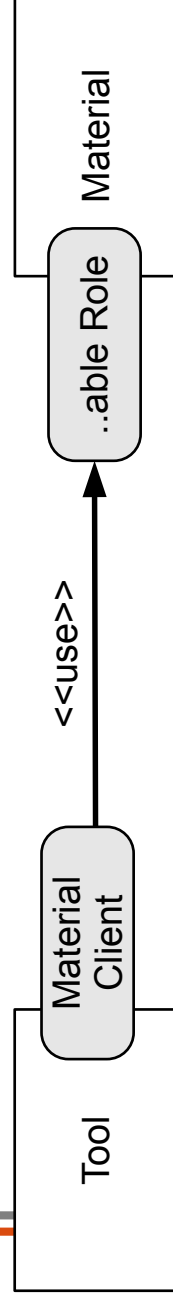
# Tool-Material Collaboration Pattern

▶ A *tool-material collaboration* (T&M role model, T&M access aspect) expresses the relation of a tool and the material

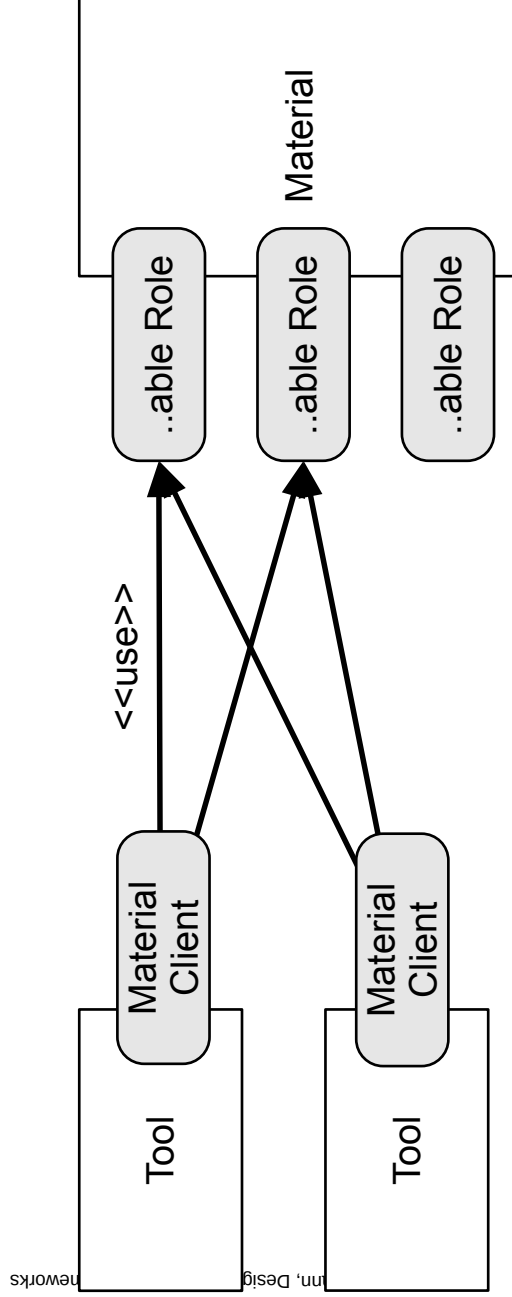
- Characterizes a tool in the context of the material
- The material in the context of a tool
- The tool's access of the material. The tool has a view on the material, several tools have different views
- ▶ More specifically:
  - A *role* of the material, in collaboration with a tool
    - An interface of the material, visible by a tool, for a specific task
    - An abstract class
  - Roles of a material define the necessary operations on a material for one specific task
    - They reflect usability: how can a material be used?
    - Express a tool's individual needs on a material

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# Tools and Their Views on Material



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# Implementing Tool-Material Roles With ..able-Interfaces

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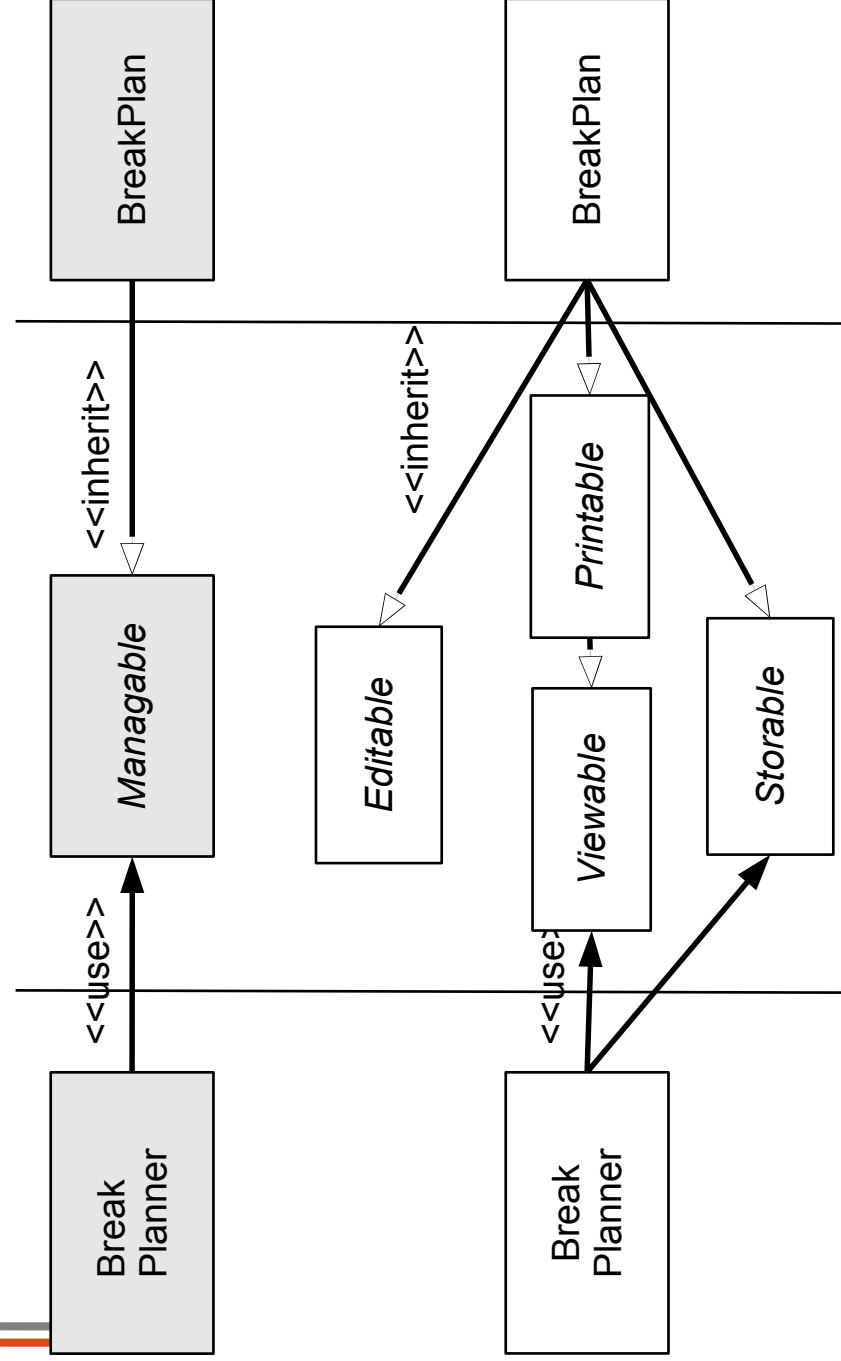


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# Tools/Views/Material with ..able- Interfaces

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# Names of Roles

- ▶ The notion of a material-role helps a lot to understand the functionality of the materials
  - And helps to separate of them
- ▶ Often a “adjectified verb”, such as Listable, Editable, Browseable, expresses the ability of a material from the perspective of a tool

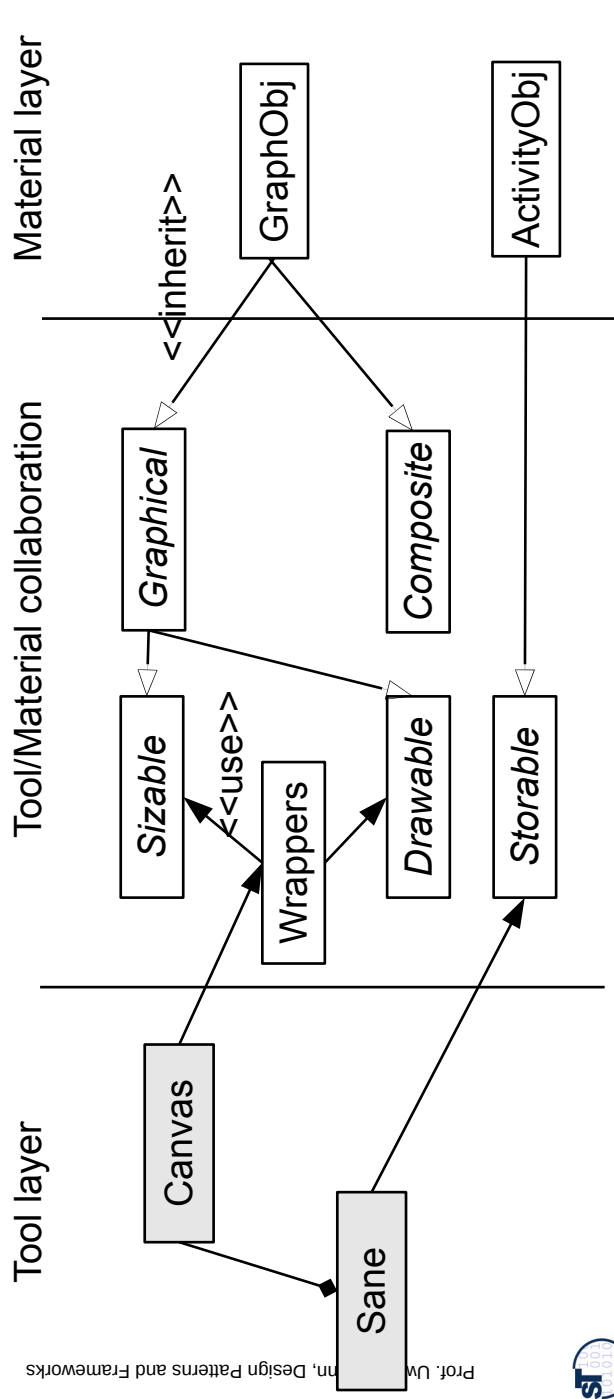
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# Ex.: Access To Materials In TORA

- ▶ Access from tools to material via material-roles
  - Main tool: Storable
  - Canvas:
    - Drawable, Sizable with the help of wrappers DragWrapper, ResizeWrapper
    - Graphical role of GraphObj

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# Alternative Implementations of Tool-Material Collaboration

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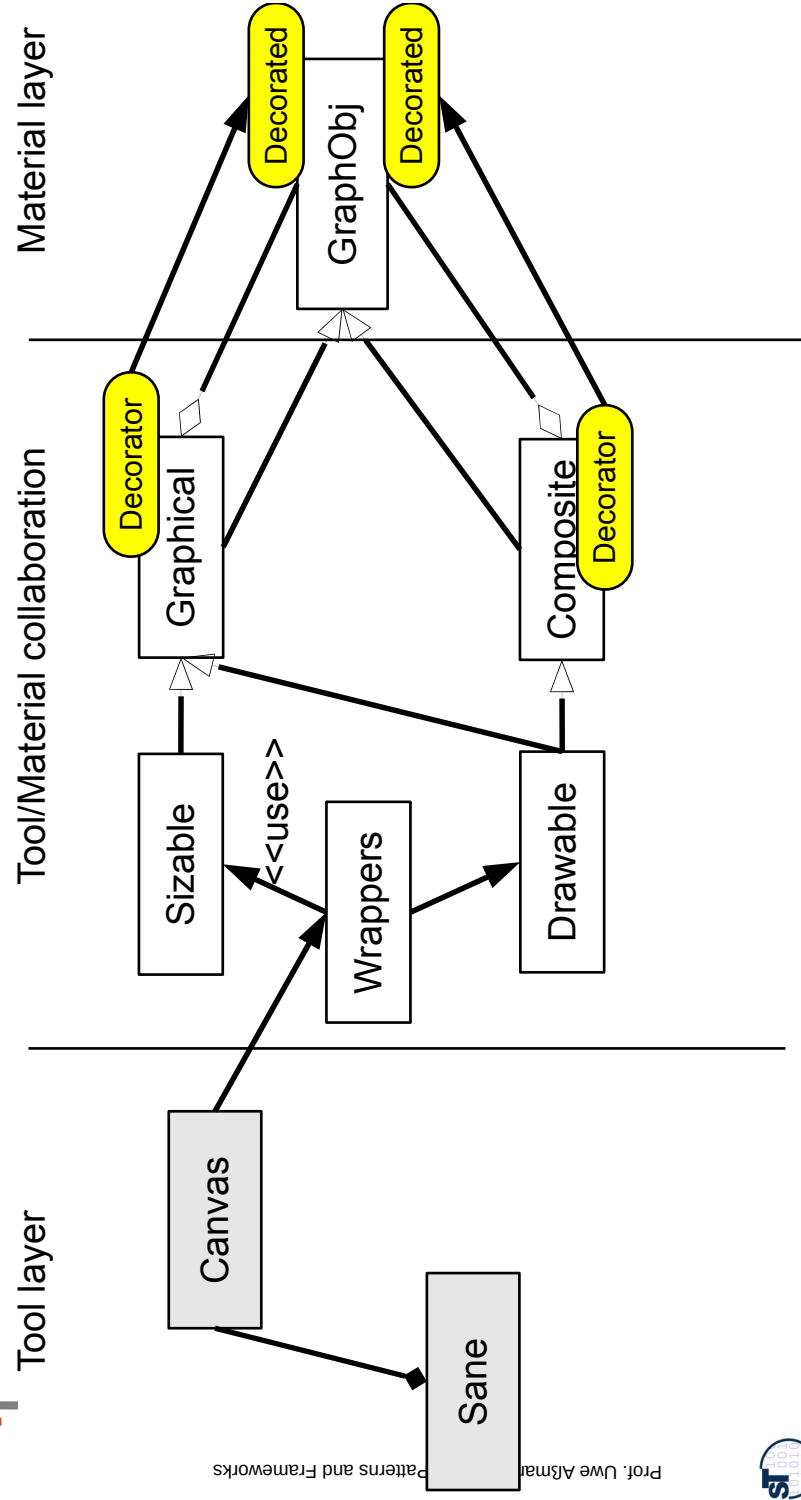
- ▶ See chapter on role implementation
  - Construction of roles by interfaces
  - By multiple or mixin inheritance
- ▶ By ObjectAdapter pattern
- ▶ By Decorator pattern
- ▶ By Role-Object Pattern
- ▶ By GenVoca Pattern



# Ex.: Tools Accessing Material Via Decorators

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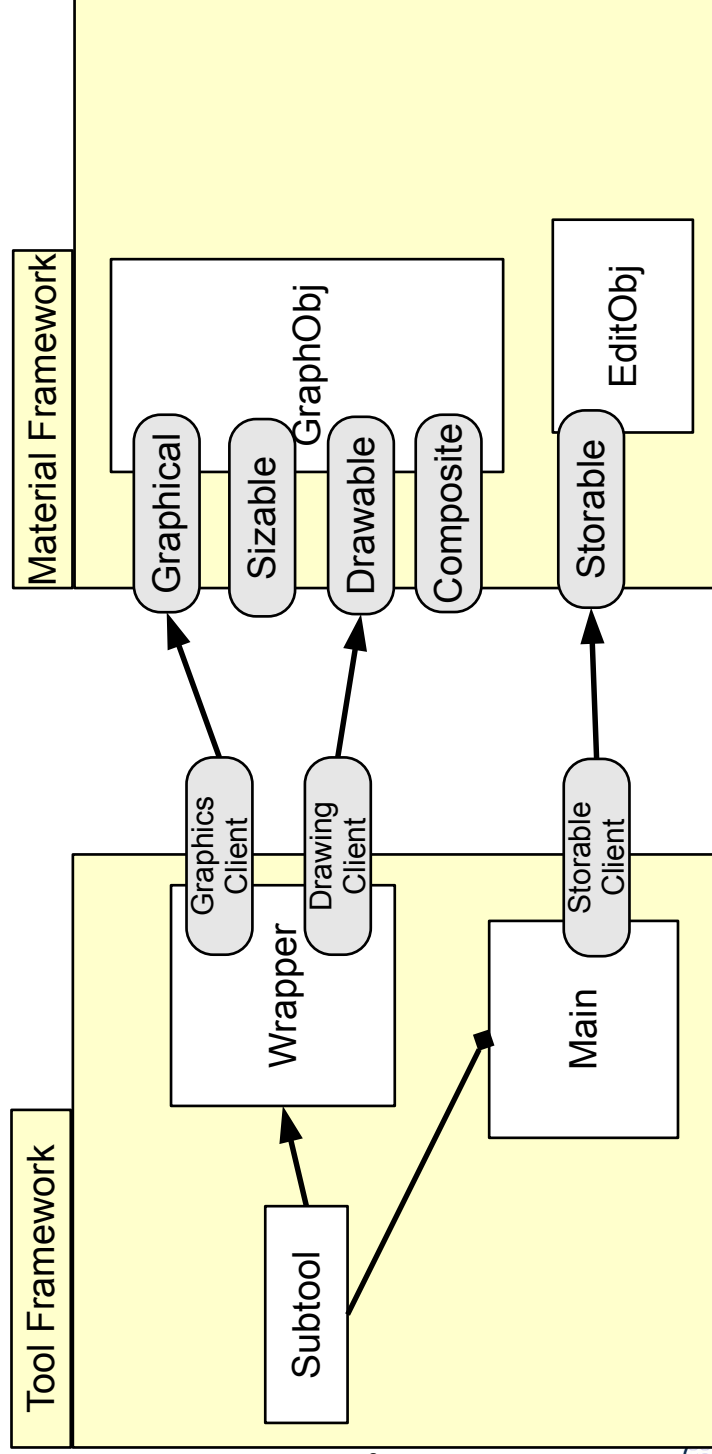
- ▶ Converting roles into decorator objects



# Composition of a Tool and a Material Framework With Collaboration Roles

- ▶ Since Material-roles are roles, Tool layer and Material layer can be modeled as frameworks (which then can be composed by role composition/use)

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# Tool Construction: Structured Tool Pattern

- ▶ Structured tools
  - Atomic tools
  - Composed tools (with subtools)
  - Recursively composed tools (Composite pattern)
- ▶ Structured along the tasks
- ▶ A complex tool creates, delegates to, and coordinates its subtools

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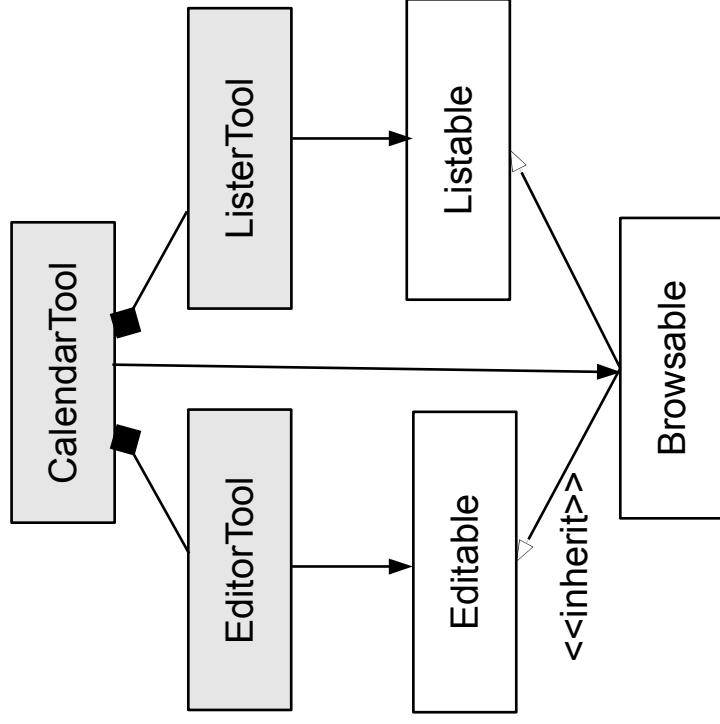
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# Tool Construction: Structured Tool Pattern

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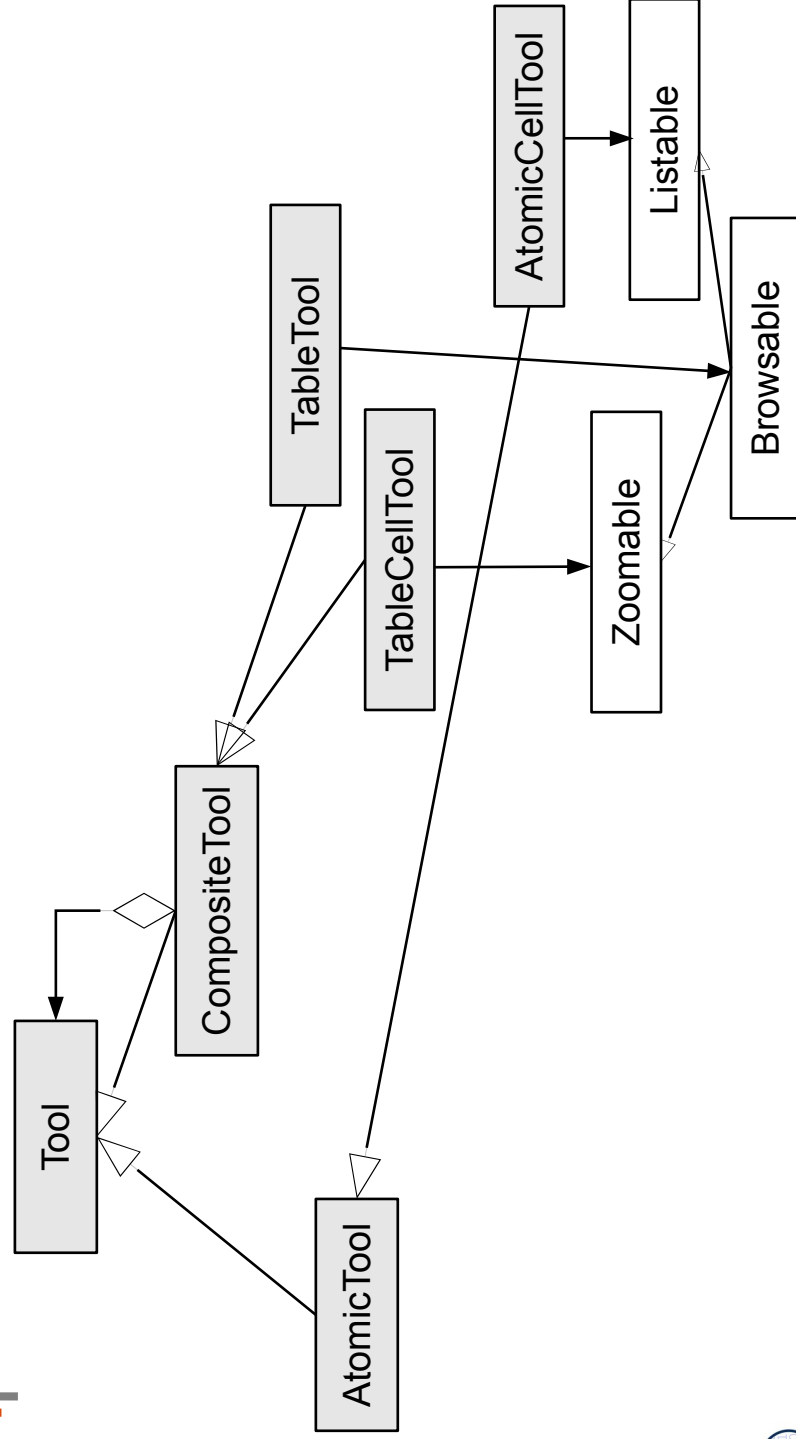
- ▶ Subtools are aggregated
- ▶ A subtool can work on its own material
  - Or on the same material as a supertool, but with fewer or less complex roles
- ▶ Advantage: complex tools see complex roles, simple tools simple roles
- ▶ The role hierarchy opens features of the material only as needed (good information hiding)



# Tool Construction: Composite as Structured Tool Pattern

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- ▶ The Composite pattern can be used to build up recursive tools



# Tool Construction: Separation of Function and Interaction

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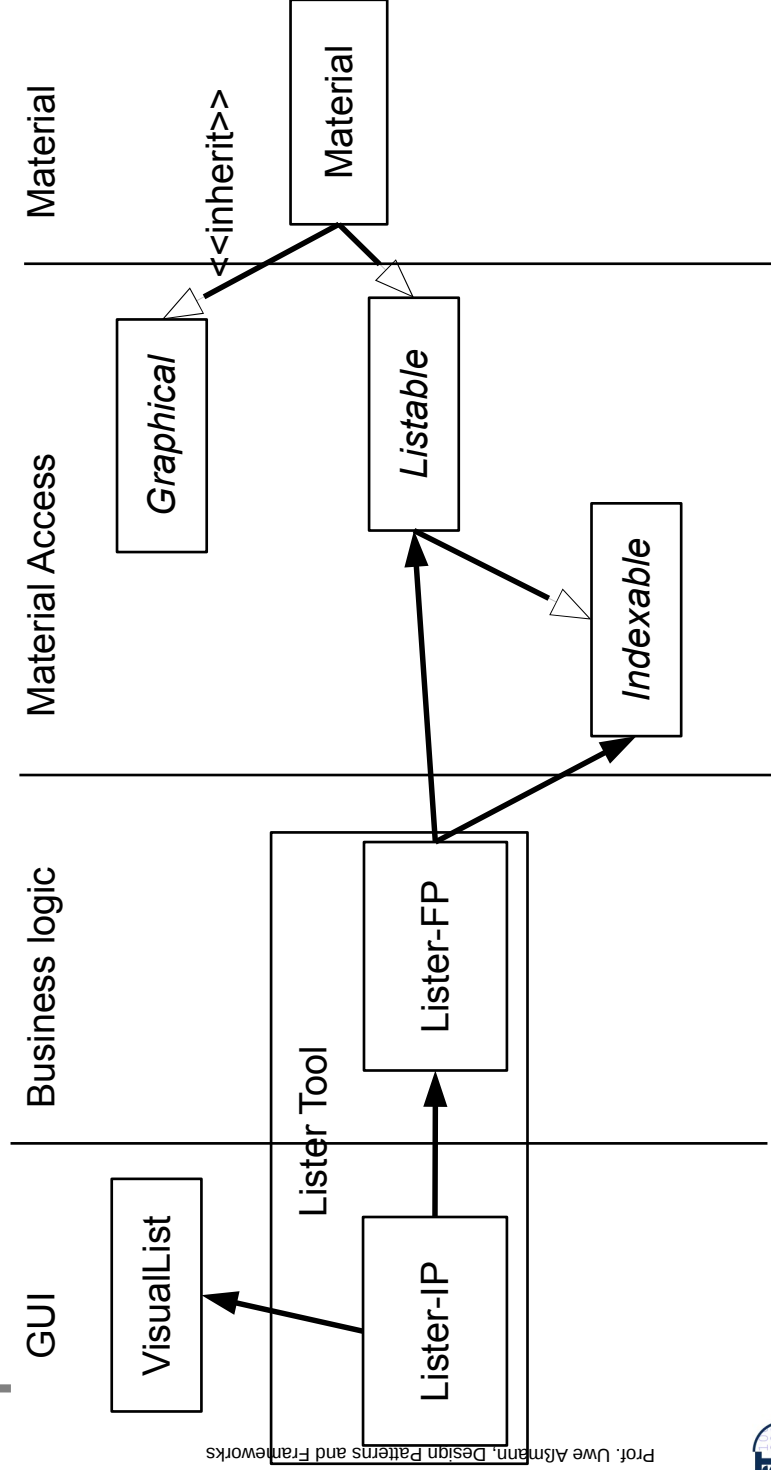
- ▶ Separation of function and interaction
  - Separation of user interface and application logic, as in 3-tier
  - Tools have one functional part and one or several interaction part
- ▶ Functional Part (FP):
  - Manipulation of the material
  - Access to Material via material-roles
- ▶ Interaction Part (IP):
  - Reactive on user inputs
  - Modeless, if possible
  - Can be replaced without affecting the functional part



# Interaction Part (IP) and Functional Part (FP)

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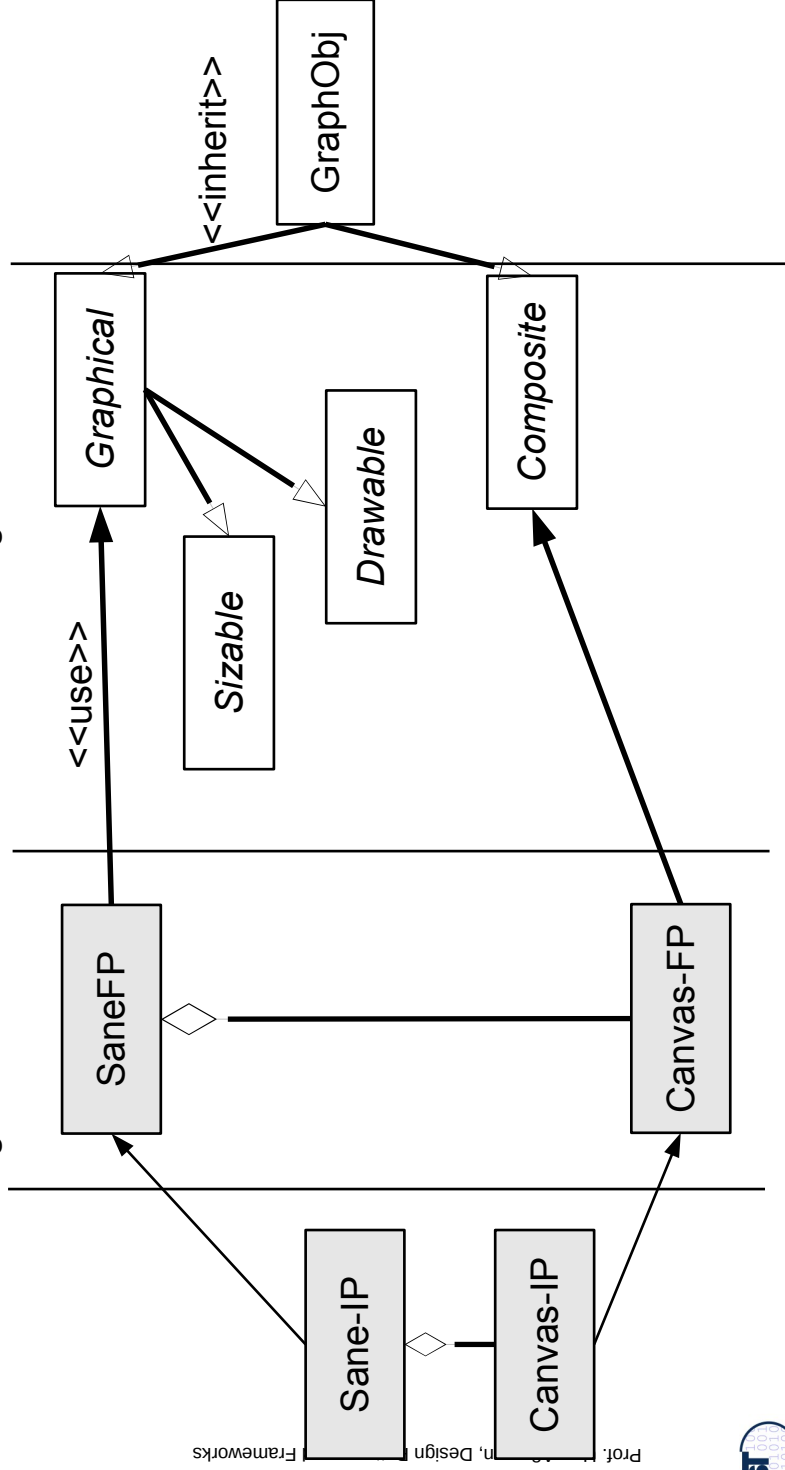
- ▶ FP create a new layer



# How TORA Tools Access Their Material

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- ▶ Tool Sane is split into IP and FP
  - Manages a frame on the screen for drawing



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# IP-FP TAM Refines MVC

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- ▶ Tools contain
  - a view (IP)
  - the controller (FP)
  - and the managing part of the model
- ▶ The model is split between tool-FP, material access, and material

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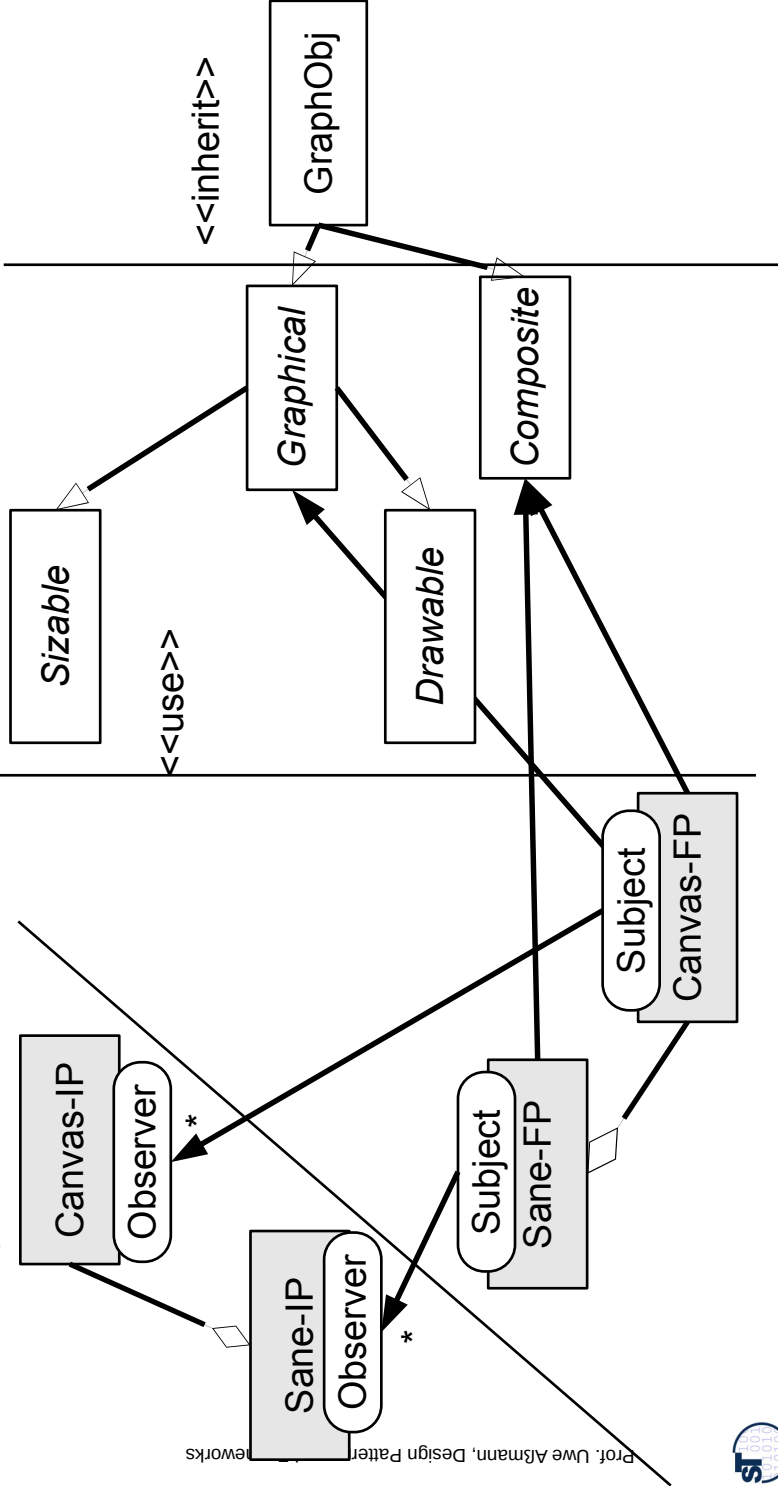




# Coupling between Function and Interaction With Observer

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- ▶ Play-Out via Observer pattern: IP listen to FP changes and actions
- ▶ Play-In via call



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# Coupling between Subtool-FP and Supertool-FP

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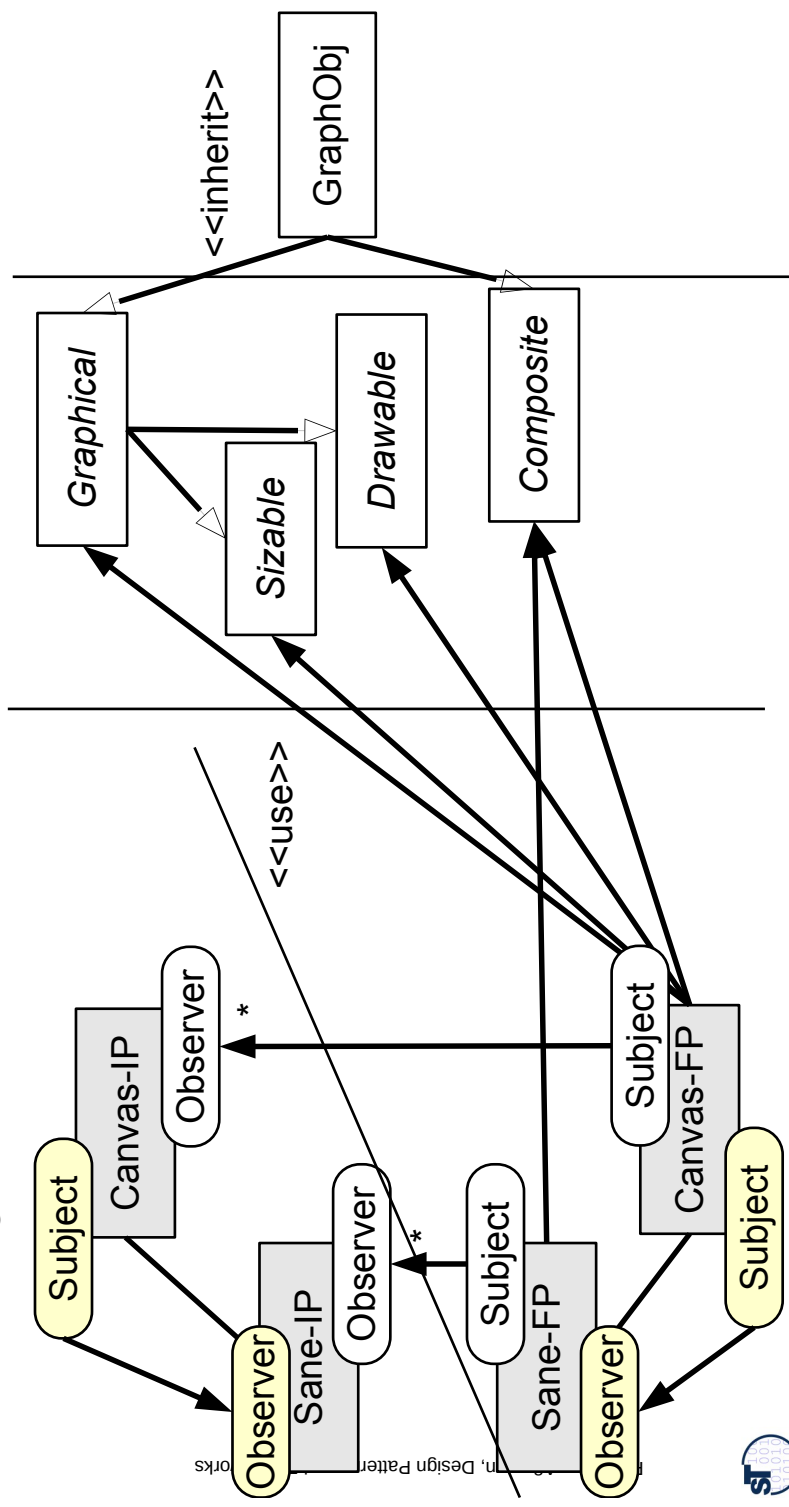
- ▶ **Vertical tool decomposition** by structuring into subtools with Bridge, Composite, Bureaucracy
- ▶ **Horizontal tool decomposition** into IP and FP
- ▶ How to add new subtools at runtime?
  - Decomposition should be extensible
    - Vertically: for Composite, this is the case
    - Horizontally, Observer serves for extensibility
  - Communication should be extensible (next slide)

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# Symmetric Coupling between Subtools and Supertools by Observer

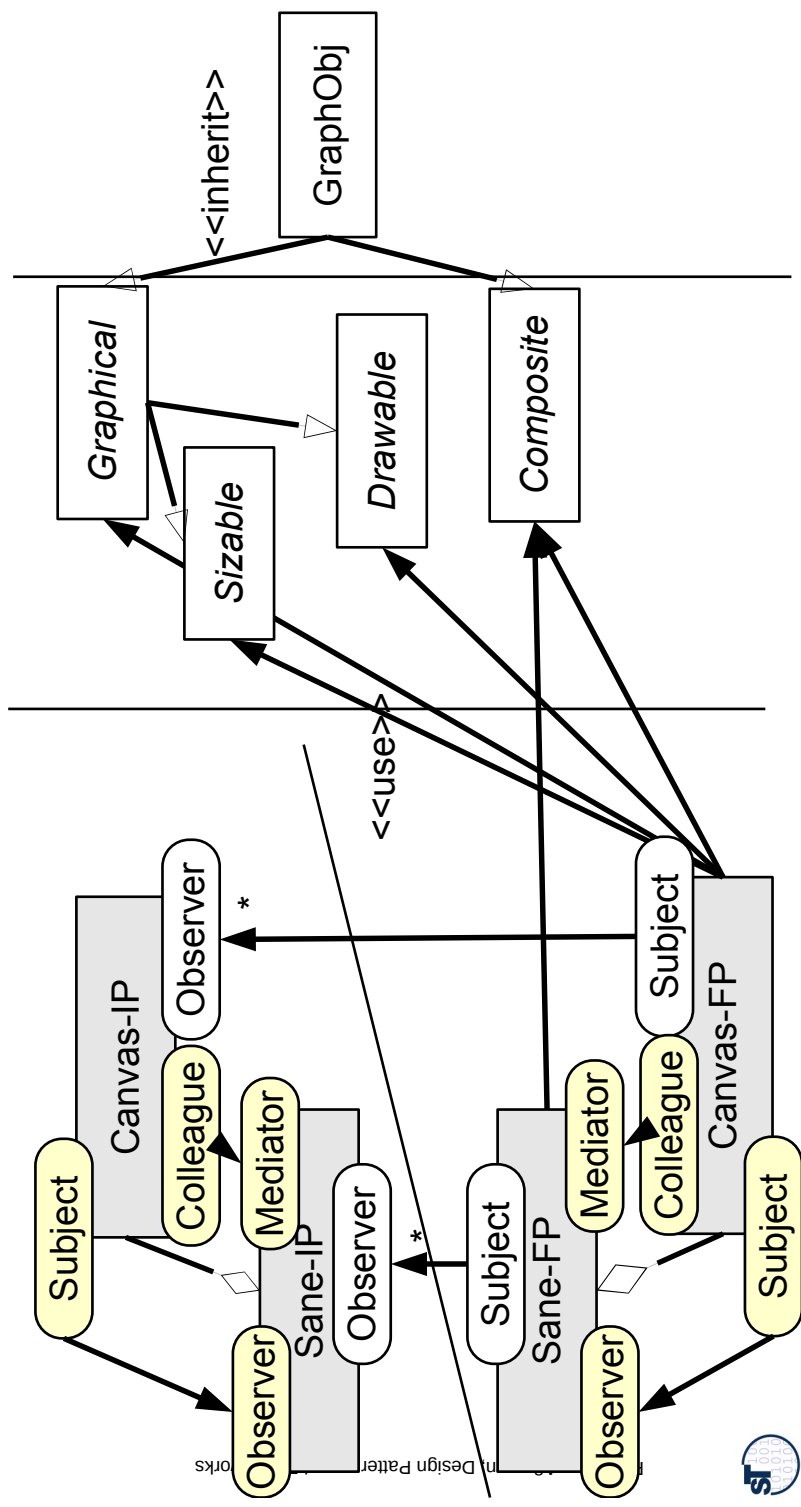
- Vertical Observer: Supertools are notified from subtools if something changes



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# Coupling between Subtools and Supertools By Symmetric Bureaucracy

- IP and FP hierarchy can work with a Bureaucracy each



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# Creation of New Subtools

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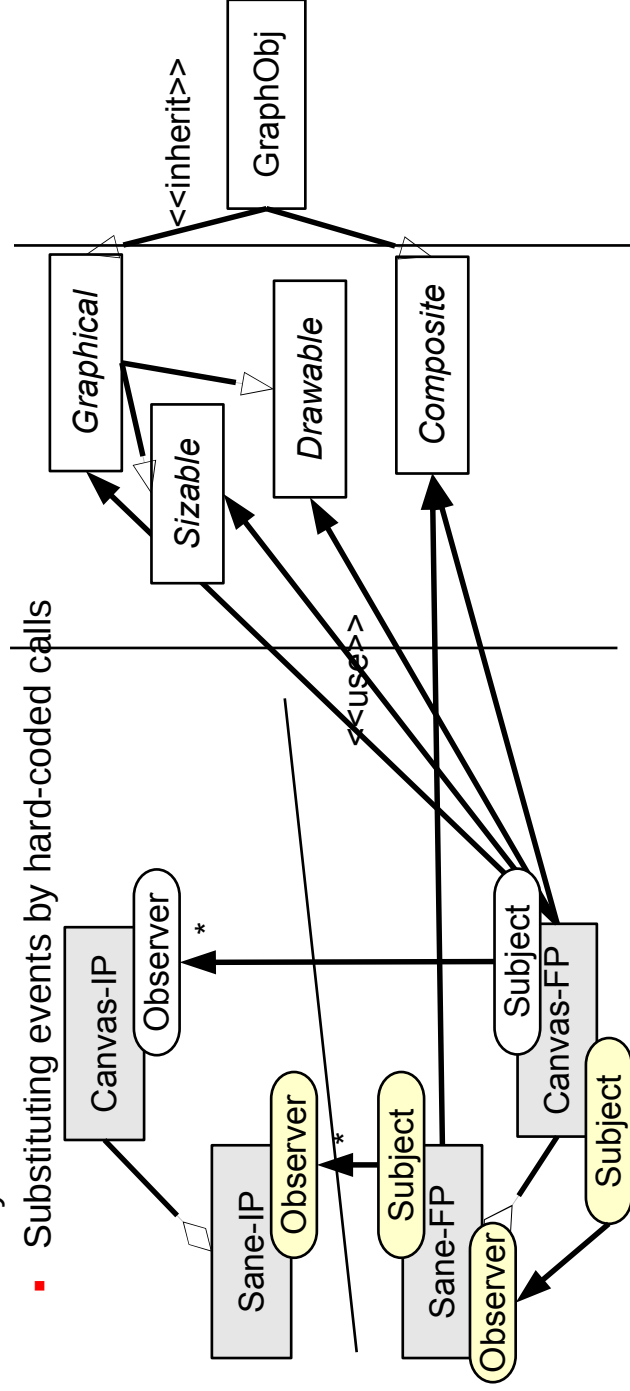
- ▶ Initiated by a Super-FP, which decides to create a new sub-FP
- ▶ Steps:
  - Super-FP notifies Super-IP
  - Super-IP may create one or several sub-IP
    - Connects them as observers to the sub-FP



# Non-Symmetric Coupling between Subtools and Supertools

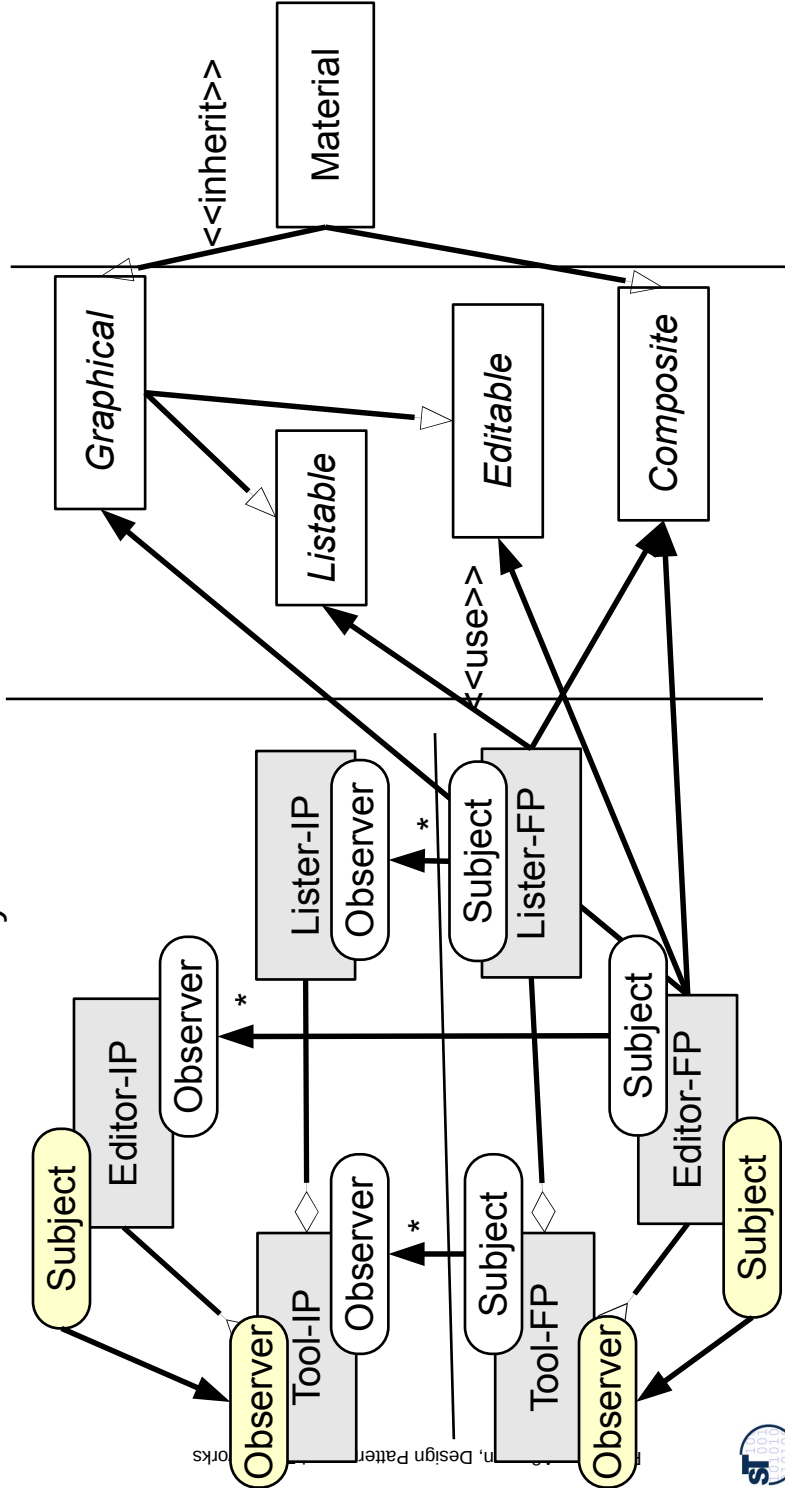
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- ▶ Super-IPs can be notified by Super-FPs
- ▶ Optimization: Several of the event channels can be coalesced for better runtime behavior
  - Merging FP and IP again, getting rid of Observer, but no extensibility anymore
  - Substituting events by hard-coded calls



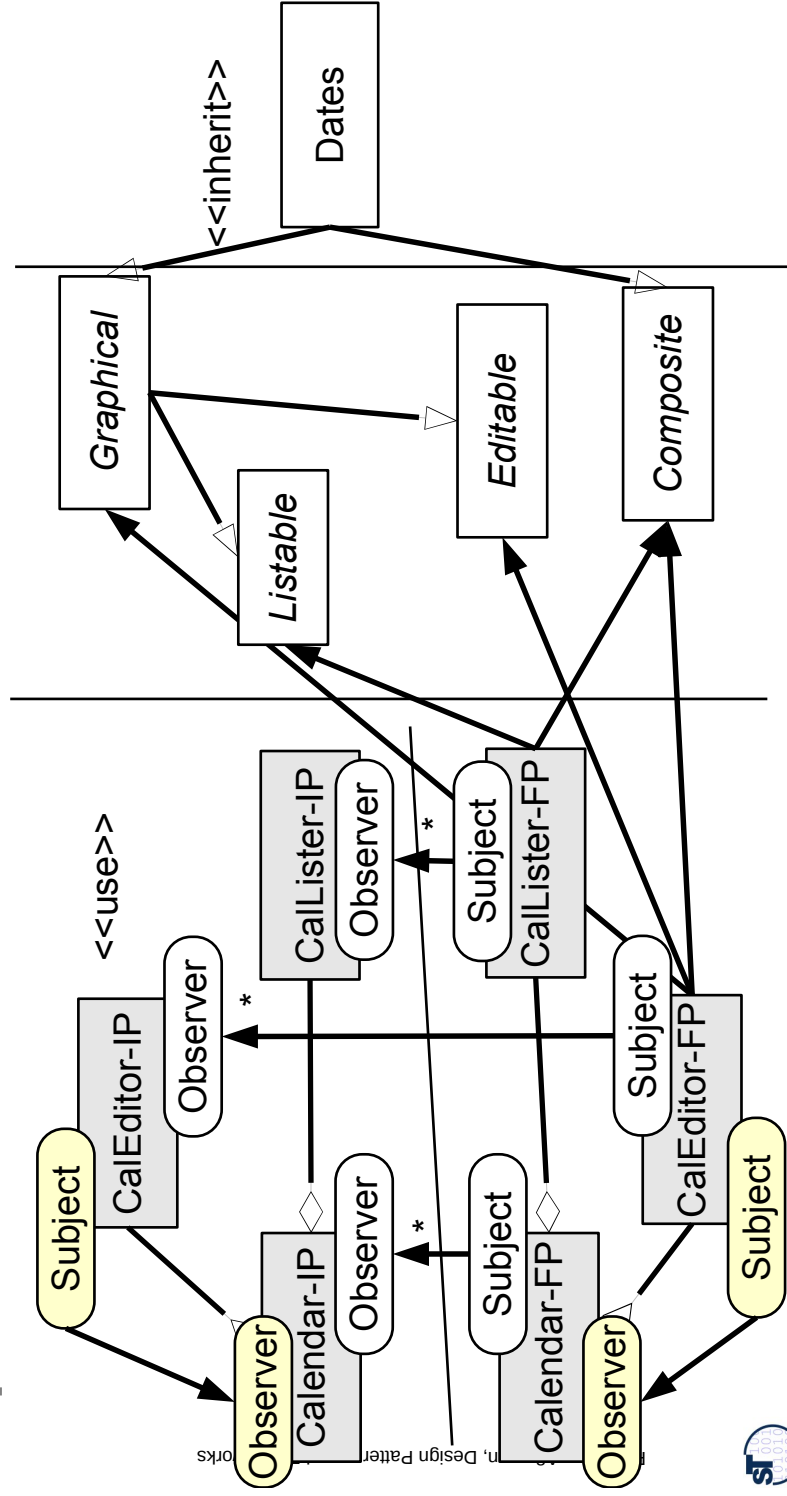
# Example: Generic Editor and Lister Framework

- Supertools are notified from subtools if something changes
- Can be used for every editor and lister of material

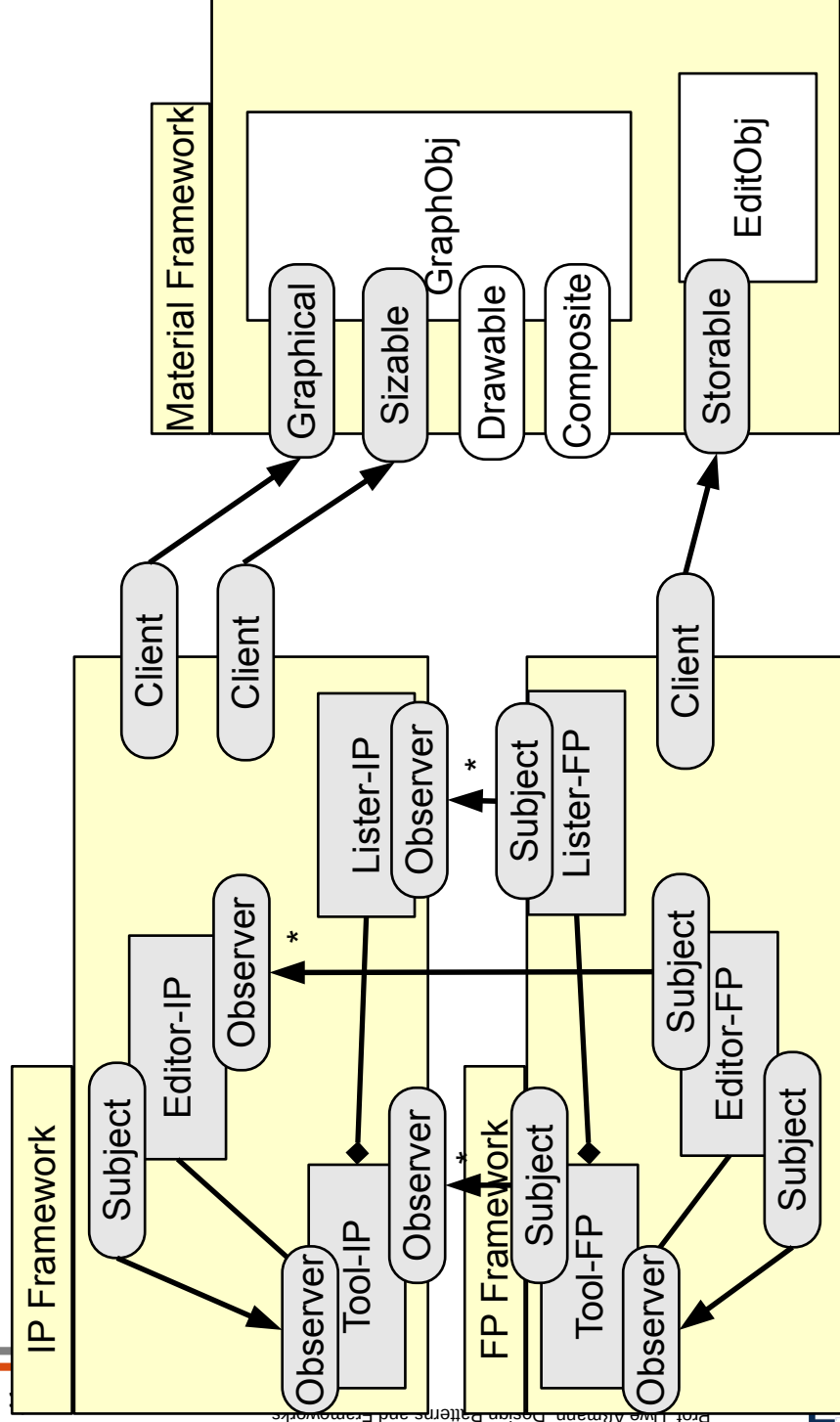


# Instantiated to a Calendar Editor and Lister Tool

- Supertools are notified from subtools if something changes



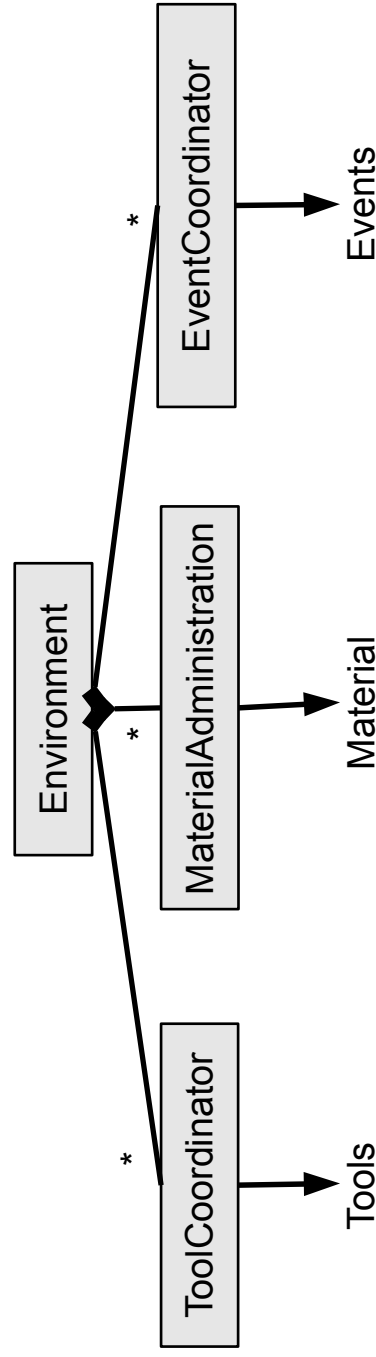
# The Generic Editor in Framework Notation



## 13.3 Environment

# The Environment

- ▶ Tools and Materials live in an environment with
  - Tool coordinators
  - Material administrations
  - Event coordinators
- ▶ The environment initializes everything, displays everything on the desktop, and waits for tool launch



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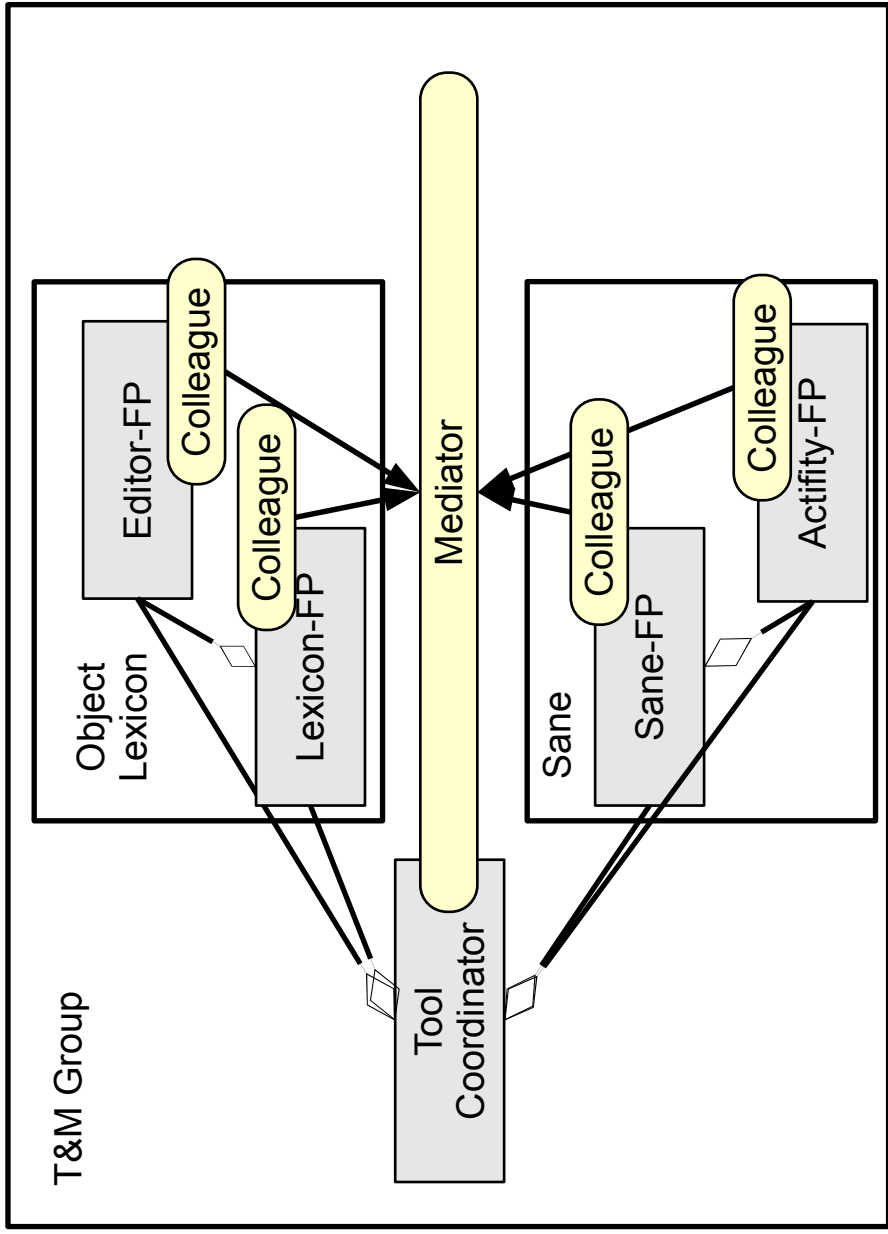
# Tool Coordinator in the Environment

- ▶ The **tool coordinator** is a global object
  - Groups a set of tools and their related material
    - Contains
      - A Tool-Material dictionary of all tools and the materials they work on
      - A tool factory
- ▶ Is a Mediator between FPs and other tools
  - Usually, FPs talk to their supertools and their related IPs. When materials depend on other materials in complex ways, other tools have to be informed
  - The ToolCoordinator uses the Tool-Material dictionary to notify tools appropriately

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# Example: TORA Tool Coordinator

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## 13.3.1. Pattern: Constrained Material Container

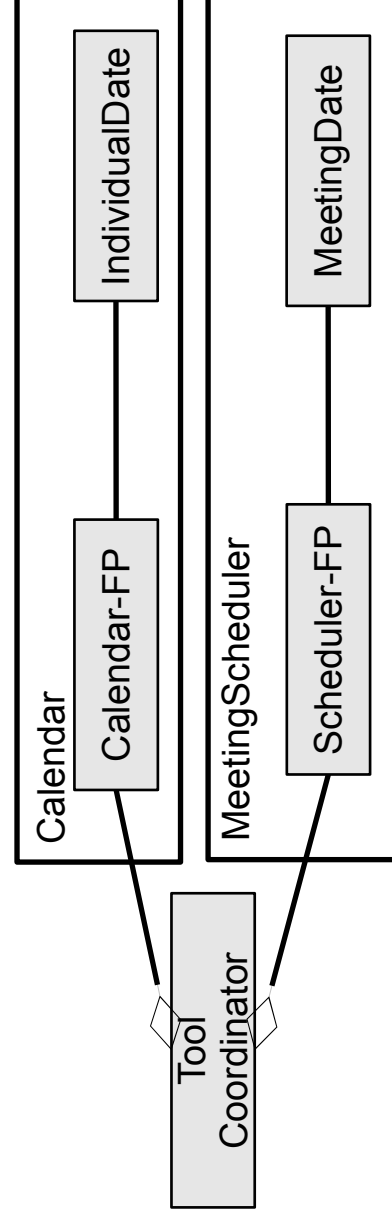
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# Problem: Dependencies Among Materials

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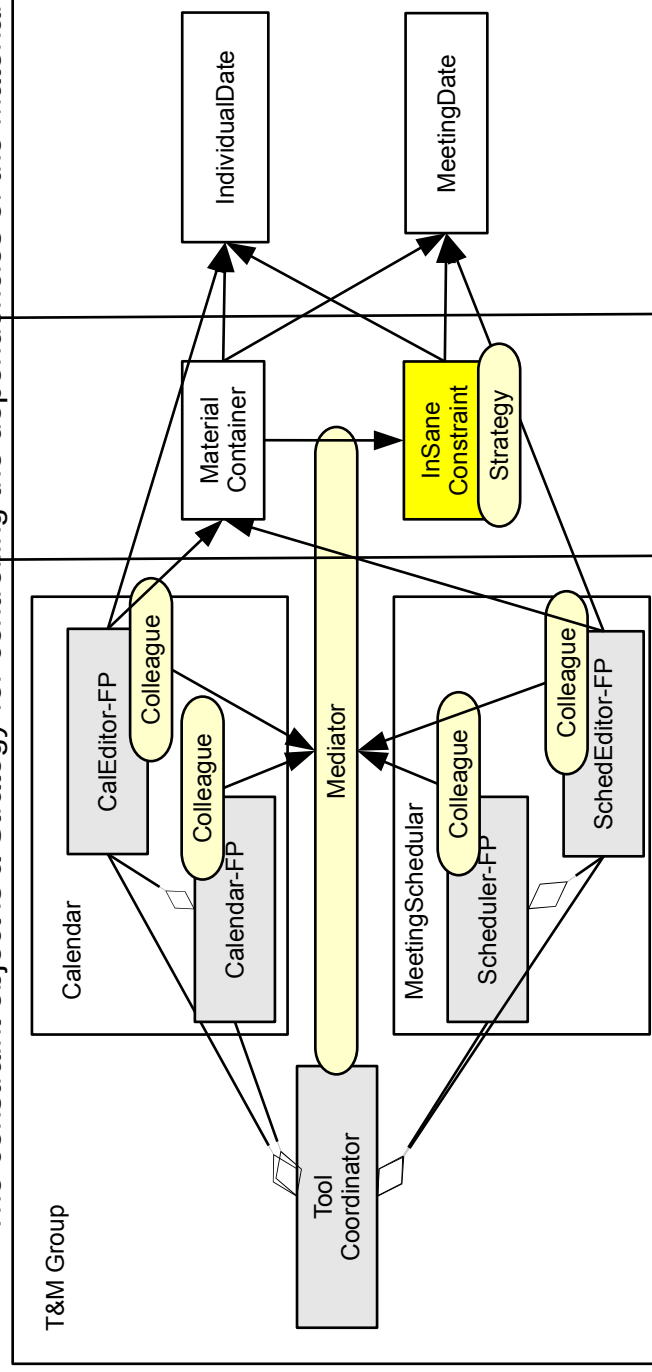
- ▶ Materials may depend on each other
- ▶ Example MeetingScheduler
  - Maintains regular meeting dates (week, month, year)
  - Should collaborate with the Calendar tool that maintains individual dates
- ▶ Clearly, these materials are dependent on each other
  - The Calendar tool should take in meetings as individual dates
  - The MeetingScheduler should block meetings if individual dates appear in the calendar



# Pattern: Constrained Material Container

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- ▶ We group all material that depend on each other into one *Material container*
  - And associate a *constraint object* InSaneConstraint that maintains the dependencies
- The constraint object is a Strategy for controlling the dependencies of the Material



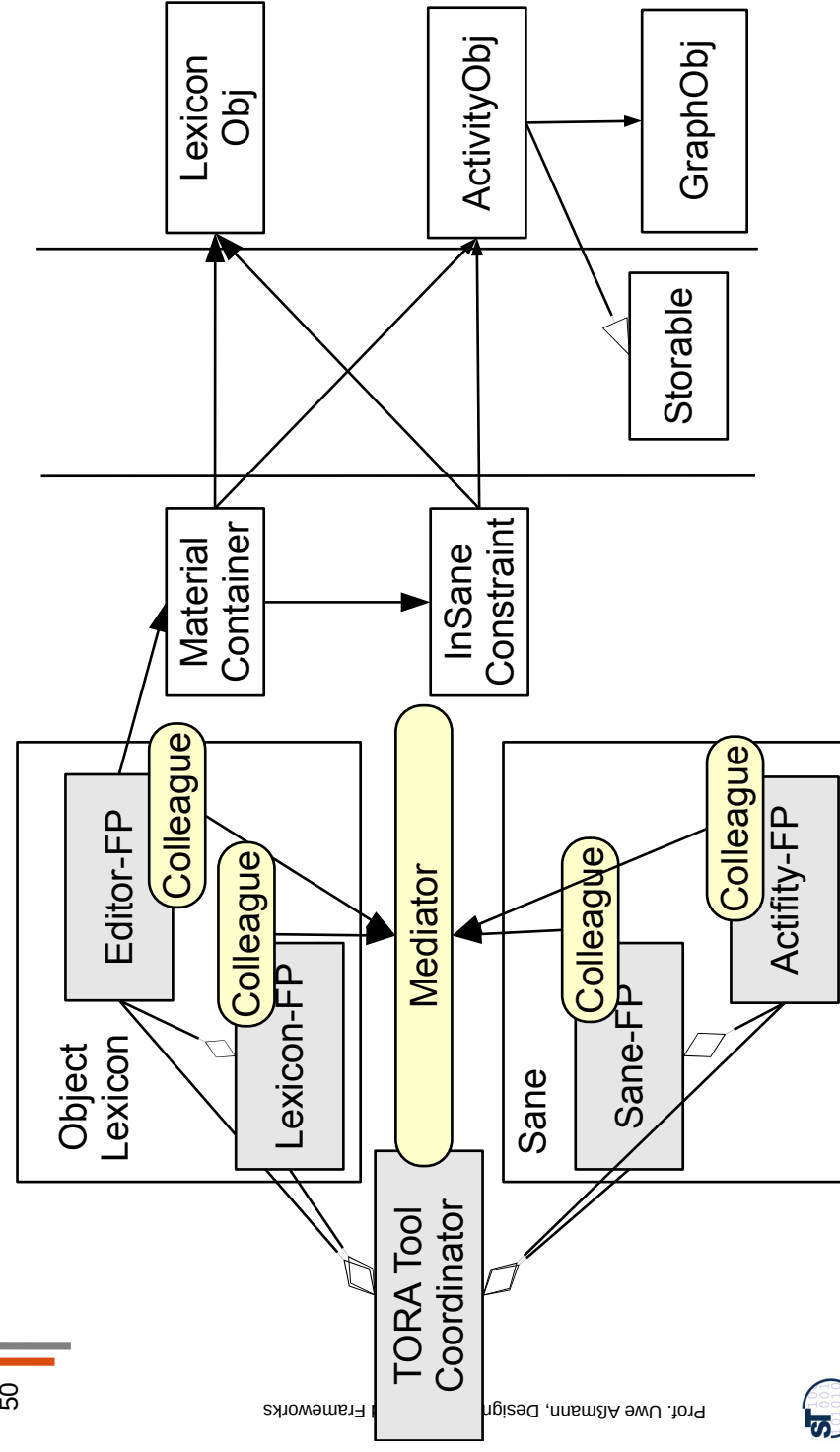


# Tool Coordinator and Material Container

- ▶ Unfortunately, Constrained Material Containers of the group must query the dictionary of the Tool Coordinator,
  - to know about the currently available tools, to activate constraints
  - (which introduces an ugly dependency between them...)

## Example:

# How TORA Tools Access Their Material



# TORA Material Constraints

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- ▶ For each ActivityObj, there is a LexiconObj
  - The user can textually edit the LexiconObj to document the ActivityObj and the GraphObj
- ▶ All Materials are in a MaterialContainer
  - Uses a ConstraintObject InSaneConstraint to make sur that the label of the ActivityObj is always the same as that of the LexiconObj
- ▶ If an ActivityObj is created, deleted, or changed, the tool coordinator is informed
  - And informs all related tools of TORA
  - The tool coordinator is a mediator



# Automaton

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- ▶ An *automaton (interpreter, workflow engine)* is an automated tool for repeated tasks
  - Similar to a macro-tool, a variant of Design Pattern Interpreter
  - Can run in the background
  - Often realized as separate machine processes
- ▶ An automaton encapsulates an automated *workflow (or process)*
  - Production of a complex artifact
  - Storing a complex technical object
  - Producing data in different versions
- ▶ Workflow can be specified by statecharts, activity diagrams, data-flow diagrams, Petrinets, workflow languages

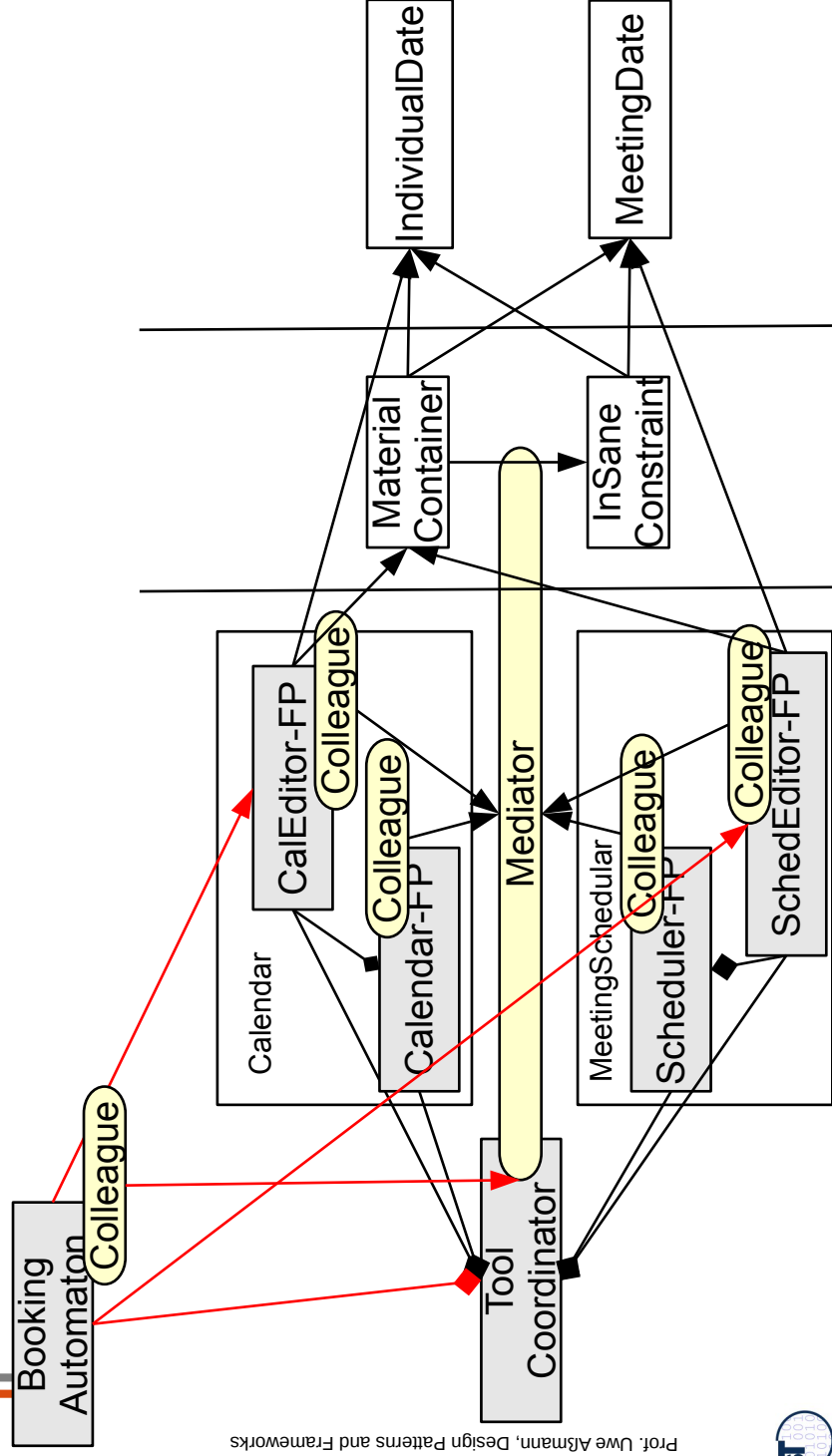


# An Automaton Booking Calendar

## Dates

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- ▶ The Automaton books regular meetings as dates into the calendar



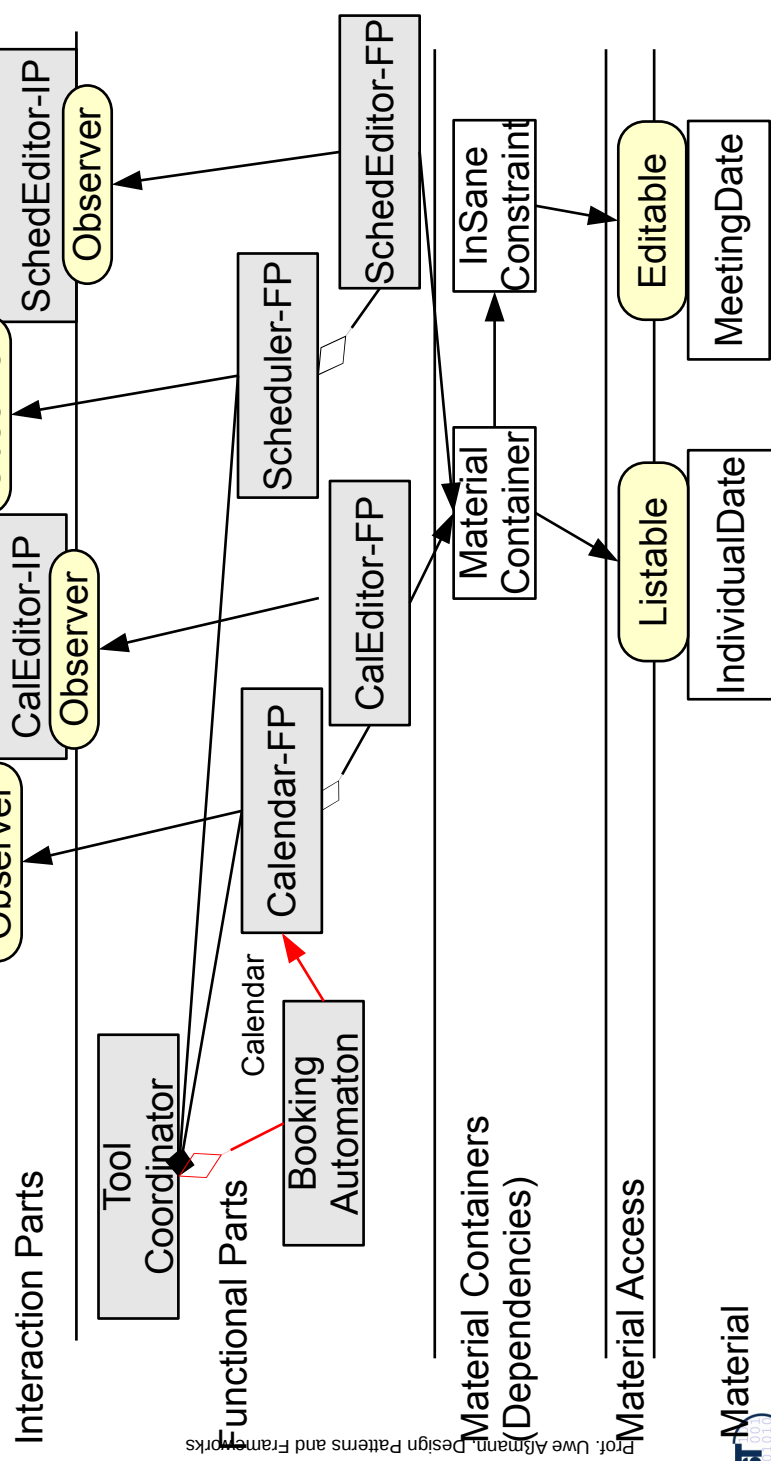
## 13.4 TAM and Layered Frameworks

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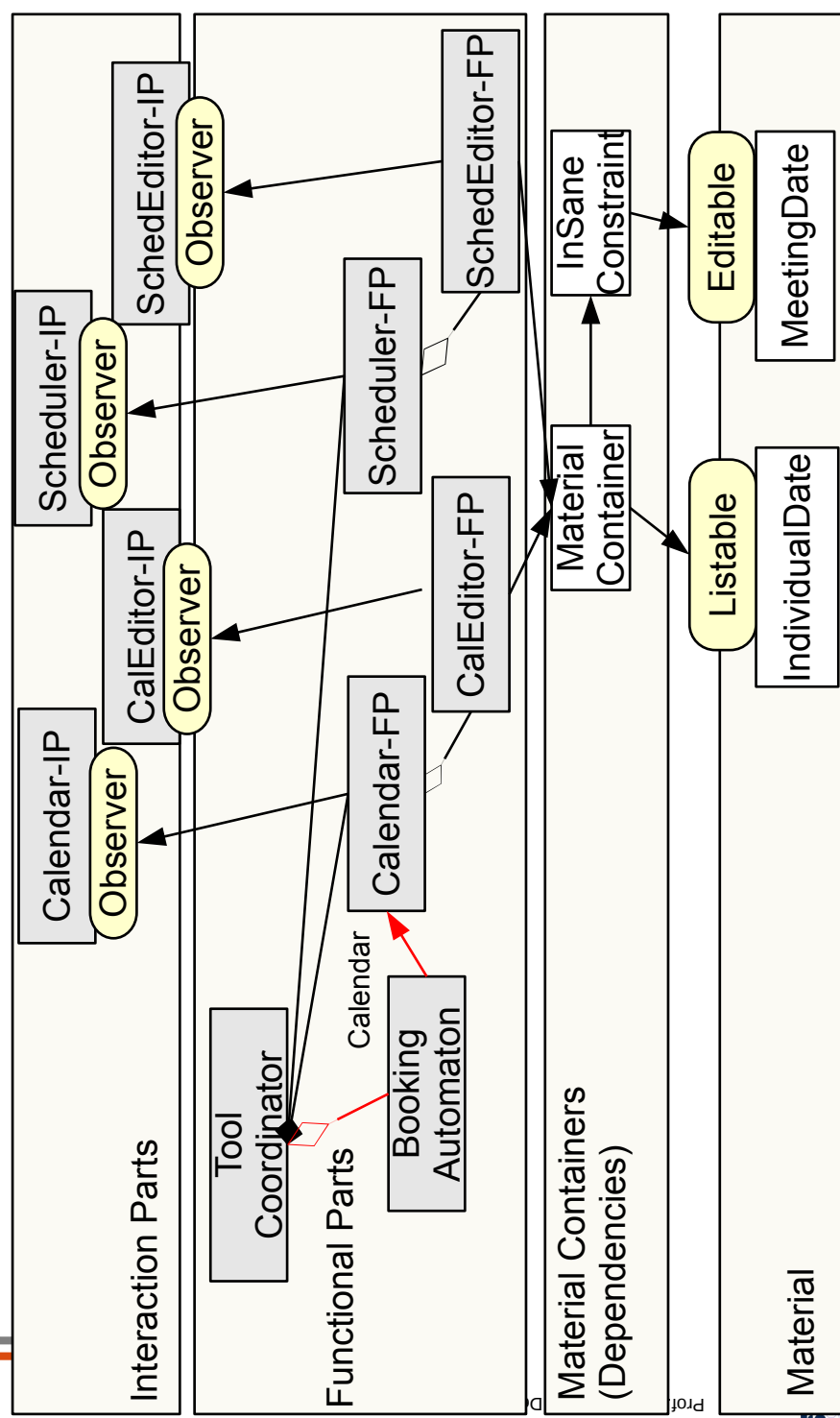
Now, let's order the patterns of TAM into layers  
What happens?



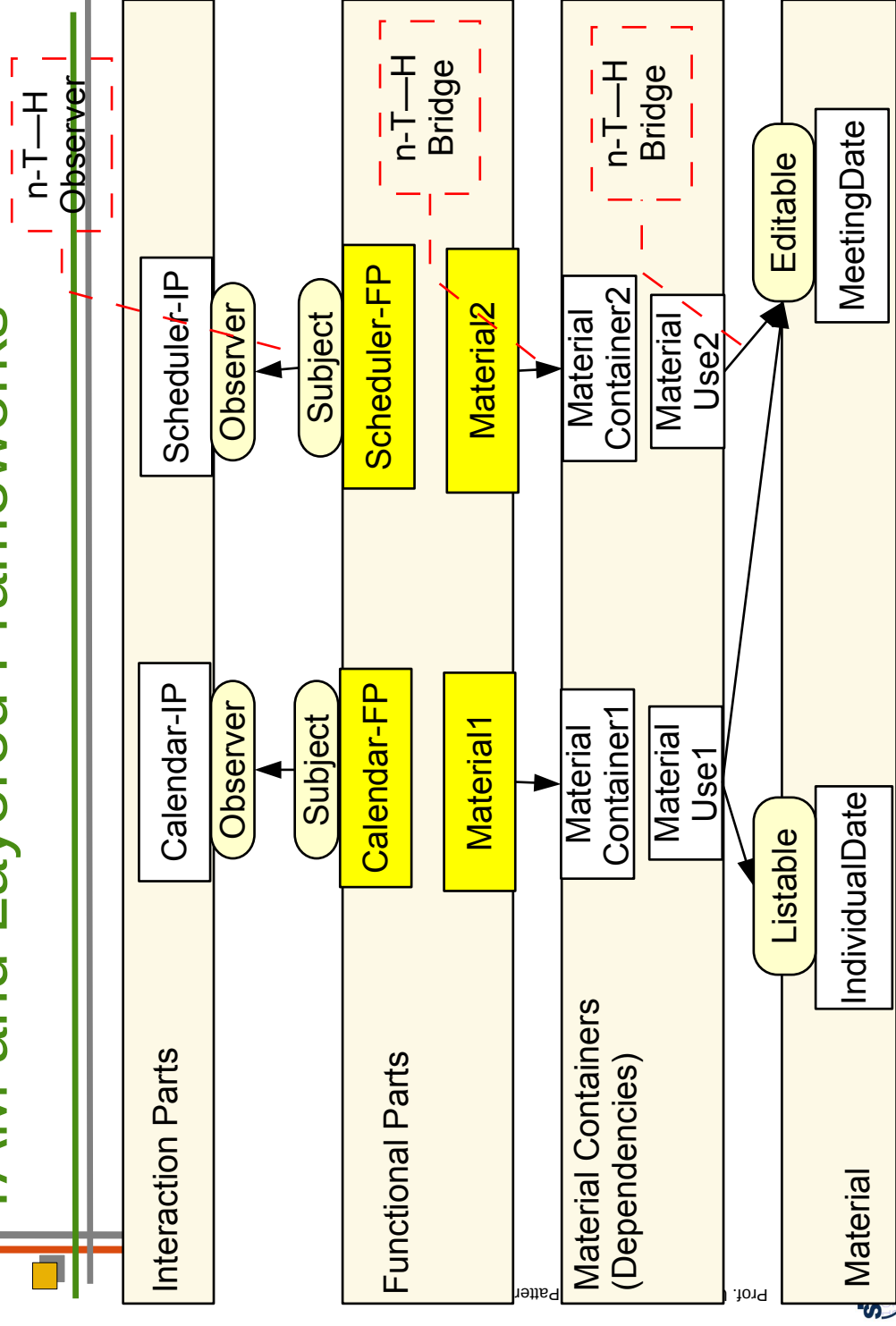
# TAM and Layered Frameworks



# TAM and Layered Frameworks



# TAM and Layered Frameworks



## TAM Is a Variant of a Layered Framework

- ▶ Combining different miniconnectors between the layers
  - n-T—H Observer between IP and FP
  - n-T—H Bridge between FP and MaterialUse
  - n-T—H Bridge between MaterialUse and Material, with roles as access for material
- ▶ Hence, interactive applications can be seen as instances of a layered framework
  - That uses not only RoleObject as mini-connectors, but also Observer and Bridge.
  - Hence the analogy to 3-tier
- ▶ This gives hope that we can construct layered frameworks for interactive applications in the future!

# Summary

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- ▶ The T&M conceptual pattern is a very important pattern for object-oriented development; all classes fall into these categories
- ▶ T&M is a pattern language for constructing interactive applications
  - Refines 3-tier and MVC
  - Uses Command, Strategy, Observer, Composite, etc.
  - Defines several new complex patterns such as Separation of IP and FP
- ▶ TAM is a variant of a layered framework, using n-T—H miniconnectors (Observer, Bridge) between the layers
  - Pree's framework hook patterns play an important role

# The End

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