33. Macromodel Single Underlying Model (SUM)

with Orthographic Software Modeling (OSM) - A 1-TS-Megamodel with Total Consistency

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http://st.inf.tu-dresden.de/teaching/most

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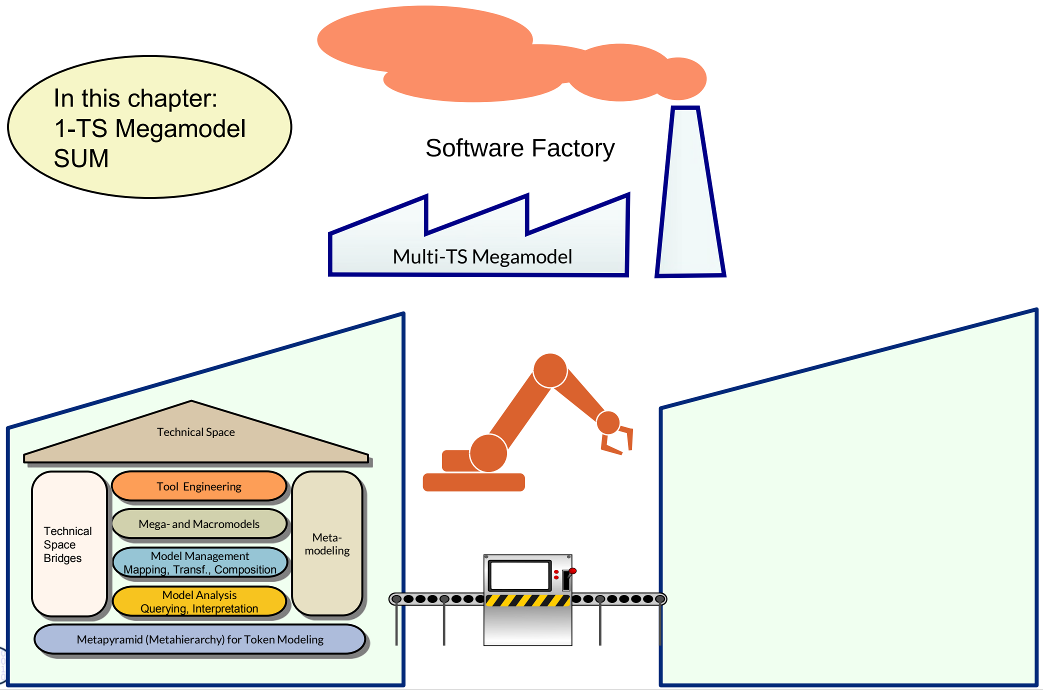
1) The megamodel "Single Underlying Model (SUM)"
2) Skeleton-SUM
3) Flat Context-Based Skeleton SUM
   1) Orthographic Software Modeling (OSM)
4) Hierarchic Context-Based Skeleton SUM
5) Multi-Skeleton SUM
6) Delta-Based Lenses
7) SUM on ROSI-CROM
8) Disjoint SkeletonSUM
9) Heterogeneous Language-SUM

Software Factories with Only 1 Technical Space

In this chapter:
1-TS Megamodel
SUM



Software Factory

Multi-TS Megamodel

Technical Space

Technical Space Bridges

Tool Engineering

Mega- and Macromodels

Model Management
Mapping, Transf., Composition

Model Analysis
Querying, Interpretation

Meta-modeling

Metapyramid (Metahierarchy) for Token Modeling

References

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- Thomas Hettel. Model Round-Trip Engineering. PhD Thesis. Queensland University of Technology, 2010
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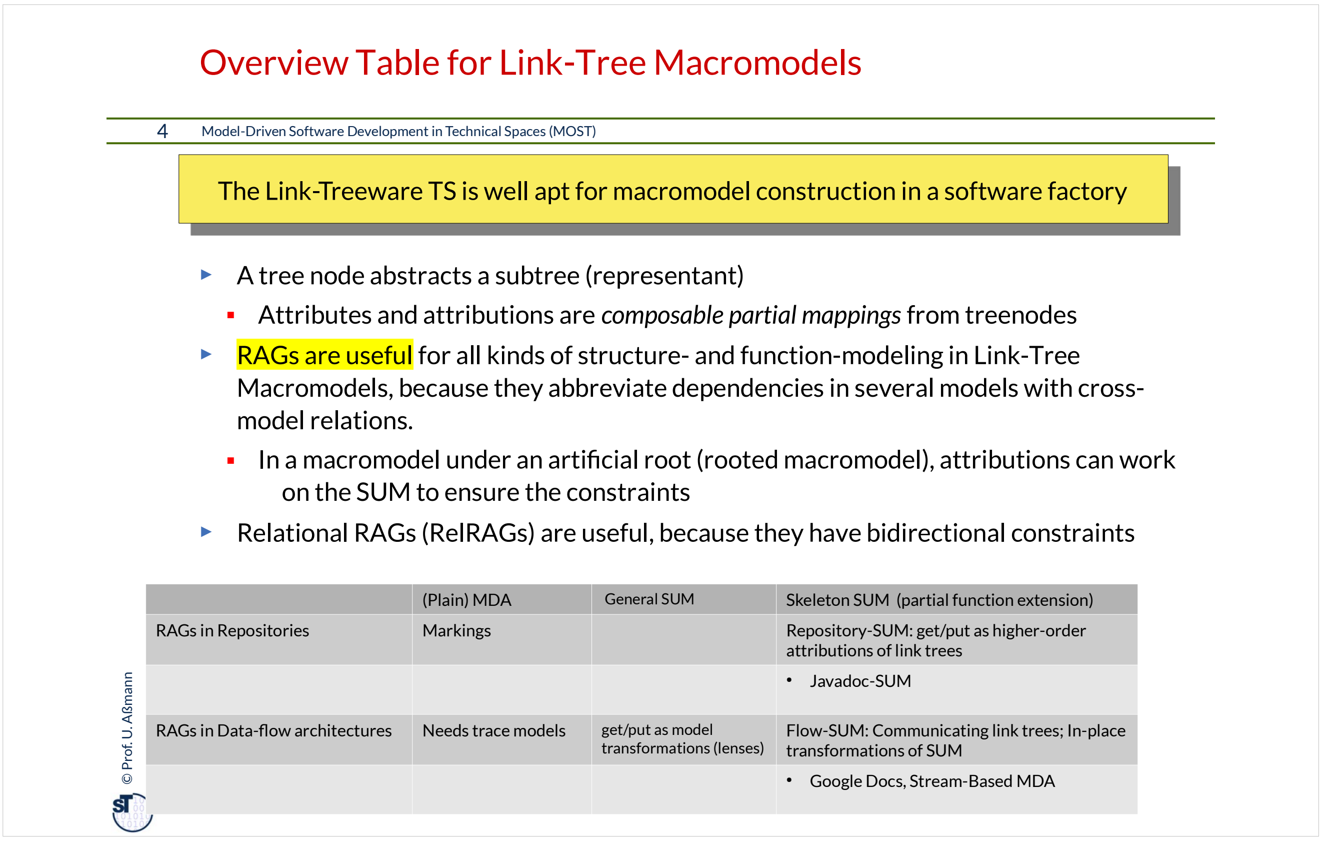
- J. Nathan Foster and Michael B. Greenwald and Jonathan T. Moore and Benjamin C. Pierce and Alan Schmitt. Combinators for Bi-Directional Tree Transformations: A Linguistic Approach to the View Update Problem, ACM Transactions on Programming Languages and Systems, Vol 29(3), pp. 17, 2007
  - http://www.cis.upenn.edu/~bcpierce/papers/newlenses-popl.pdf



Overview Table for Link-Tree Macromodels

The Link-Treeware TS is well apt for macromodel construction in a software factory

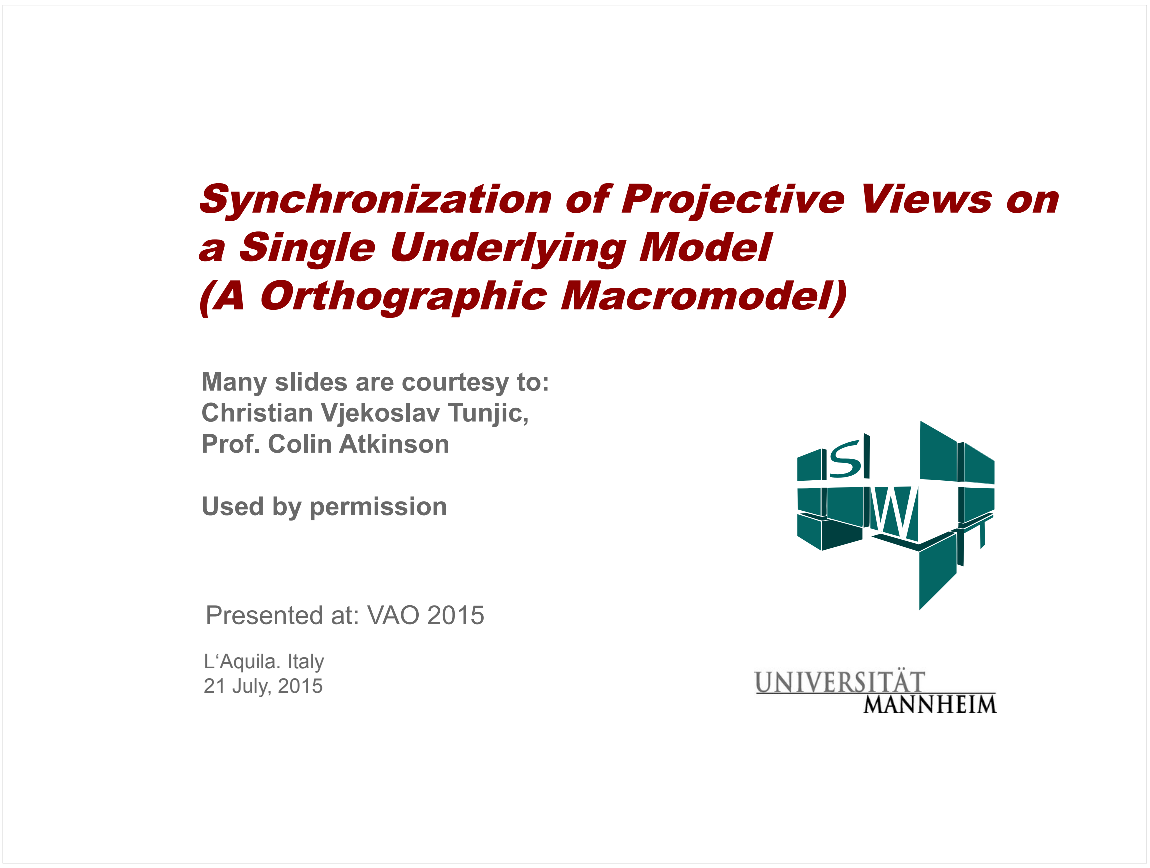
- A tree node abstracts a subtree (representant)
  - Attributes and attributions are *composable partial mappings* from treenodes
- RAGs are useful for all kinds of structure- and function-modeling in Link-Tree Macromodels, because they abbreviate dependencies in several models with cross-model relations.
  - In a macromodel under an artificial root (rooted macromodel), attributions can work on the SUM to ensure the constraints
- Relational RAGs (RelRAGs) are useful, because they have bidirectional constraints

	(Plain) MDA	General SUM	Skeleton SUM (partial function extension)
RAGs in Repositories	Markings		Repository-SUM: get/put as higher-order attributions of link trees
			• Javadoc-SUM
RAGs in Data-flow architectures	Needs trace models	get/put as model transformations (lenses)	Flow-SUM: Communicating link trees; In-place transformations of SUM
			• Google Docs, Stream-Based MDA

Other Examples form

•Olympic ring decomposition (EAI) marks all modules with “rings” and thereby decomposes them (course ST-1)

•VSUM (Reussner, Burger et al) generates dependent parts by create trace links



Synchronization of Projective Views on a Single Underlying Model (A Orthographic Macromodel)

Many slides are courtesy to:
Christian Vjekoslav Tunjic,
Prof. Colin Atkinson

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Presented at: VAO 2015

L'Aquila. Italy
21 July, 2015

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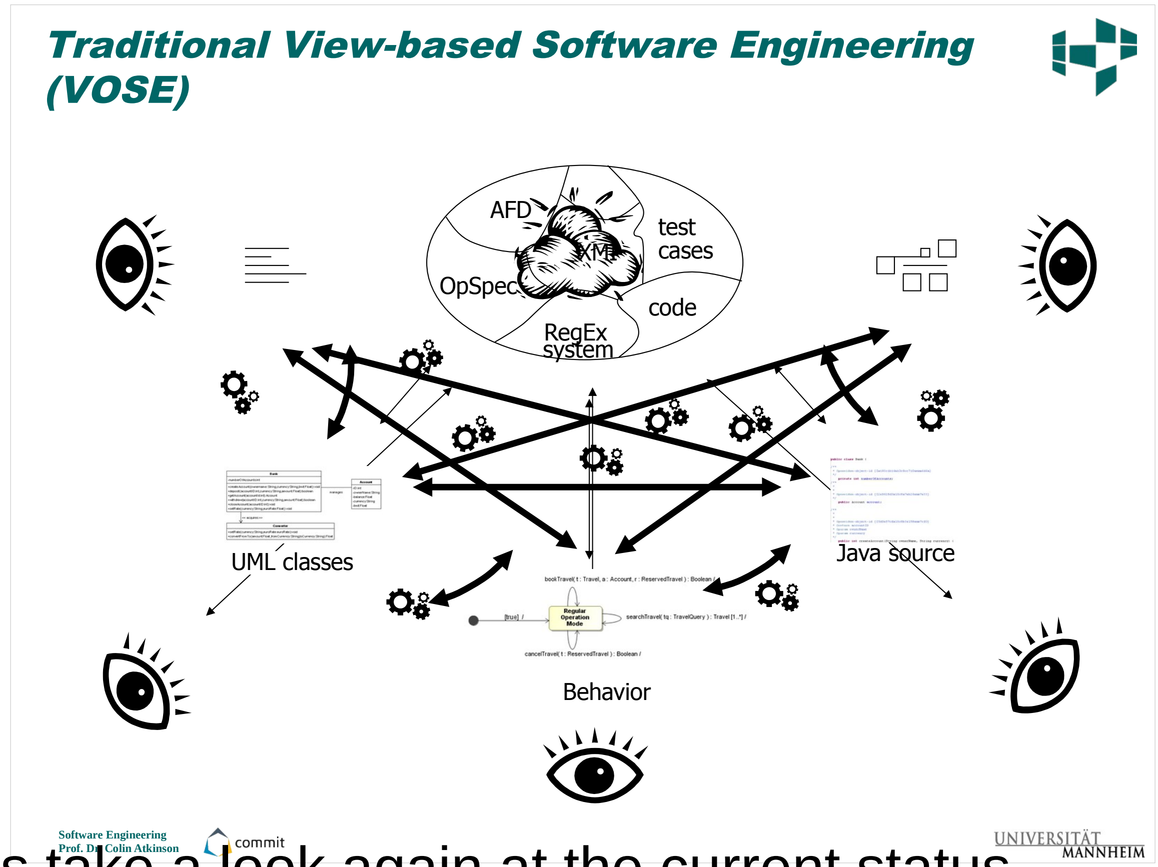
33.1. The Macromodel "Single-Underlying Model (SUM)"

- is based on a ***repository (repository-based SUM)*** [Atkinson19]

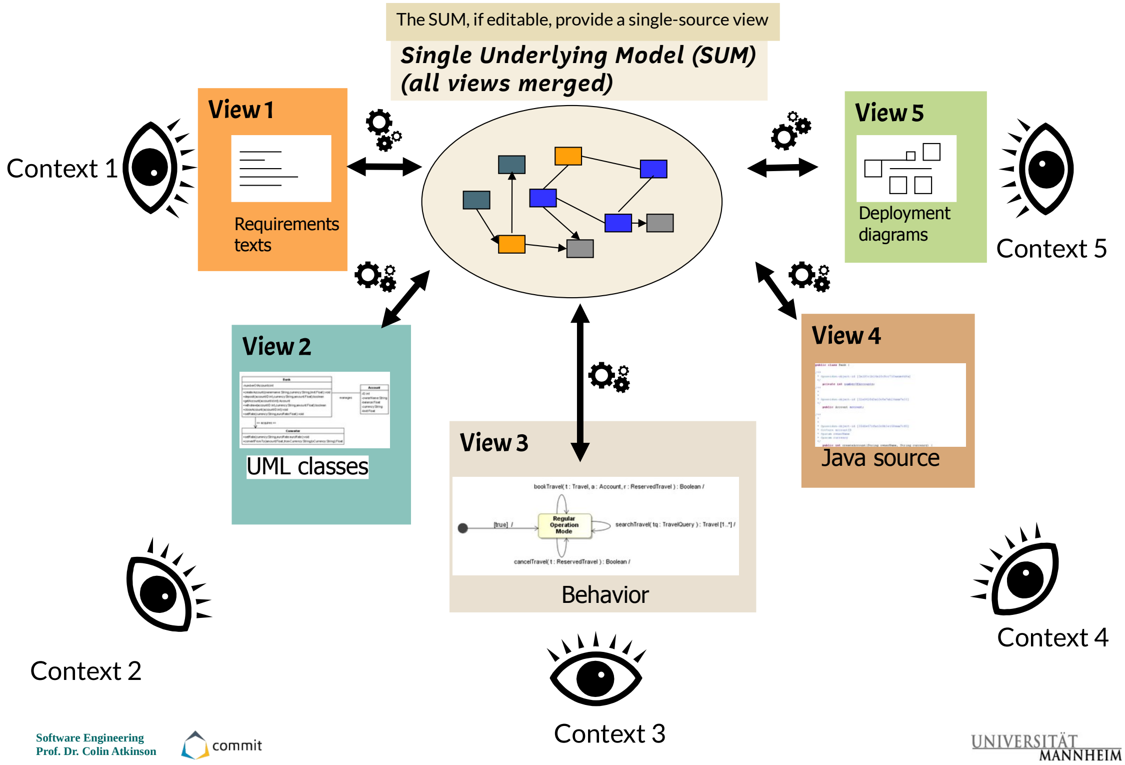


Traditional View-based Software Engineering (VOSE)

AFD
test cases
XMI
OpSpec
code
RegEx system
UML classes
Java source
bookTravel(t : Travel, a : Account, r : ReservedTravel) : Boolean /
[true] /
Regular Operation Mode
searchTravel(tq : TravelQuery) : Travel [1..*] /
cancelTravel(t : ReservedTravel) : Boolean /
Behavior

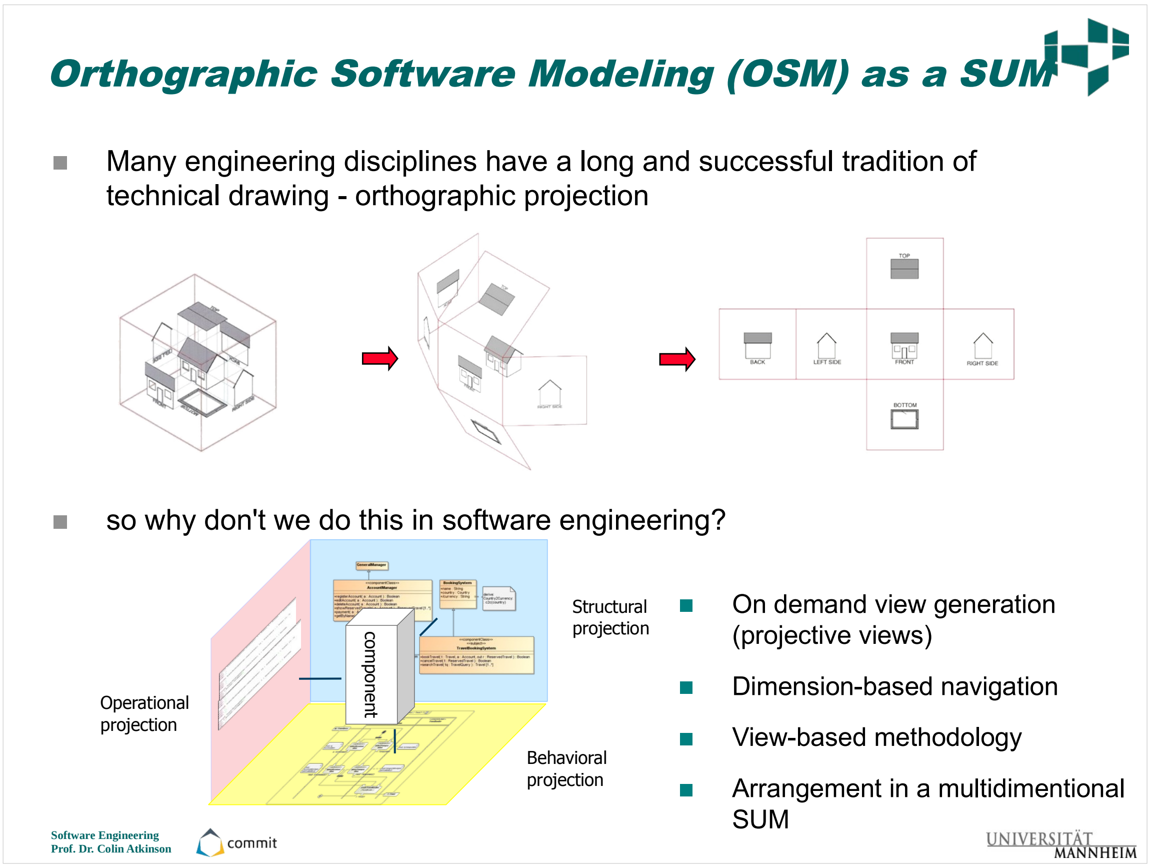
let‘s take a look again at the current status with a picture

On-Demand View Generation in a SUM (Flat Contexts Correspond to Colors or Tags)



The SUM, if editable, provide a single-source view

Single Underlying Model (SUM) (all views merged)



Orthographic Software Modeling (OSM) as a SUM

- Many engineering disciplines have a long and successful tradition of technical drawing - orthographic projection

- so why don't we do this in software engineering?

Structural projection

Operational projection

Behavioral projection

- On demand view generation (projective views)
- Dimension-based navigation
- View-based methodology
- Arrangement in a multidimentional SUM

Software Engineering
Prof. Dr. Colin Atkinson

commit

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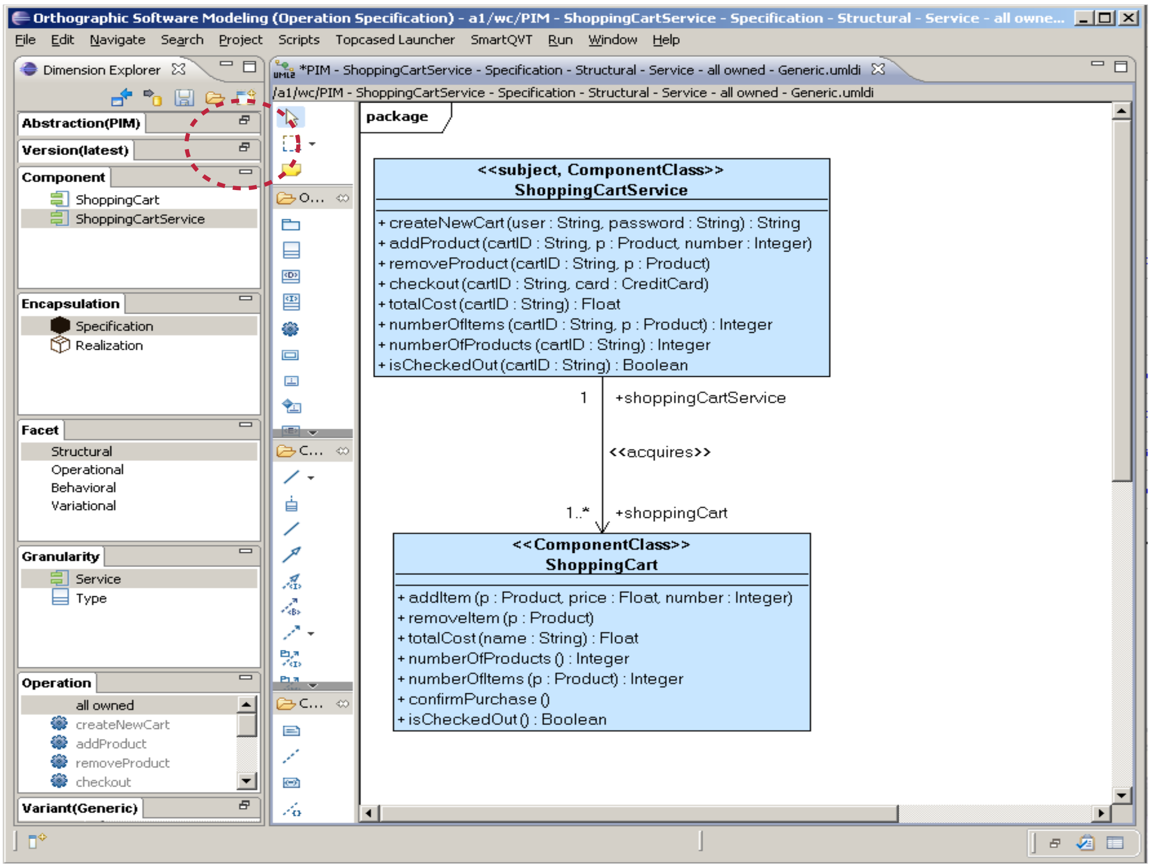
apply this metaphor to SE



Orthographic Software Modeling (Operation Specification) - a1/wc/PIM - ShoppingCartService - Specification - Structural - Service - all owne...
File Edit Navigate Search Project Scripts Topcased Launcher SmartQVT Run Window Help
Dimension Explorer
*PIM - ShoppingCartService - Specification - Structural - Service - all owned - Generic.umldi
/a1/wc/PIM - ShoppingCartService - Specification - Structural - Service - all owned - Generic.umldi
Abstraction(PIM)
Version(latest)
Component
ShoppingCart
ShoppingCartService
Encapsulation
Specification
Realization
Facet
Structural
Operational
Behavioral
Variational
Granularity
Service
Type
Operation
all owned
createNewCart
addProduct
removeProduct
checkout
Variant(Generic)
O...
C...
C...
package

<<subject, ComponentClass>>
ShoppingCartService

+ createNewCart (user : String, password : String) : String
+ addProduct (cartID : String, p : Product, number : Integer)
+ removeProduct (cartID : String, p : Product)
+ checkout (cartID : String, card : CreditCard)
+ totalCost (cartID : String) : Float
+ numberOfItems (cartID : String, p : Product) : Integer
+ numberOfProducts (cartID : String) : Integer
+ isCheckedOut (cartID : String) : Boolean

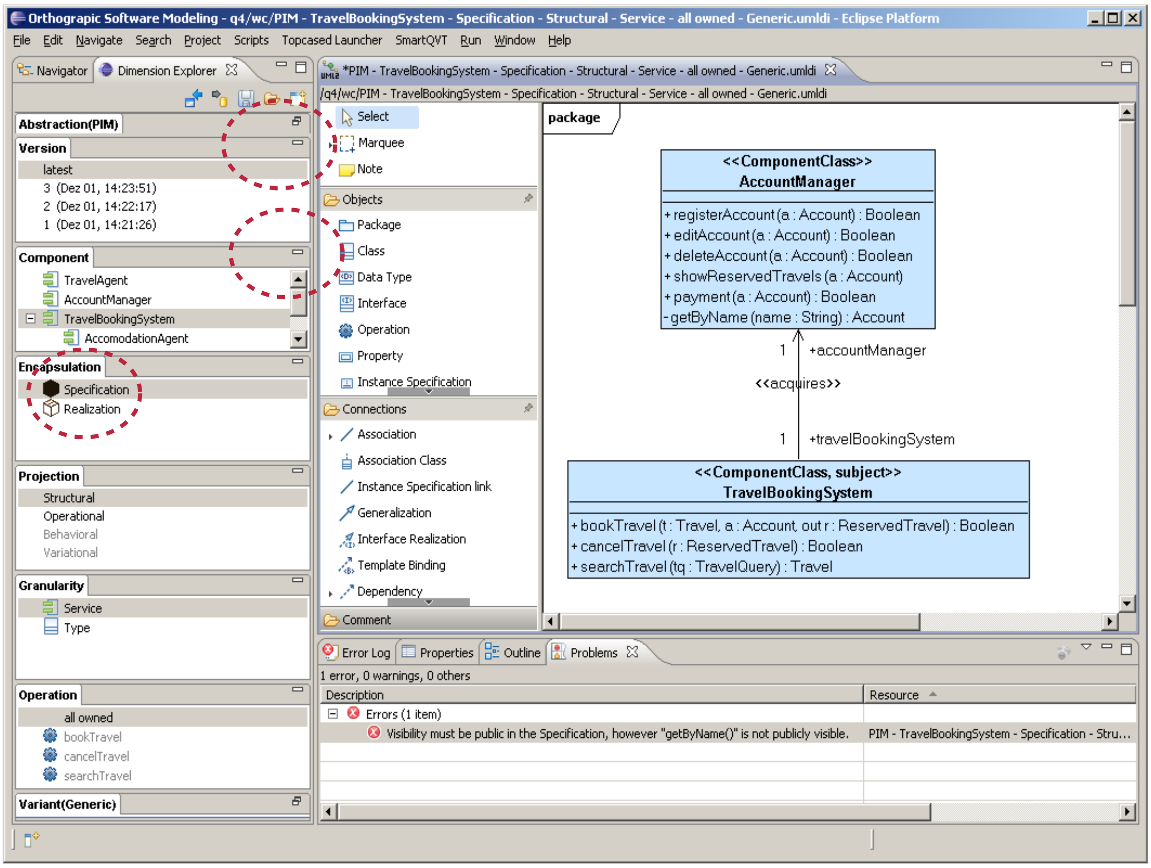
1 +shoppingCartService

<<acquires>>

1..* +shoppingCart

<<ComponentClass>>
ShoppingCart

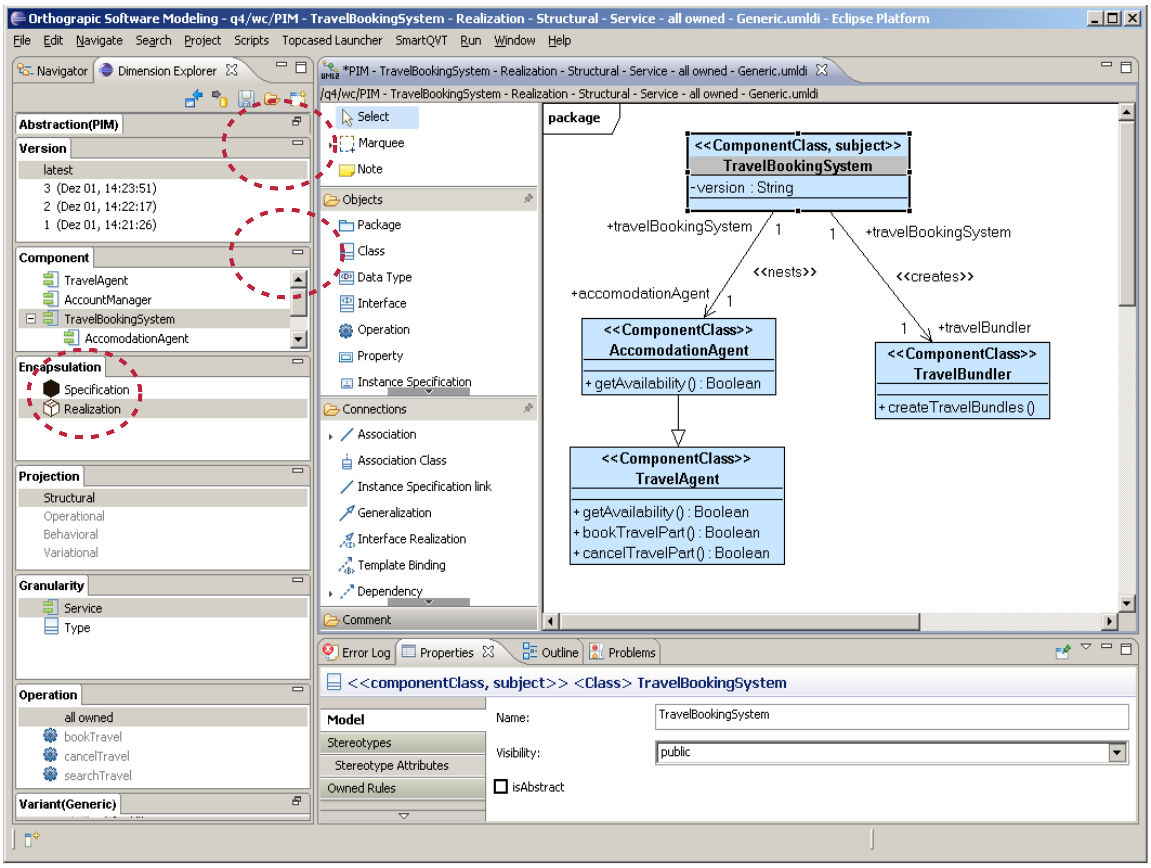
+ addItem (p : Product, price : Float, number : Integer)
+ removeItem (p : Product)
+ totalCost (name : String) : Float
+ numberOfProducts () : Integer
+ numberOfItems (p : Product) : Integer
+ confirmPurchase ()
+ isCheckedOut () : Boolean



Orthograpic Software Modeling - q4/wc/PIM - TravelBookingSystem - Specification - Structural - Service - all owned - Generic.umldi - Eclipse Platform

1 error, 0 warnings, 0 others

Description	Resource
Errors (1 item)	
Visibility must be public in the Specification, however "getByName()" is not publicly visible.	PIM - TravelBookingSystem - Specification - Stru...



<<componentClass, subject>> <Class> TravelBookingSystem

Name: TravelBookingSystem

Visibility: public

□ isAbstract

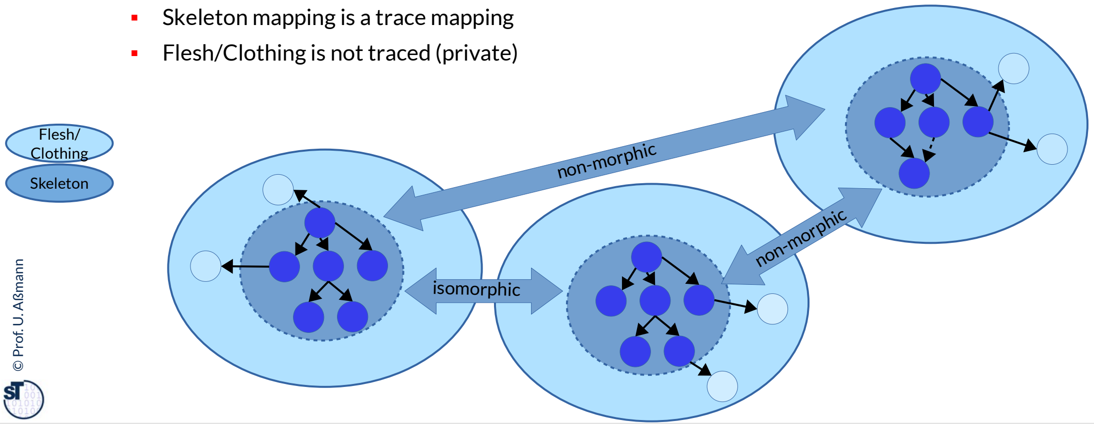
33.2. The Skeleton-SUM

[Hettel08]
[Seifert11]

Skeletons and Flesh

[Hettel08] [Seifert11]

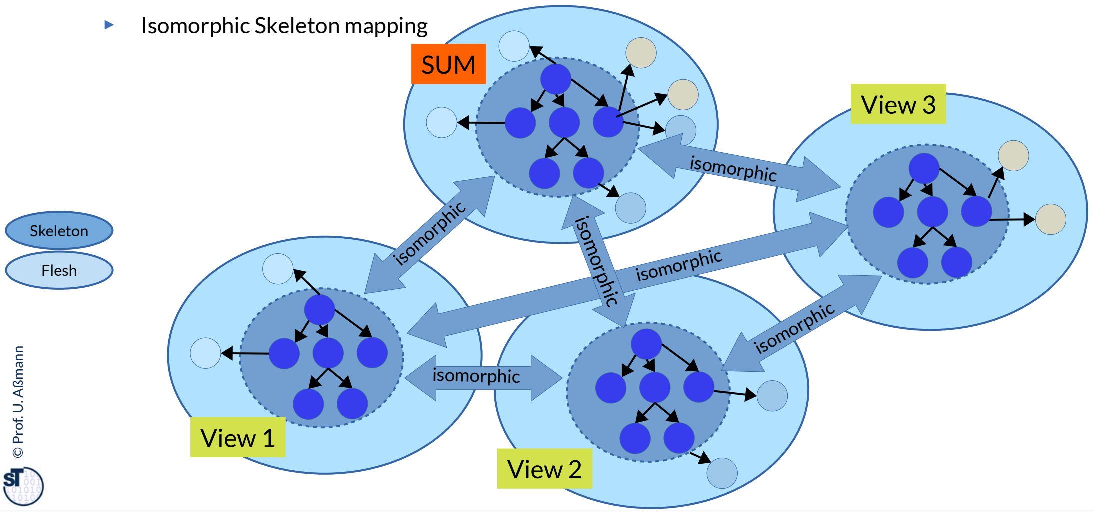
- Skeleton splits models into
  - **Skeletons** (redundant) (several contexts)
  - and **flesh (clothing)** (locally different stuff in views, mono-context)
- Global invariants on skeletons vs. local „flesh“ variants
- Flesh must be non-overlapping, extending the skeleton
- Skeletons can have isomorphic, homomorphic, monotonically extended “skeleton” mappings,
  - or may be non-morphic
  - Skeleton mapping is a trace mapping
  - Flesh/Clothing is not traced (private)



Mono-Skeleton-SUM

[Hettel08] [Seifert11]

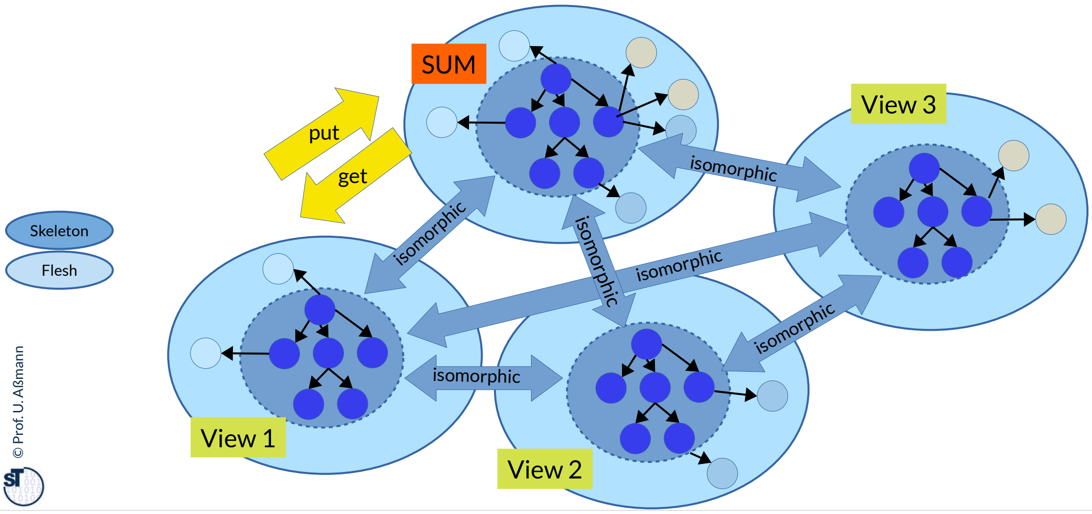
- Mono-Skeleton-SUM splits models into
  - **One common Skeleton** (redundant) (several contexts)
  - and **flesh (clothing)** (locally different stuff in views, mono-context) is stored in SUM together with skeleton
- Flesh must be non-overlapping, extending the skeleton
- Isomorphic Skeleton mapping



Get/Put in Mono-Skeleton-SUM

[Hettel08] [Seifert11]

- From a Skeleton-SUM
  - get operation produces a view
  - put operation commits it into SUM

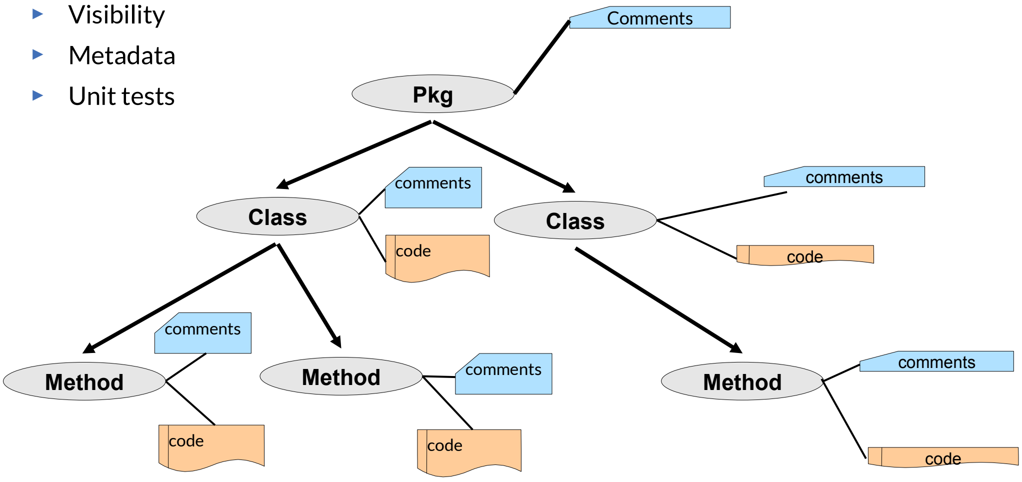


33.2.1 Javadoc-SUM, a Mono-Skeleton-SUM for Documentation

Example Skeleton-SUM:
Scope tree of a program (static structuring)

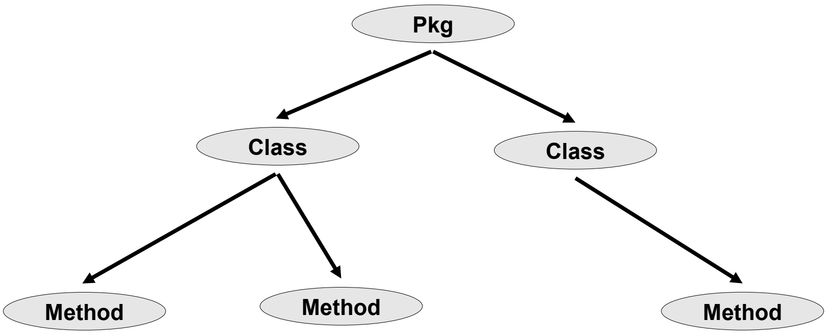
Javadoc comment relies on several attributes of nodes of the syntax tree:

- Comments (package, class, method, parameter)
- Code (*skeleton*)
- Visibility
- Metadata
- Unit tests



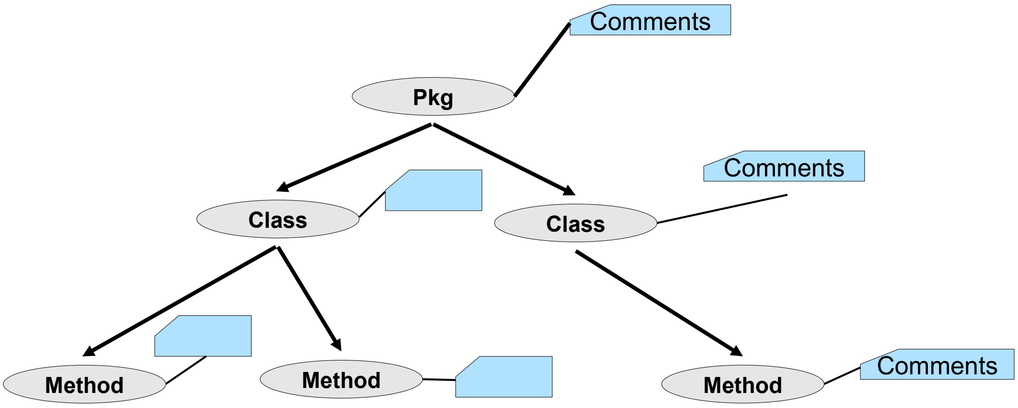
Projecting A Scope Tree for Skeleton

- `put/get` operations transform SUM to views and back
- `Get`: partial function projection
- `Put`: merge of partial function of view and of SUM
- Exa.: result of `get` operation for Scope Tree “Skeleton”:



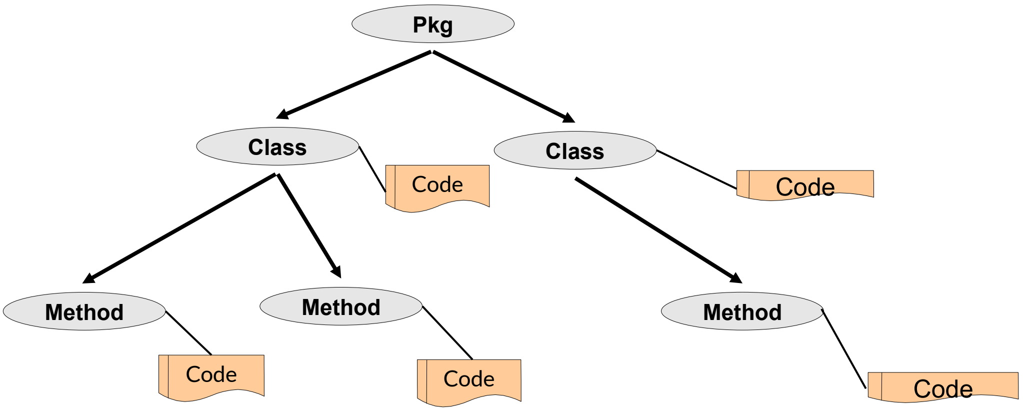
Projecting A Scope Tree for Skeleton

- Result of get operation for For Comment Context “Comment Flesh”:



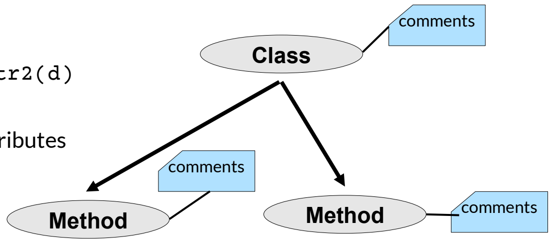
Projecting A Scope Tree for Skeleton

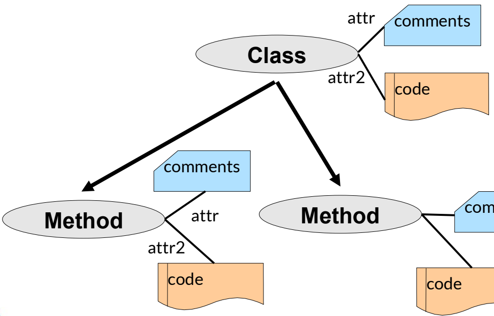
- Result of get operation for Code Context “Code Flesh”:

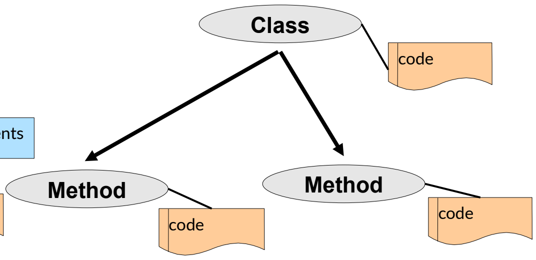


Merge of Partial Functions and Partial Trees in a Mono-Skeleton-SUM

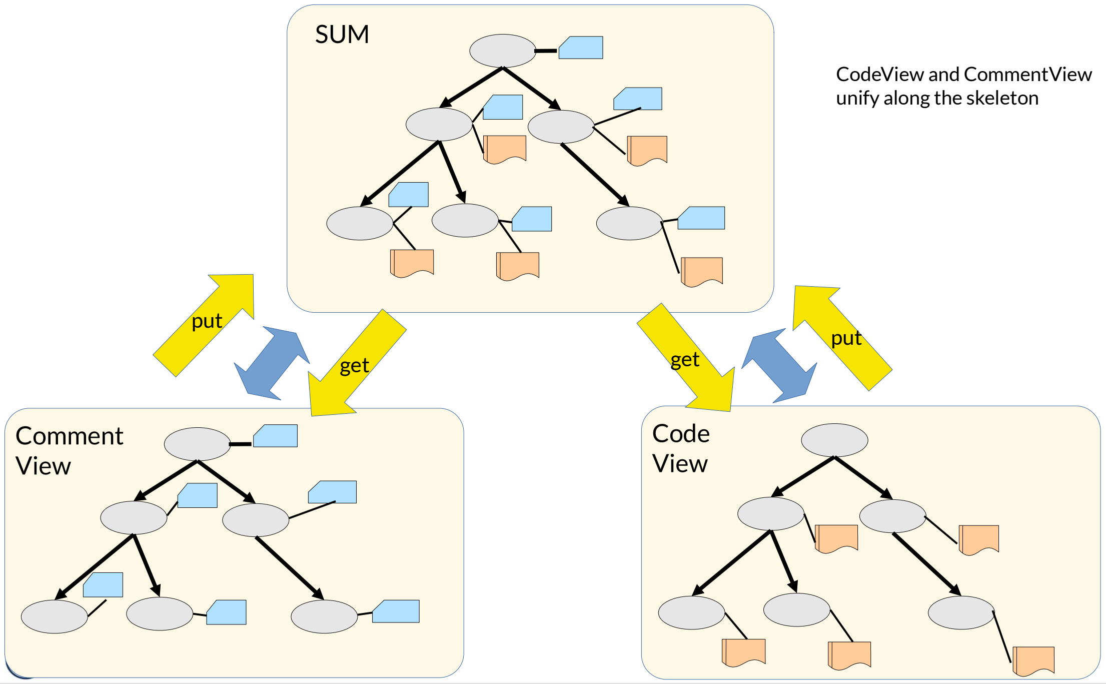
- Given two partial functions on tree-node domain D and two domains E, F:
  - `attr: D → E` and
  - `attr2: D → F`
- Their merge `merged-attr:D → E ◊ F`
  - `merged-attr(d) = attr (d) ◊ attr2(d)`
- Skeleton-SUM are trees of objects which work on a partial function space of attributes
  - Every view adds a new partial function







Javadoc-SUM:
A Simple Metamodel-based Mono-Skeleton-SUM



CodeView and CommentView unify along the skeleton

Remarks on Mono-Skeleton-SUM

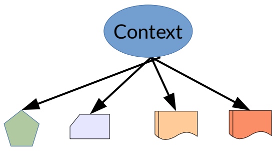
- **Generality:** The Skeleton need not be a link tree; it can be an arbitrary graph data structure
  - But RAGs can model Mono-Skeleton-SUMs very easily: inherit the flesh attributes to all nodes
- Between Skeleton and Flesh there holds a **key dependency**
  - A partial function describes the mapping between skeleton and flesh
  - Different partial functions exist for every view
  - Flesh-skeleton unification employs partial function merge (feature term unification)

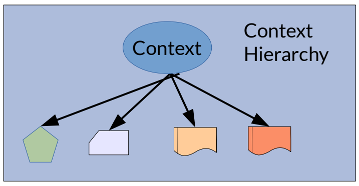
33.3. Context-Based Skeleton-SUM

[Hettel08]
[Seifert11]

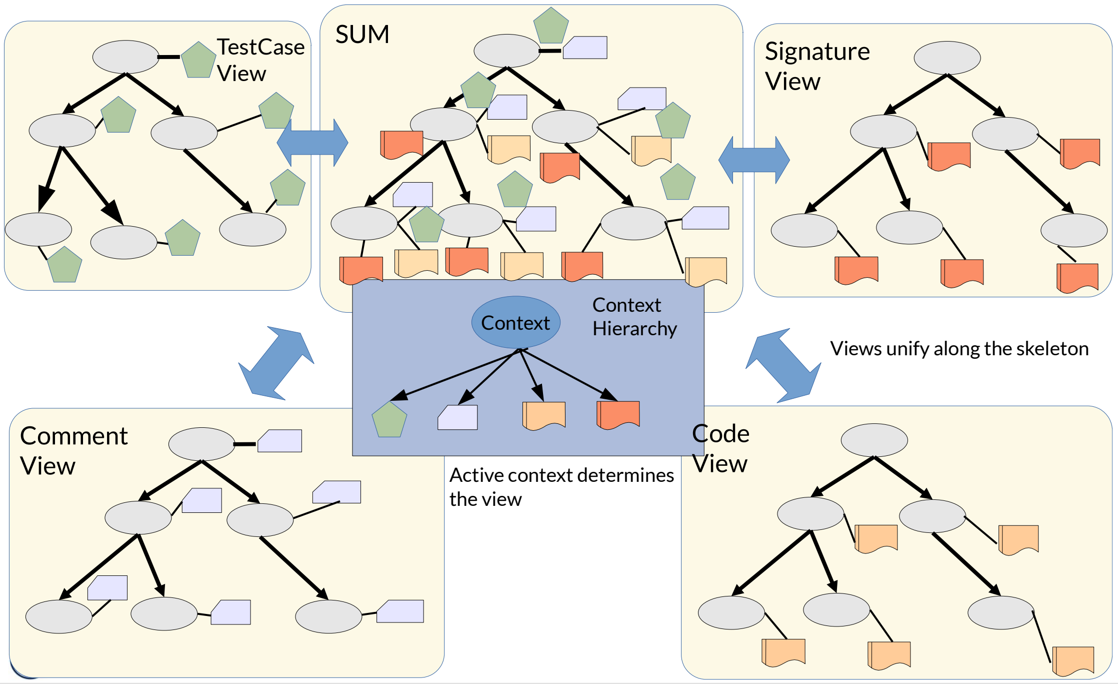
Skeleton-SUM

- Clothing can be associated to context (context-aware clothing)
  - Code context
  - Comment context
- If all clothings have mono-context, the SUM is called ***flat contextual SUM.***





A Metamodel-based Skeleton-SUM with Flat Context Hierarchy



Views unify along the skeleton

Active context determines the view

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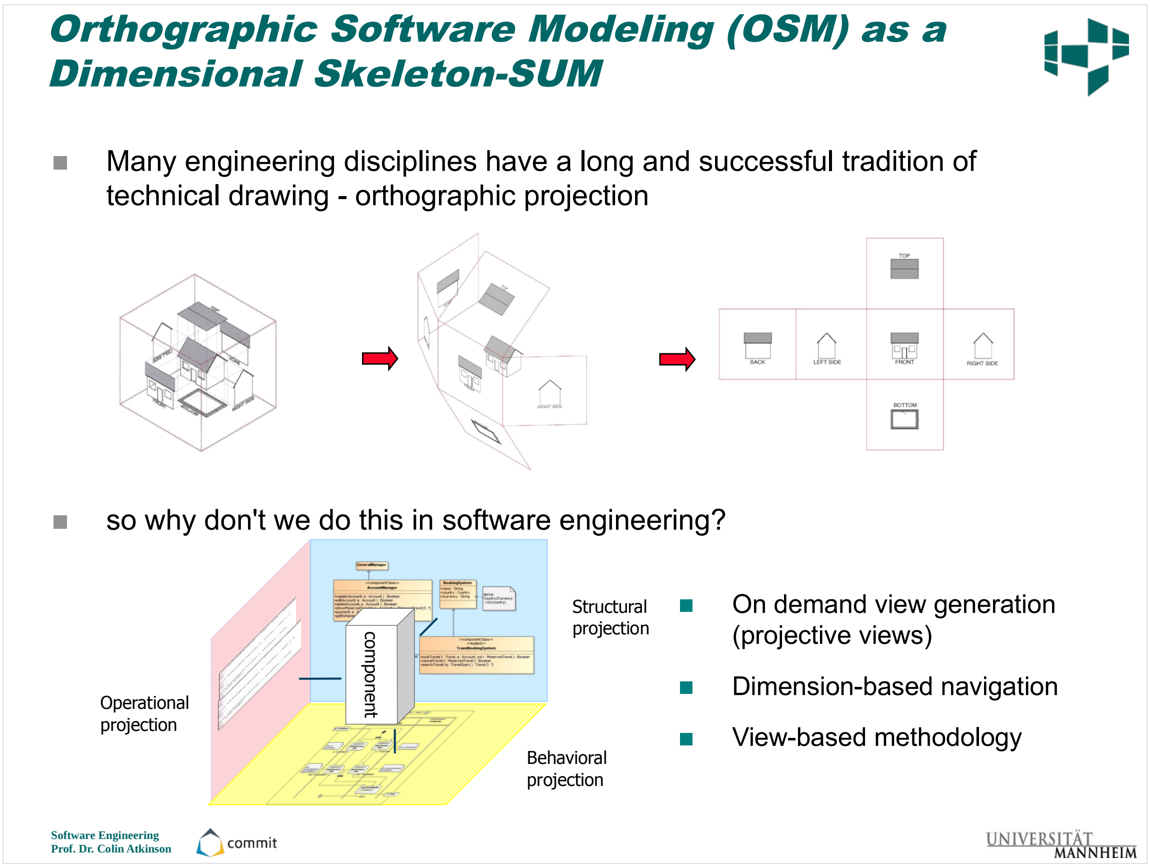
33.3.1. Orthographic Software Modeling (OSM) as a Dimensional, Context-Based Skeleton-SUM

[Hettel08]

[Seifert11]

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur



Orthographic Software Modeling (OSM) as a Dimensional Skeleton-SUM

- Many engineering disciplines have a long and successful tradition of technical drawing - orthographic projection

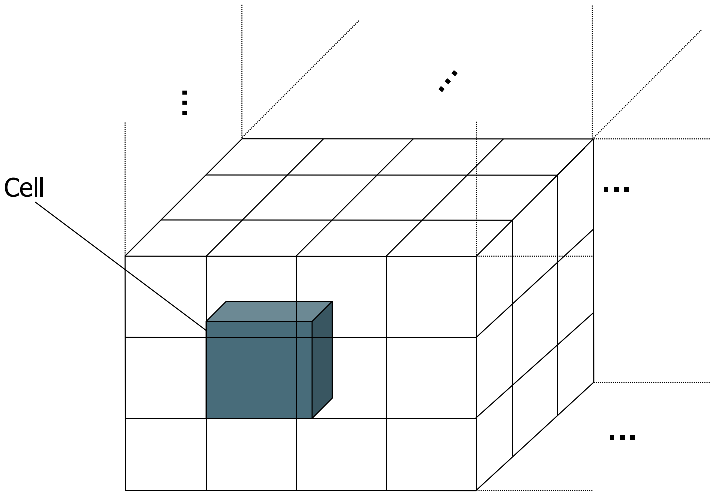
- so why don't we do this in software engineering?

- On demand view generation (projective views)
- Dimension-based navigation
- View-based methodology

apply this metaphor to SE

Dimension Based Navigation

- views organized in a multi-dimensional cube
- one choice always “selected” from each dimension
- each cell represents a viewpoint



OSM is a Flat Contextual Skeleton-SUM

- OSM defines *n-dimensional contexts*, i.e., every model element is related to n contexts.
- OSM can be realized by a Skeleton-SUM providing n mono-contextual clothings
  - i.e., n mono-contextual attributes for every model element (link tree node).
- The n dimensions (contexts) are used for projection
- Instead of attributes, model elements have roles (CROM-Skeleton-SUM)

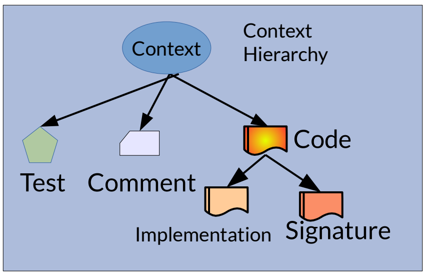
- ROSIMA is a CROM-Skeleton-SUM

33.4. Hierarchic Context-Based Skeleton-SUM

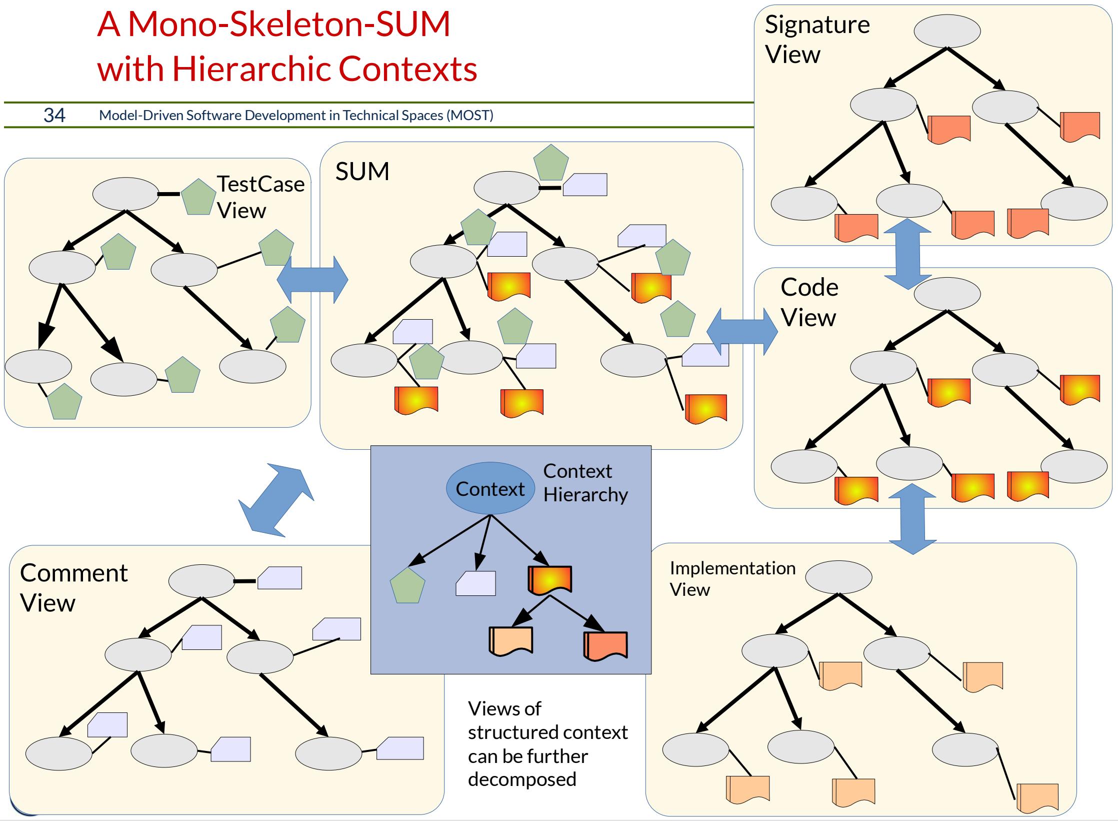
[Hettel08]
[Seifert11]

Hierarchic Skeleton-SUM

- Clothing can be associated to structured context
  - Code context
    - Signatures
    - Implementation
  - Comment context
- If som clothings have an inner (structured) context, the SUM is called **hierarchic contextual SUM.**



A Mono-Skeleton-SUM with Hierarchic Contexts



Views of structured context can be further decomposed

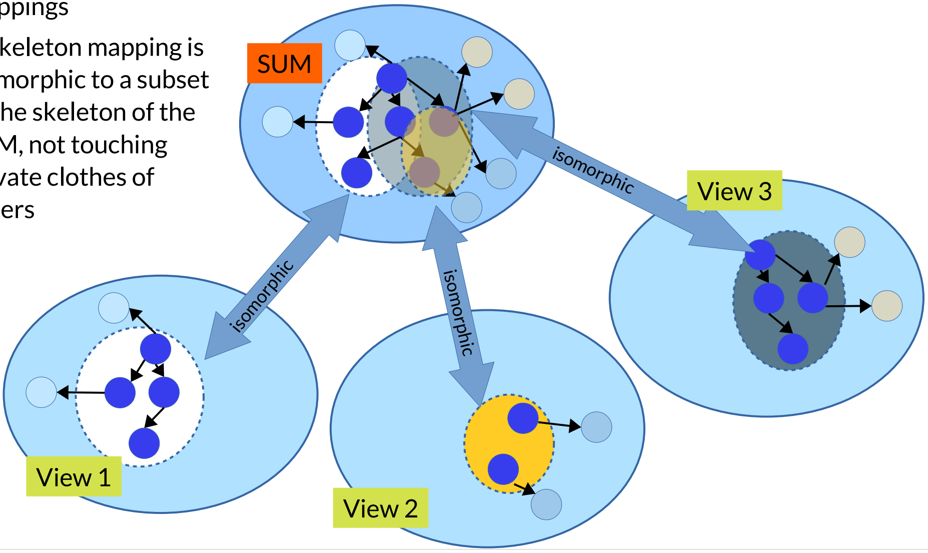
33.5. Multi-Skeleton-SUM

[Seifert11]

Multi-Skeleton-SUM

- In SUMs, not all Skeletons need not be a linked by isomorphic mappings
- A Skeleton mapping is isomorphic to a subset of the skeleton of the SUM, not touching private clothes of others

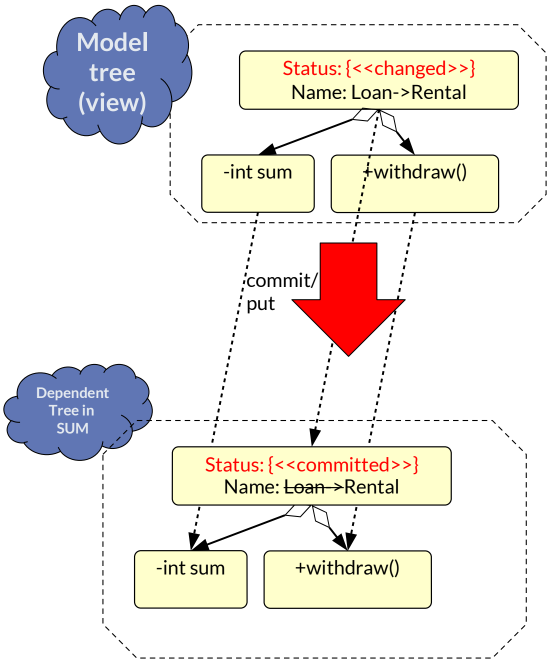
- Every Skeleton must be invariant, and within the SUM, a Skeleton—Skeleton mapping must exist



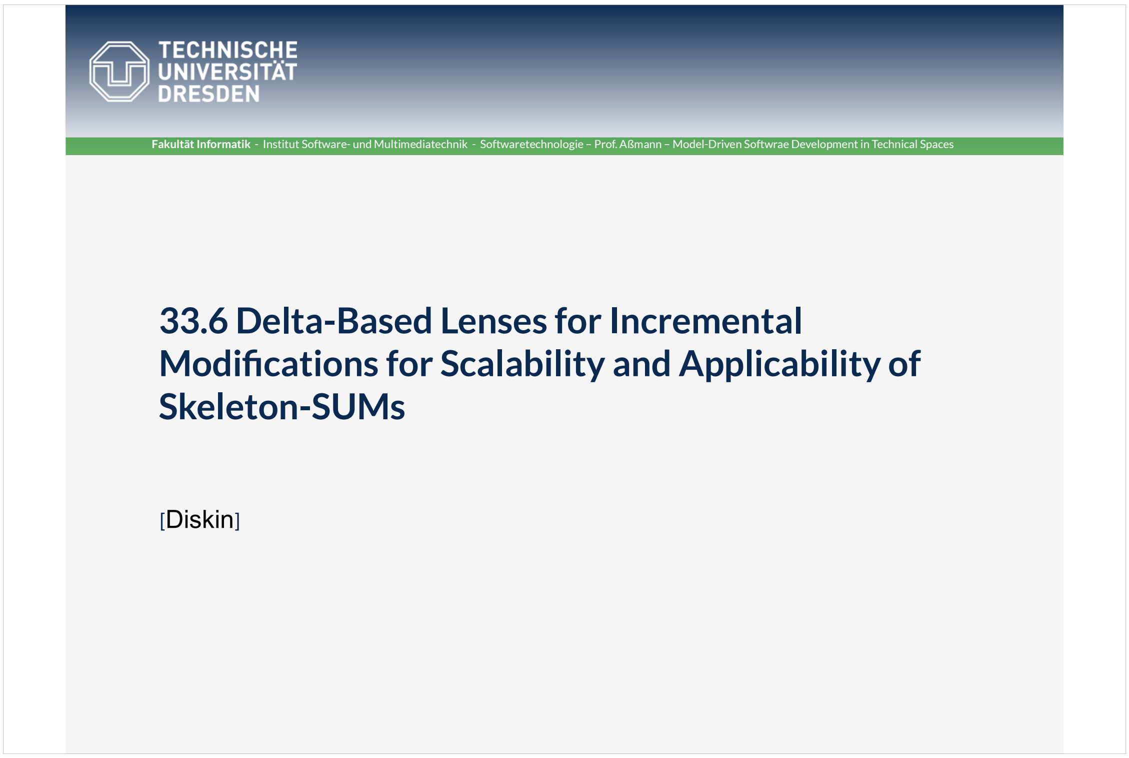
33.5.2 Put Operations in the MDA-Multi-Skeleton-SUM

Model Synchronization in RAG-MDA by `Put` Operations on Single Underlying Models (SUM)

- A single underlying model (SUM) is a cultimodel with *views*
- MDA can be arranged as MDA-SUM
- A **evolution operation** changes a global name or definition in one model tree a view, which used in several other model trees in the SUM
- To synchronize dependent model elements, we need a `commit/put` operation ("**commit/put to SUM**")
- Its implementation needs to repeat the rewrite in all referencing places
  - Follow the references introduced by global name analysis
  - Standard process in RAG
- Easy traceability by dependency graph between global names



Example: different class implementations of a connector class in a PIM



33.6 Delta-Based Lenses for Incremental Modifications for Scalability and Applicability of Skeleton-SUMs

[Diskin]

Delta-Based Lenses for Scalability and Applicability

- Simple minded implementation approach –
  - uni-directional *exhaustive* transformations
    - get: SUM-to-view, put: view-to-SUM
  - create a new (version of the) view whenever there is a change in the SUM
  - create a new (version of the) SUM whenever there is a change in a view
- Would work but too large grained
  - Not scalable (inefficient)
  - No incrementality
  - transformation more complex than necessary

⇒ The necessary get/put operations are called ***bidirectional lenses***

Delta-Based Lenses and Skeleton SUMs

- ***Lenses*** (Pierce et al. 2007) are pairs of bidirectional transformations based on get (exhaustive projection, decomposition, checkout) and put (exhaustive integration, checkin) operations on models
  - axioms for *well-behaved lenses*

    v: View; s:SUM
    $\text{get}(\text{put}(v, s)) = v$ // *PUTGET invariant rule*
    $\text{put}(\text{get}(s), s) = s$ // *GETPUT invariant rule*

  - axiom for *very well behaved lenses:* "intermediary puts can be forgotten"

    $\text{put}(v', \text{put}(v, s)) = \text{put}(v', s)$ // *PUTPUT invariant rule*

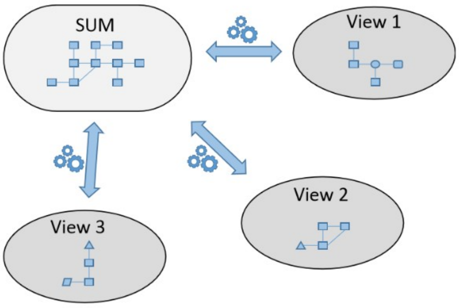
- ***Delta-based Lenses*** optimize the checkin/checkout (Diskin et al. 2011)
  - *Incremental* delta operations dput and dget are driven by the changes to the views
  - axiom for delta-put: "If a delta-commit results in a delta of the SUM, then the next delta-checkout refers only to this delta of the SUM"

    if $\Delta s = \text{dput}(\Delta v, s)$, then $\text{dget}(\Delta s) = \Delta v$ // *DeltaPUTPUT rule*

  - much more fine-grained and scalable

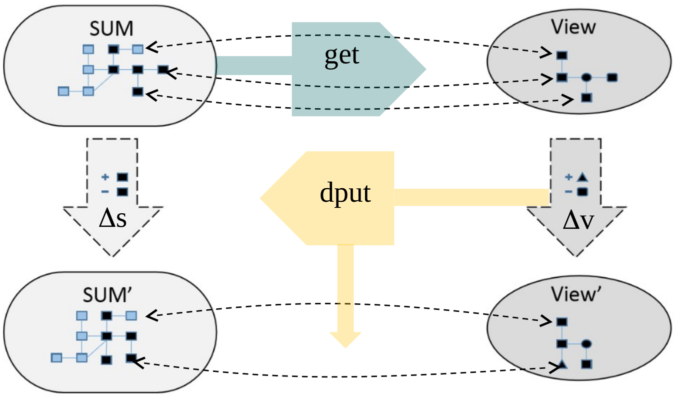
The Background of Orthographic Software Modeling (OSM)

- In OSM, the SUM is much larger than the views
  - the views are relatively small and compact
- Views can be updated concurrently
  - axioms only applicable locally (i.e. to one view at a time)
- Usually have one-to-one correspondences between view elements and SUM elements
  - changes can conveniently be traced to the affected element
- View elements cannot be changed just locally
  - for example, cannot delete an element from just the view, but not the SUM



Hybrid Approach with dput

- use ***get*** to create views from the SUM
- use ***dput*** (delta put) to update the SUM when a view is changed
  - incremental put operation only transmits the delta (increment)

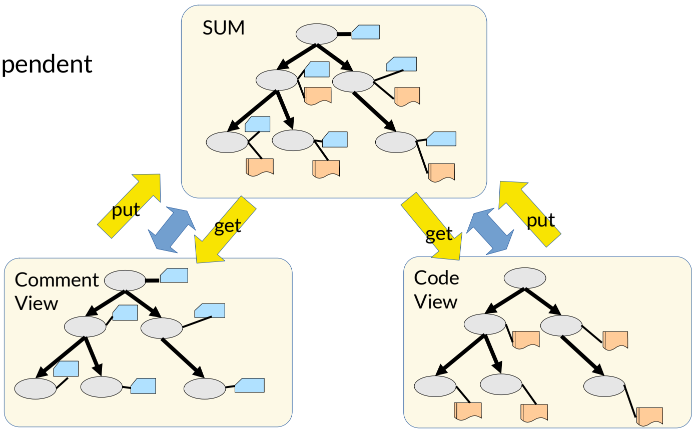


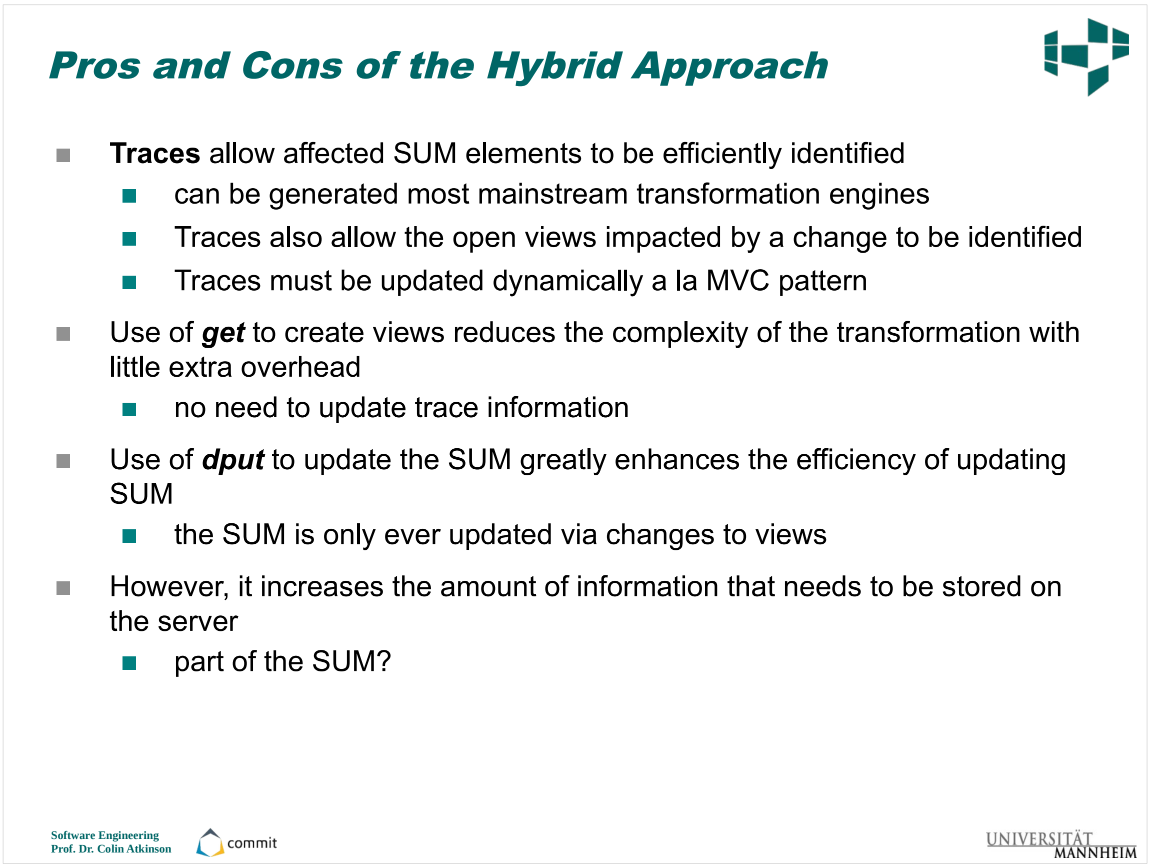
if $\Delta s = \text{dput}(\Delta v, s)$, then $\text{dget}(\Delta s) = \Delta v$ // *DeltaPUTPUT rule*

Skeleton-SUM and DeltaPutPut

A Skeleton-SUM fulfills the DeltaPutPut rule.

- Reason:
  - Partial functions are independent
  - Skeleton stays invariant
- Corollary
  - therefore OSM
  - therefore Javadoc-SUM





Pros and Cons of the Hybrid Approach

- **Traces** allow affected SUM elements to be efficiently identified
  - can be generated most mainstream transformation engines
  - Traces also allow the open views impacted by a change to be identified
  - Traces must be updated dynamically a la MVC pattern
- Use of ***get*** to create views reduces the complexity of the transformation with little extra overhead
  - no need to update trace information
- Use of ***dput*** to update the SUM greatly enhances the efficiency of updating SUM
  - the SUM is only ever updated via changes to views
- However, it increases the amount of information that needs to be stored on the server
  - part of the SUM?

33.7 Skeleton-SUM on RoSI CROM

Skeleton-SUM on RoSI CROM

- The SUM principle can be played on all metalanguages, e.g., CROM
- CROM supports Mono-Skeleton-SUM for all
  - Contexts provide *viewpoints*
  - Cores provide *Skeleton*, Roles provide *flesh/clothing*
  - Role-play provides *partial functions from objects to roles* for a SkeletonSUM over cores and roles

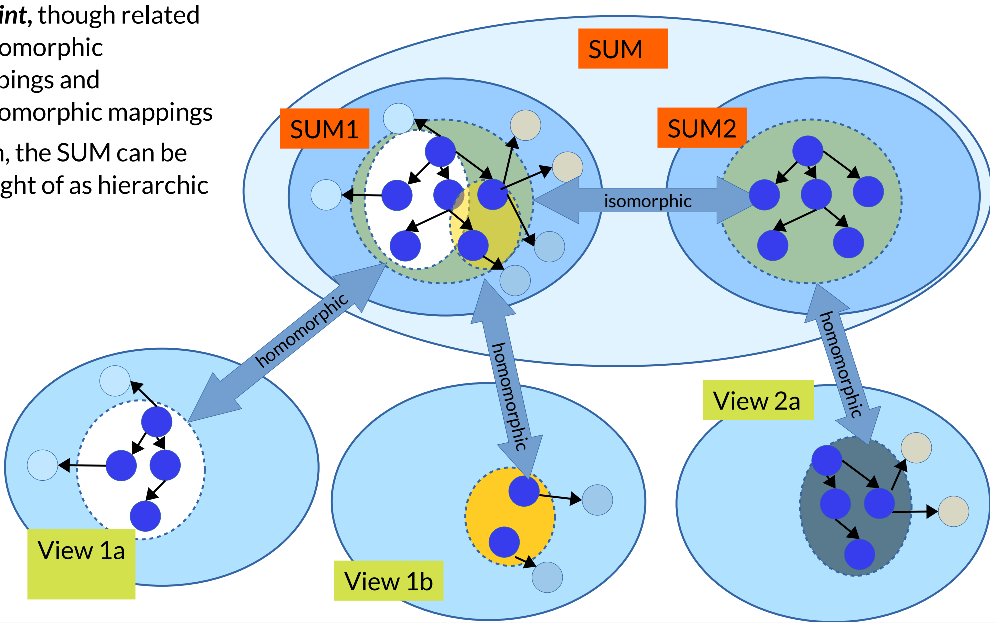
Theorem: A CROM-based Skeleton-SUM fulfils the delta-putput invariant.

33.8. Disjoint-Skeleton-SUM

[Seifert11]

Disjoint-Skeleton-SUM

- Skeletons can be ***disjoint***, though related by isomorphic mappings and homomorphic mappings
- Then, the SUM can be thought of as hierarchic

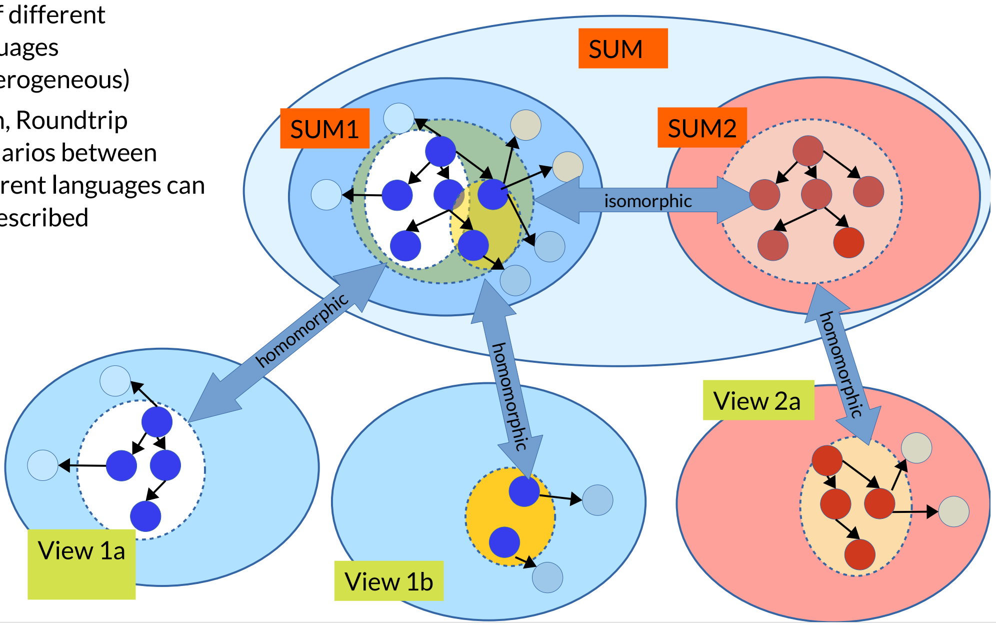


33.8.1 Heterogeneous-Language-Skeleton-SUM

[Seifert11]

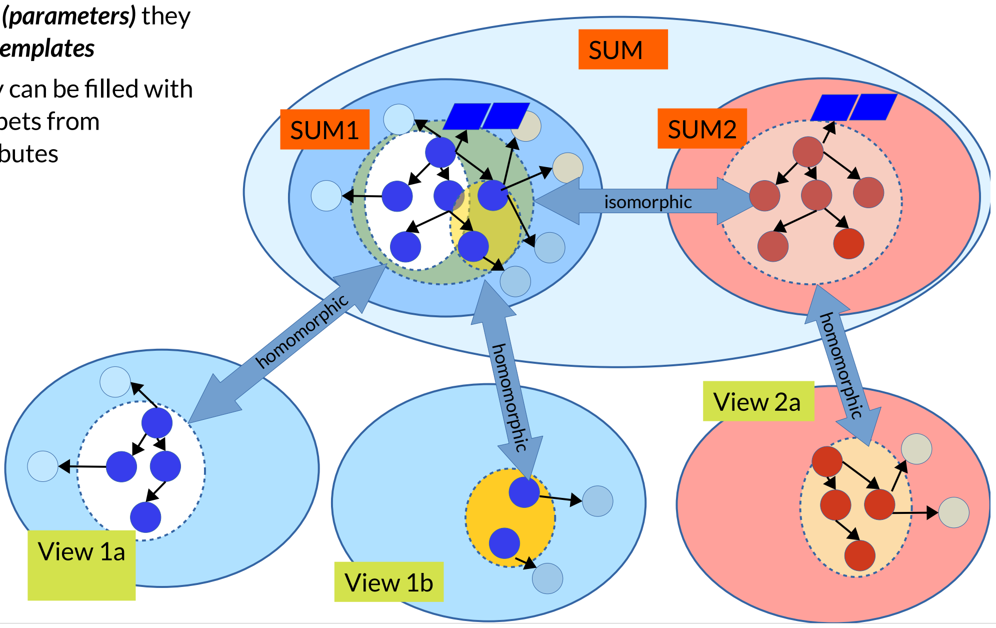
Heterogeneous-Language-Skeleton-SUM

- Disjoing Skeletons can be of different languages (heterogeneous)
- Then, Roundtrip Scenarios between different languages can be described



Heterogeneous-Language-Skeleton-SUM with Templates

- When skeletons have ***slots (parameters)*** they are ***templates***
- They can be filled with snippets from attributes



The End

- Explain, how partial functions between objects and attributes enable the projections (get) and the merge functions (put) of a Skeleton-SUM
- Why are contexts important for views?
- What happens if the SUM has several skeletons?
- Which are the contexts of Javadoc-SUM? Why does Javadoc-SUM fulfill the DeltaPutPut rule?
- Which are the contexts of OSM? Why does OSM fulfill the DeltaPutPut rule?
- Why does ROSI-CROM enable Skeleton-SUM?
- Some slides are courtesy to Prof. Colin Atkinson, Mannheim. Used by permission.