

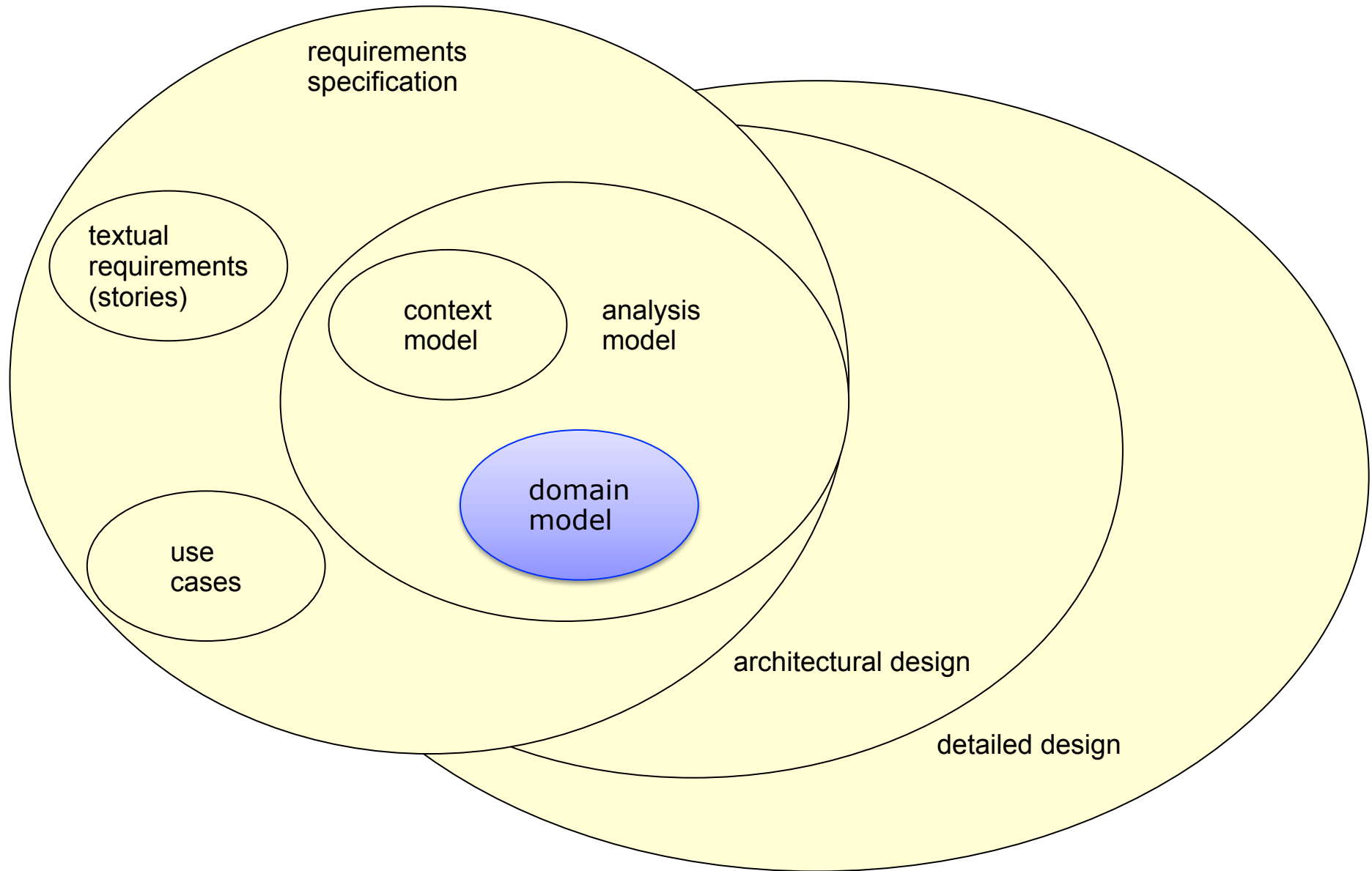
31) Feature Models and MDA for Product Lines

- 1. Feature Models**
- 2. Product Line Configuration with Feature Models**
- 3. Multi-Stage Configuration**

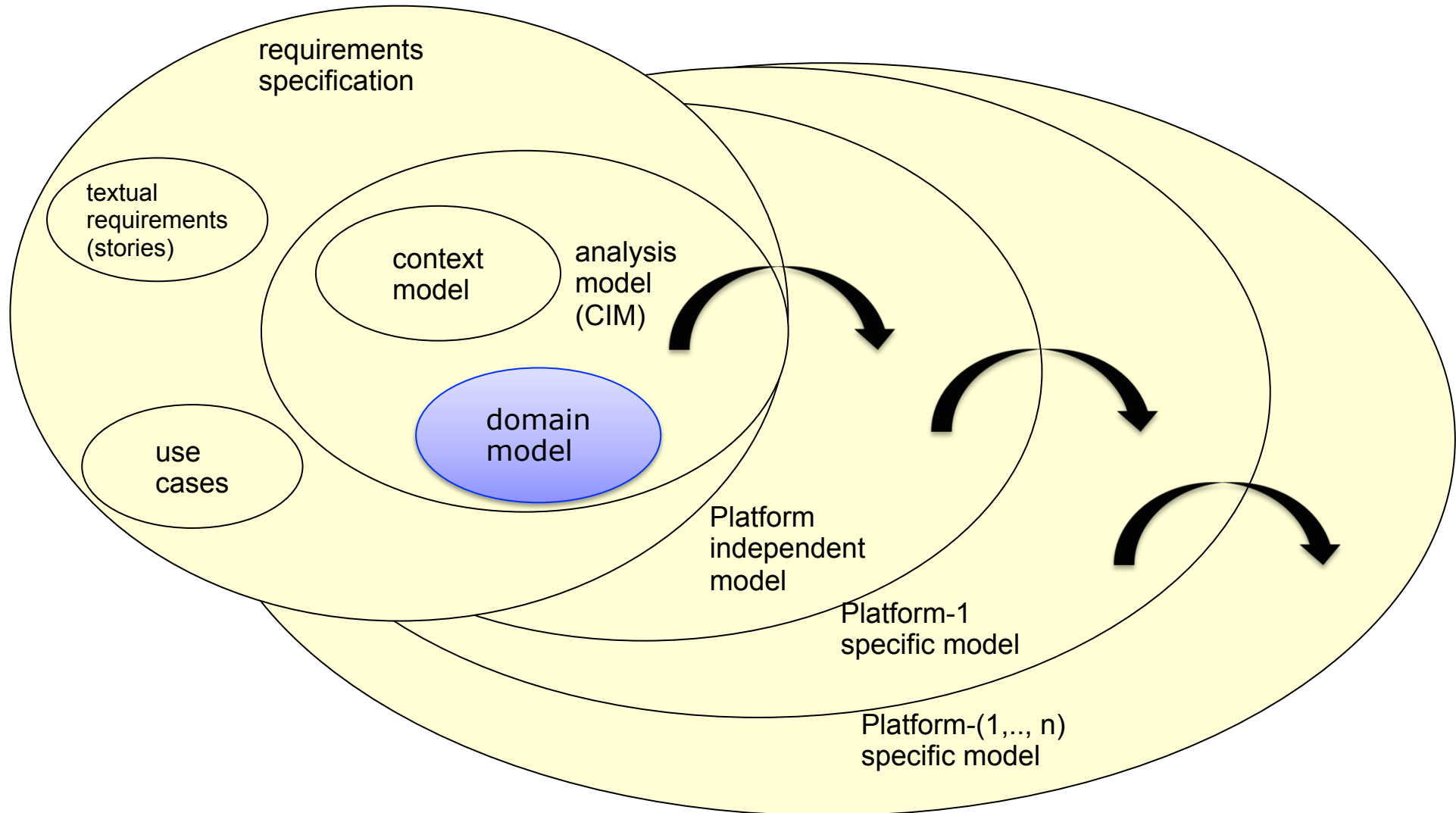
- **Prof. Dr. U. Aßmann**
- **Florian Heidenreich**
- **Technische Universität Dresden**
- **Institut für Software- und Multimediatechnik**
- **Gruppe Softwaretechnologie**
- **<http://st.inf.tu-dresden.de>**
- **Version 12-0.2, January 23, 2013**

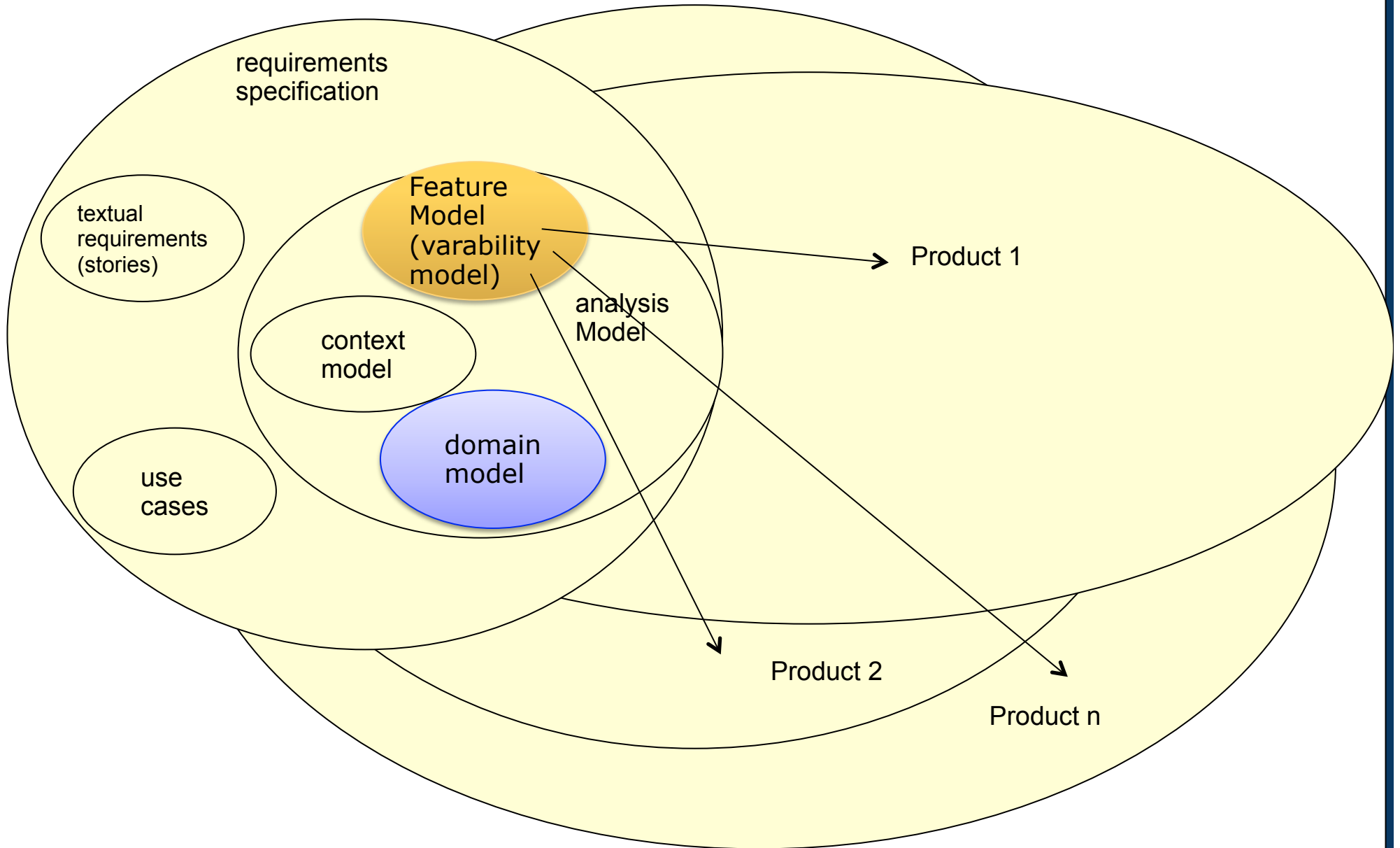
- **Florian Heidenreich, Jan Kopcsek, and Christian Wende. FeatureMapper: Mapping Features to Models. In Companion Proceedings of the 30th International Conference on Software Engineering (ICSE'08), Leipzig, Germany, May 2008.**
 - <http://fheidenreich.de/work/files/ICSE08-FeatureMapper--Mapping-Features-to-Models.pdf>

- **[Aßm03] U. Aßmann. Invasive Software Composition. Springer, 2003.**
- **[Cza05] K. Czarnecki and M. Antkiewicz. Mapping Features to Models: A Template Approach Based on Superimposed Variants. In R. Glück and M. Lowry, editors, Proceedings of the 4th International Conference on Generative Programming and Component Engineering (GPCE'05), volume 3676 of LNCS, pages 422-437. Springer, 2005.**
- **[Cza06] K. Czarnecki and K. Pietroszek. Verifying Feature-Based Model Templates Against Well-Formedness OCL Constraints. In Proceedings of the 5th International Conference on Generative Programming and Component Engineering (GPCE'06), pages 211-220, New York, NY, USA, 2006. ACM.**
- **[Hei08a] F. Heidenreich, J. Kopcsek, and C. Wende. FeatureMapper: Mapping Features to Models. In Companion Proceedings of the 30th International Conference on Software Engineering (ICSE'08), pages 943-944, New York, NY, USA, May 2008. ACM.**
- **[Hei08b] Florian Heidenreich, Ilie Şavga and Christian Wende. On Controlled Visualisations in Software Product Line Engineering. In Proc. of the 2nd Int'l Workshop on Visualisation in Software Product Line Engineering (ViSPLE 2008), collocated with the 12th Int'l Software Product Line Conference (SPLC 2008), Limerick, Ireland, September 2008.**
- **[Hei09] Florian Heidenreich. Towards Systematic Ensuring Well-Formedness of Software Product Lines. In Proceedings of the 1st Workshop on Feature-Oriented Software Development (FOSD 2009) collocated with MODELS/GPCE/SLE 2009. Denver, Colorado, USA, October 2009. ACM Press**

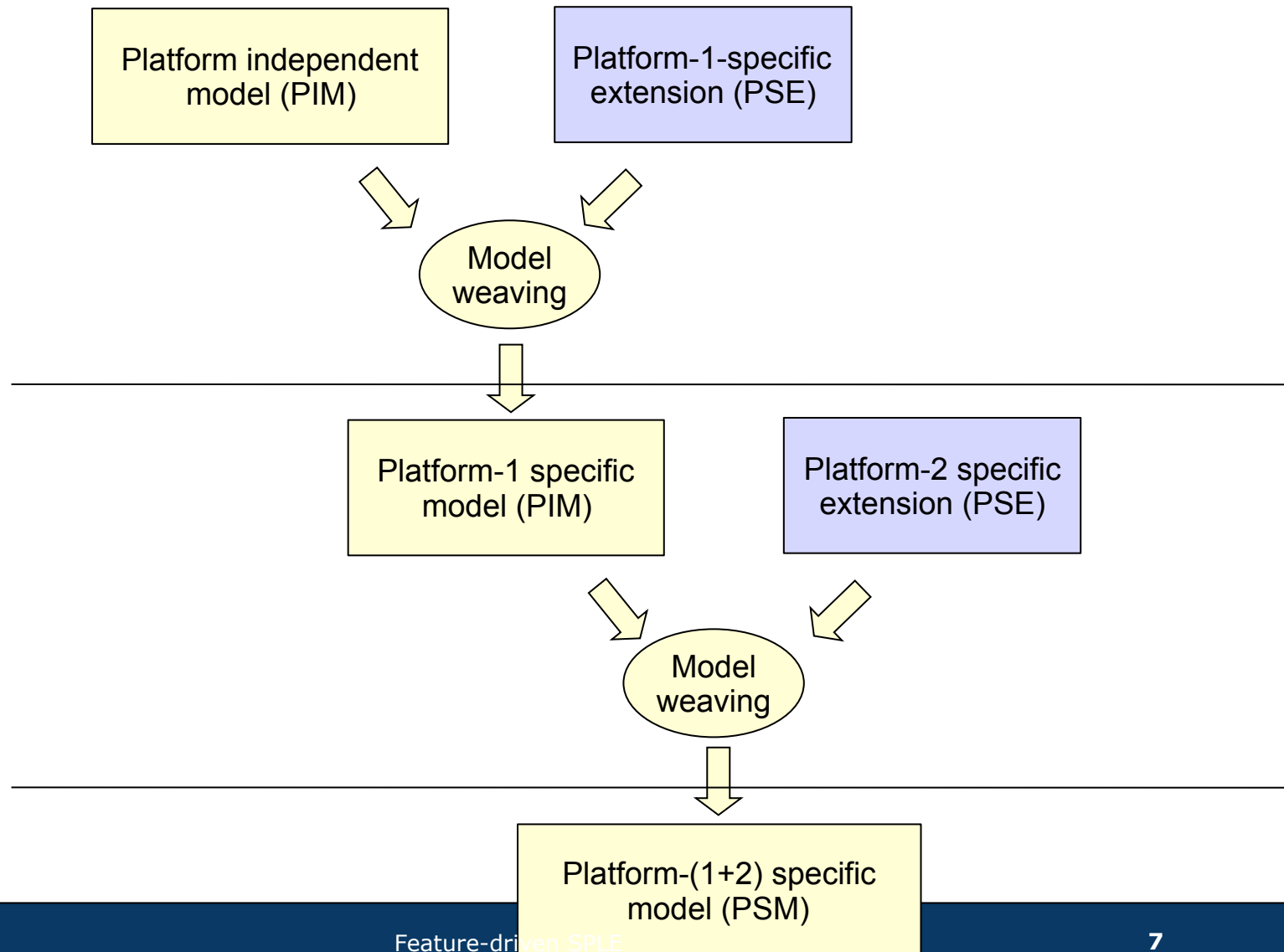


➤ **Horizontal product line: one product idea in several markets**

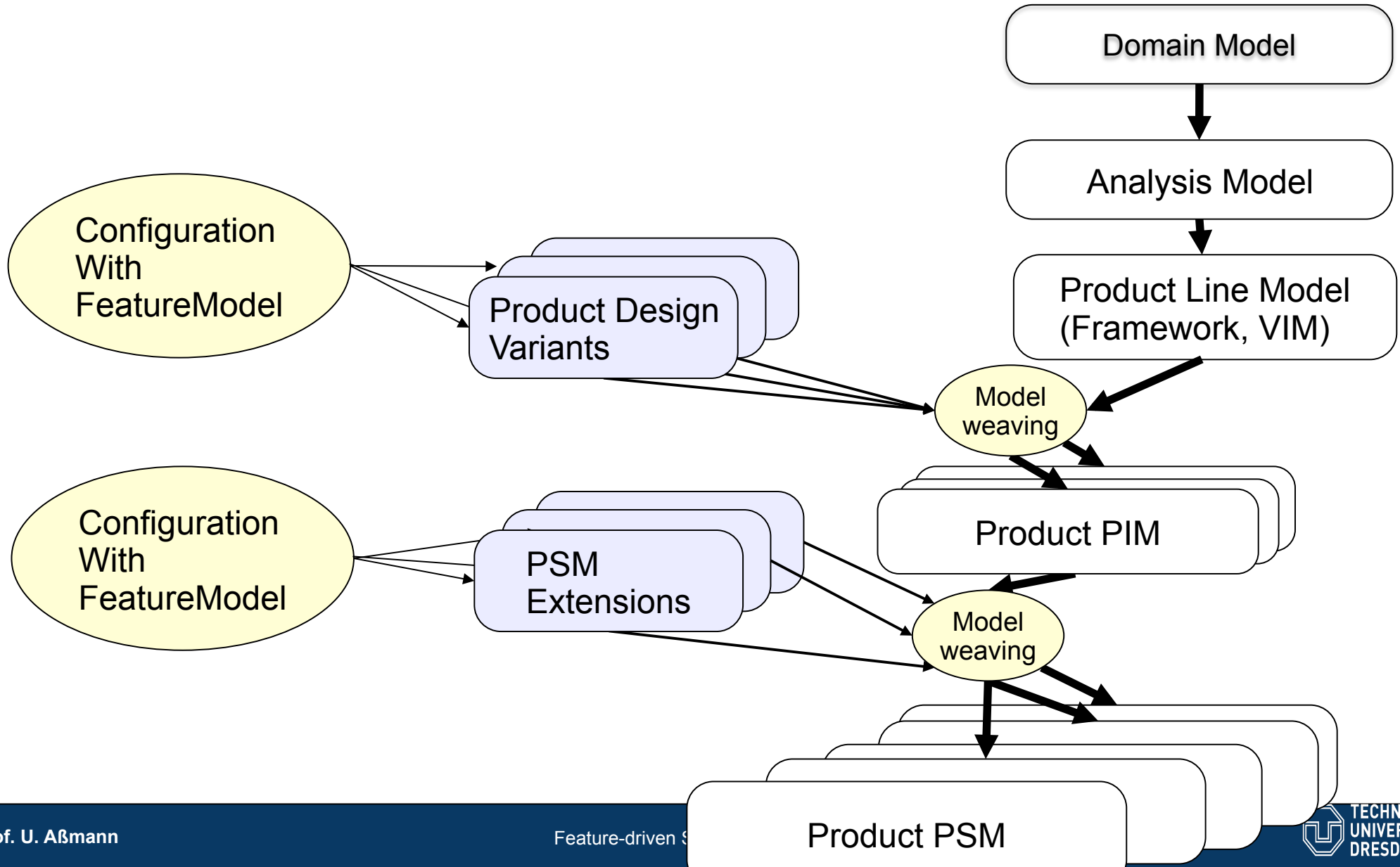




- In the following, we extend the MDA (below) with configuration



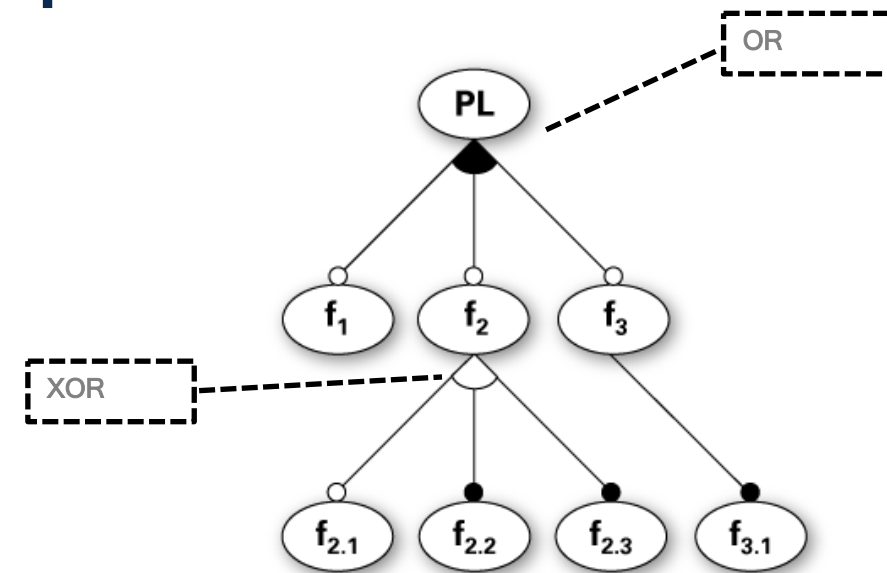
- ▶ **Vertical product line: several products in one or several markets**
 - ▶ The VIM (variant independent model) is the common model of the product family



31.1 PRODUCT LINES WITH FEATURE TREES AND FEATURE MODELS

➤ **Feature models are used to express variability in Product Lines**

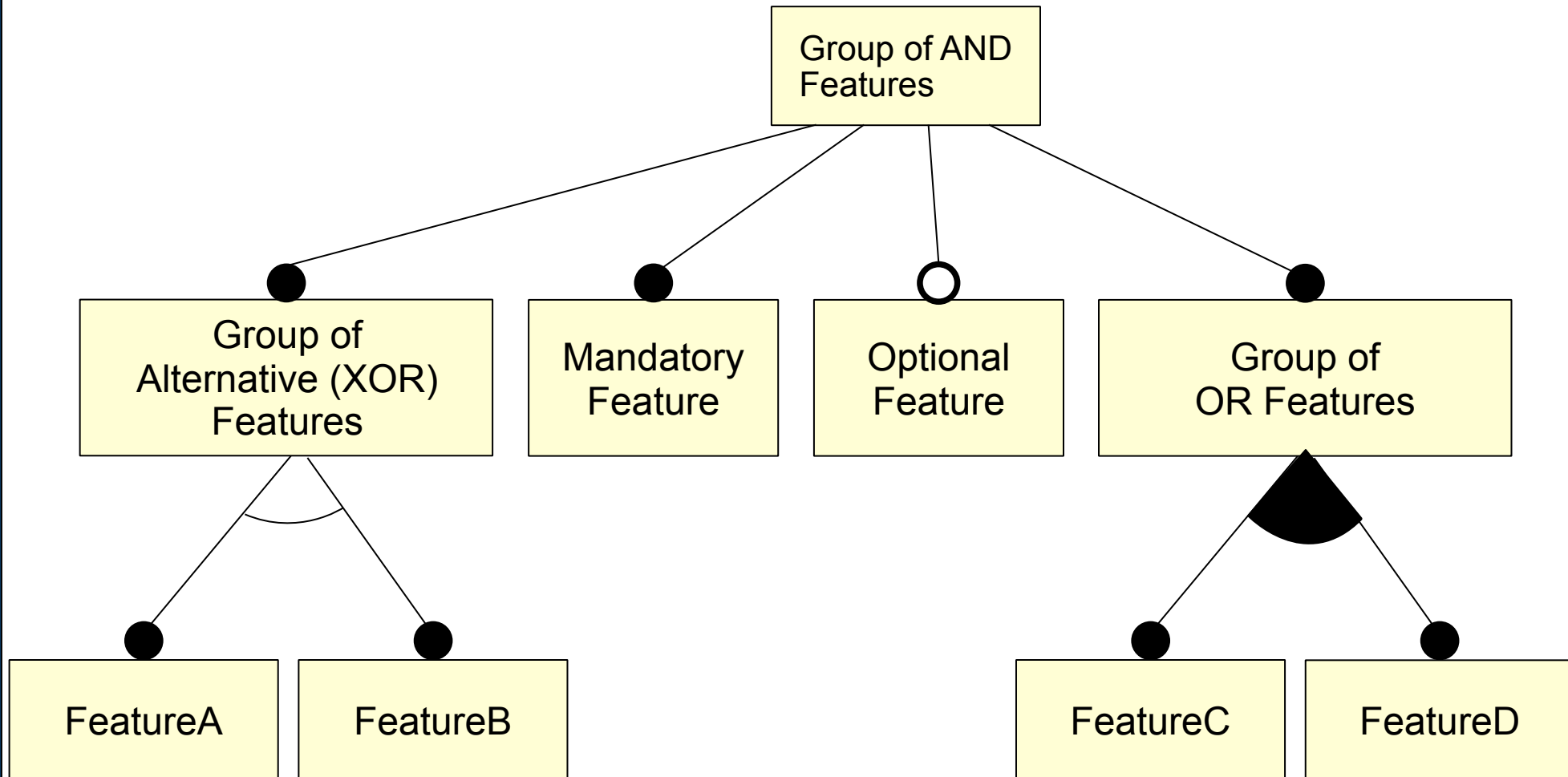
- alternative,
- mandatory,
- optional features, and
- their relations



➤ **A *variant model* represents a concrete product (variant) from the product line**

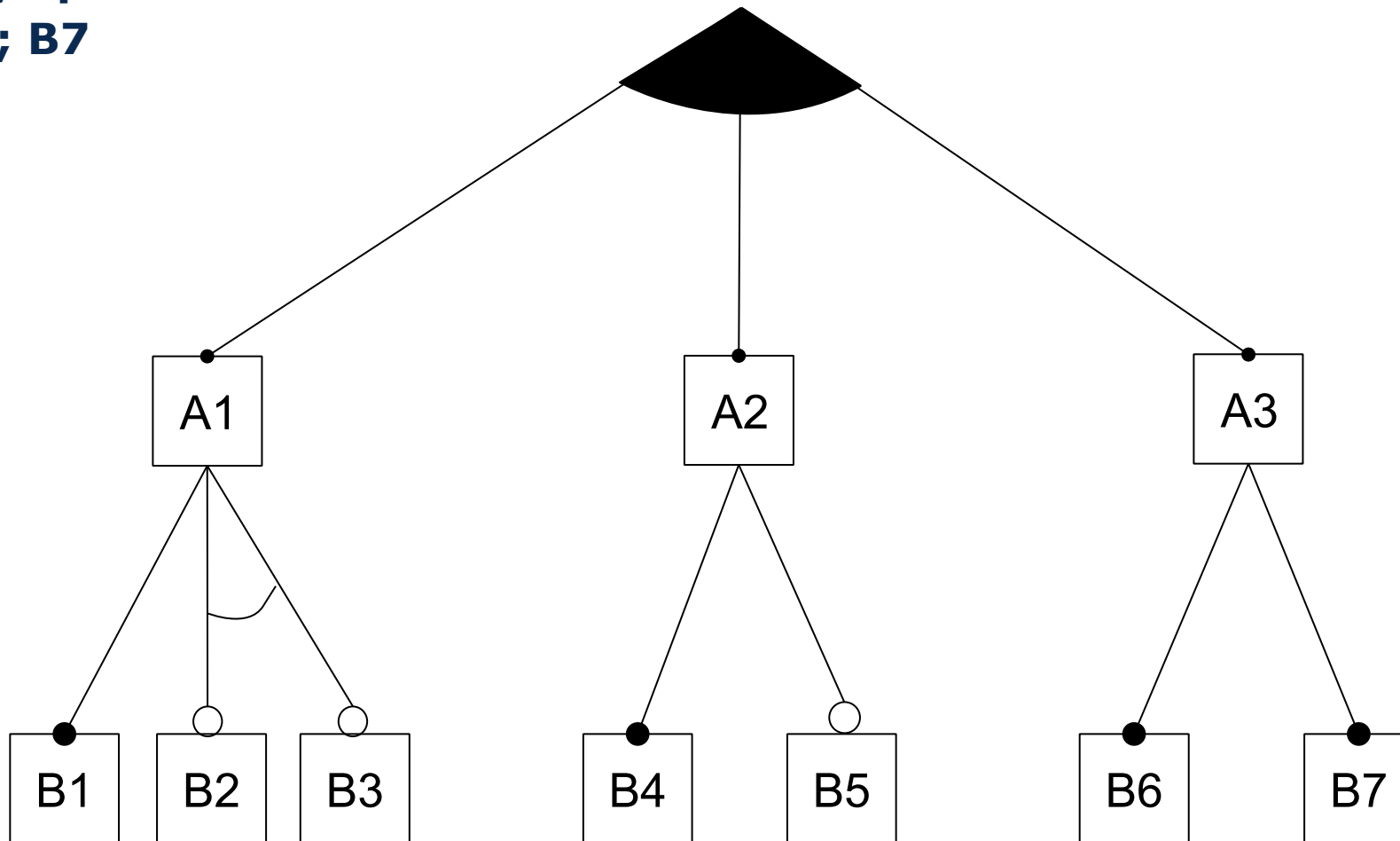
- The variant model results from a selection of a subgraph of the feature model
- The variant model can be used to parameterize and drive the product instantiation process

➤ **The Feature Tree Notation is derived from And-Or-Trees**

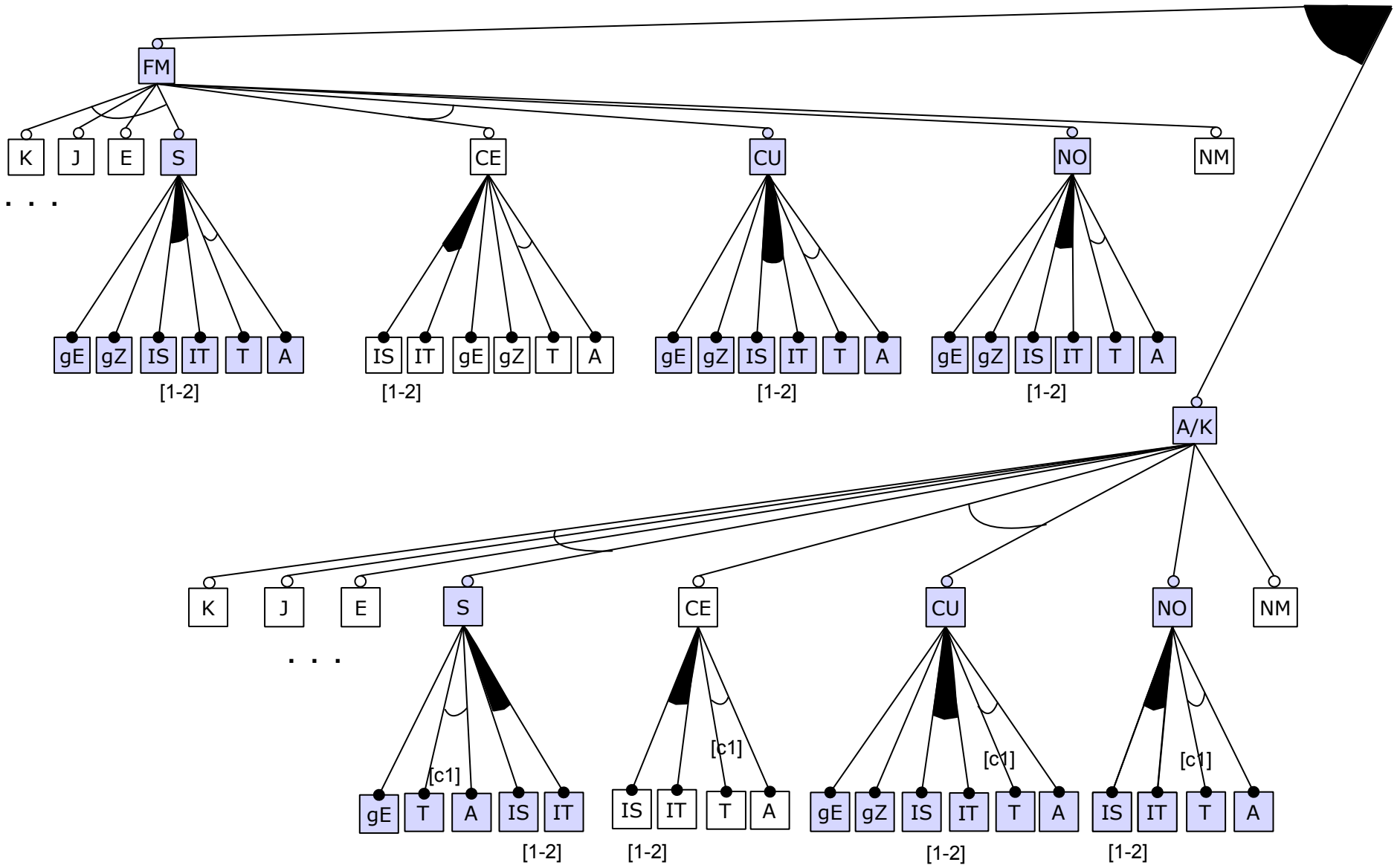


PhD Thesis, Czarnecki (1998)
 based on FODA-Notation by Kang et al. (1990)

- **A1 or A2 or A3**
- **B1; B2 xor B3**
- **B4; optional B5**
- **B1; B7**



➤ [K. Lehmann-Siegemund, Diplomarbeit]



- **Bridging the gap between configuration and solution space**
- **Need for mapping of features from feature models to artefacts of the solution space**
- **Possible artefacts**
 - Models defined in DSLs
 - Model fragments (snippets)
 - Architectural artefacts (components, connectors, aspects)
 - Source code
 - Files
- **But how can we achieve the mapping... ?**

Plug-ins and Fragments

Plug-ins and Fragments

Select plug-ins and fragments that should be packaged in this feature.

- org.eclipse.core.filesystem.linux.ppc (1.0.100.v20080604-1400)
- org.eclipse.core.filesystem.linux.x86 (1.2.0.v20080604-1400)
- org.eclipse.core.filesystem.linux.x86_64 (1.0.100.v20080604-1400)
- org.eclipse.core.filesystem.macosx (1.1.0.v20090112)
- org.eclipse.core.filesystem.solaris.sparc (1.0.100.v20080604-1400)
- org.eclipse.core.filesystem.win32.x86 (1.1.0.v20080604-1400)
- org.eclipse.core.resources.win32.x86 (3.5.0.v20081020)
- org.eclipse.equinox.launcher.carbon.macosx (1.0.200.v20090520-1835)
- org.eclipse.equinox.launcher.gtk.linux.ppc (1.0.200.v20090519)
- org.eclipse.equinox.launcher.gtk.linux.x86 (1.0.200.v20090520)
- org.eclipse.equinox.launcher.gtk.linux.x86_64 (1.0.200.v20090519)
- org.eclipse.equinox.launcher.gtk.solaris.sparc (1.0.200.v20090519)
- org.eclipse.equinox.launcher.win32.win32.x86 (1.0.200.v20090519)
- org.eclipse.equinox.security.macosx (1.100.0.v20090520-1800)
- org.eclipse.equinox.security.win32.x86 (1.0.100.v20090520-1800)
- org.eclipse.swt.carbon.macosx (3.5.0.v3550b)
- org.eclipse.swt.gtk.linux.ppc (3.5.0.v3550b)
- org.eclipse.swt.gtk.linux.x86 (3.5.0.v3550b)
- org.eclipse.swt.gtk.linux.x86_64 (3.5.0.v3550b)
- org.eclipse.swt.gtk.solaris.sparc (3.5.0.v3550b)
- org.eclipse.swt.win32.win32.x86 (3.5.0.v3550b)
- org.eclipse.ui.carbon (4.0.0.I20090525-2000)
- org.eclipse.ui.win32 (3.2.100.v20090429-1800)
- org.eclipse.update.core.linux (3.2.100.v20081008)
- org.eclipse.update.core.win32 (3.2.100.v20080107)

Total: 25

Add...

Versions...

Plug-in Details

Specify installation details for the selected plug-in.

Name: Core File System for Linux PPC

Version: 1.0.100.v20080604-1400

Download Size (kB): 0

Installation Size (kB): 0

Unpack the plug-in archive after the installation

Specify environment combinations in which the selected plug-in can be installed. Leave blank if the plug-in does not contain platform-specific code.

Operating Systems: linux Browse...

Window Systems: Browse...

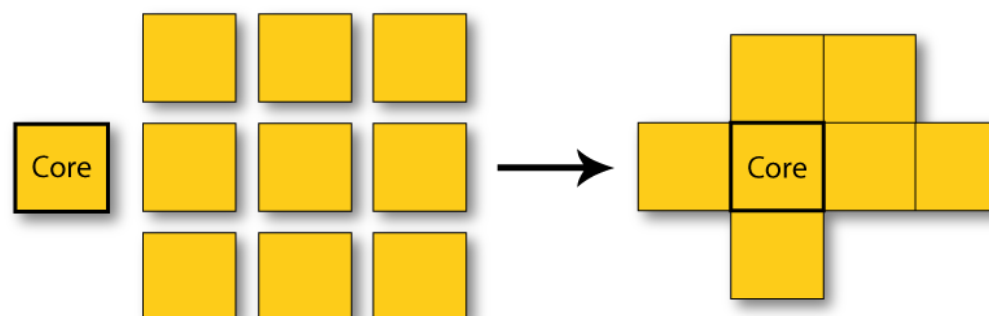
Languages: Browse...

Architecture: ppc Browse...

Overview
Information
Plug-ins
Included Features
Dependencies
Installation
Build
feature.xml
build.properties

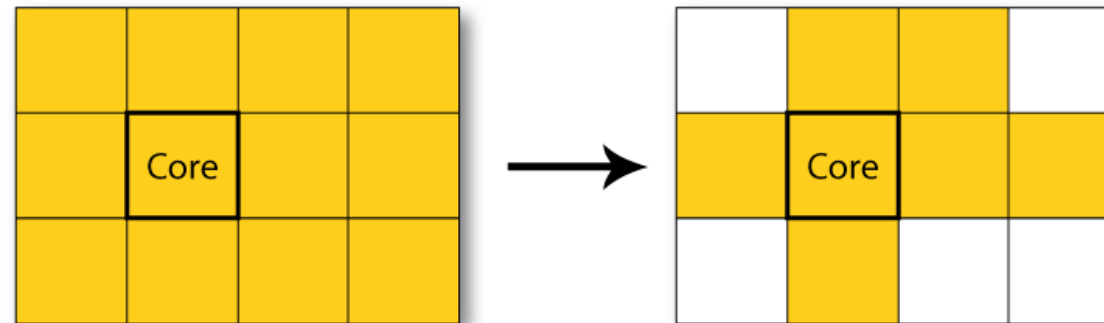
31.2 PRODUCT-LINE CONFIGURATION WITH FEATURE MODELS

- **Map all features to model fragments (model snippets)**
- **Compose them with a core model based on the presence of the feature in the variant model**



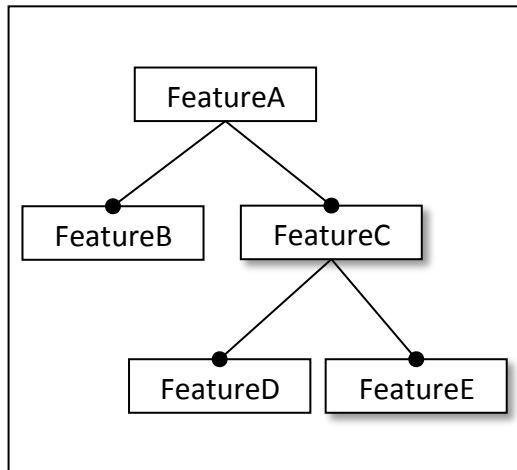
- **Pros:**
 - conflicting variants can be modelled correctly
 - strong per-feature decomposition
- **Cons:**
 - traceability problems
 - increased overhead in linking the different fragments

- **Model all features in one model**
- **Remove elements based on absence of the feature in the variant model**



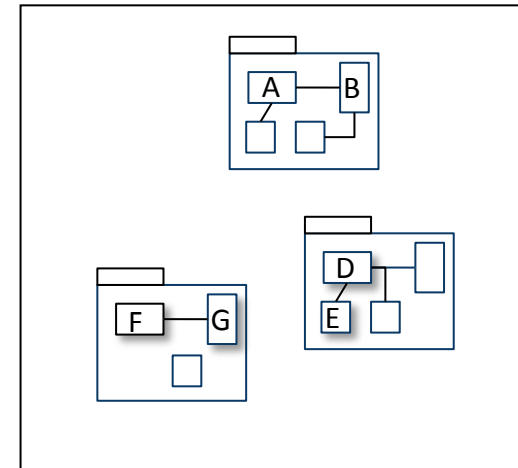
- Pros:
 - no need for redundant links between artifacts
 - short cognitive distance
- Cons:
 - conflicting variants can't be modelled correctly
 - huge and inconcise models

Problem Space



Creation
Visualisation
Validation
Derivation

Solution Space



- **FeatureMapper - a tool for mapping of feature models to modelling artefacts developed at the ST Group**
- **Screencast and paper available at <http://featuremapper.org>**

- **Advantages:**
 - Explicit representation of mappings
 - Configuration of large product lines from selection of variants in feature trees
 - Customers understand
 - Consistency of each product in the line is simple to check
 - Model and code snippets can be traced to requirements



FeatureMapping - ContactManagement/solution/ClassDiagram.umldi - Eclipse - /Users/Florian/Documents/workspace2

MappingView

ContactManagement/mapping/ContactManagementApp

- Constraint OWL
- Feature ContactManagement
 - Group 0
 - Feature Addresses
 - Feature Relationships
 - Feature ContactOpportunities
 - Feature Notes
 - Feature Groups
 - Group 0
 - Feature MultipleAssignment
 - Feature ArbitraryDepth
 - Feature Synchronisation
 - Group 1
 - Feature Gmail
 - Feature Highrise
 - Feature MobilePhone

Current Expression

Feature Relationships

Assigned Feature Expression

Feature Addresses

UML ClassDiagram.umldi

/ContactManagement/solution/ClassDiagram.umldi

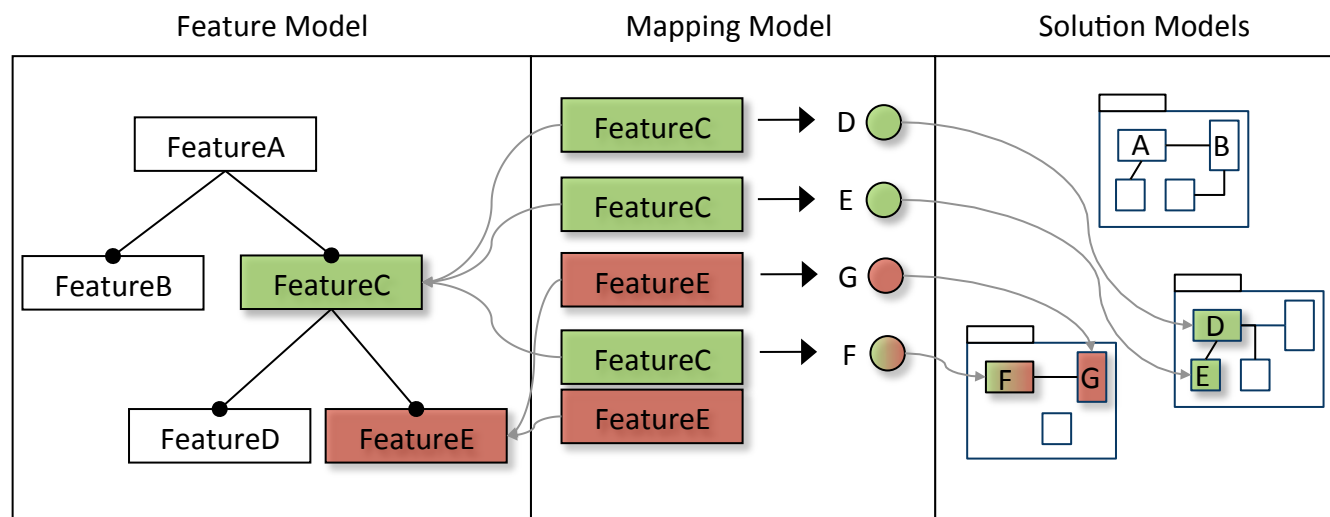
```

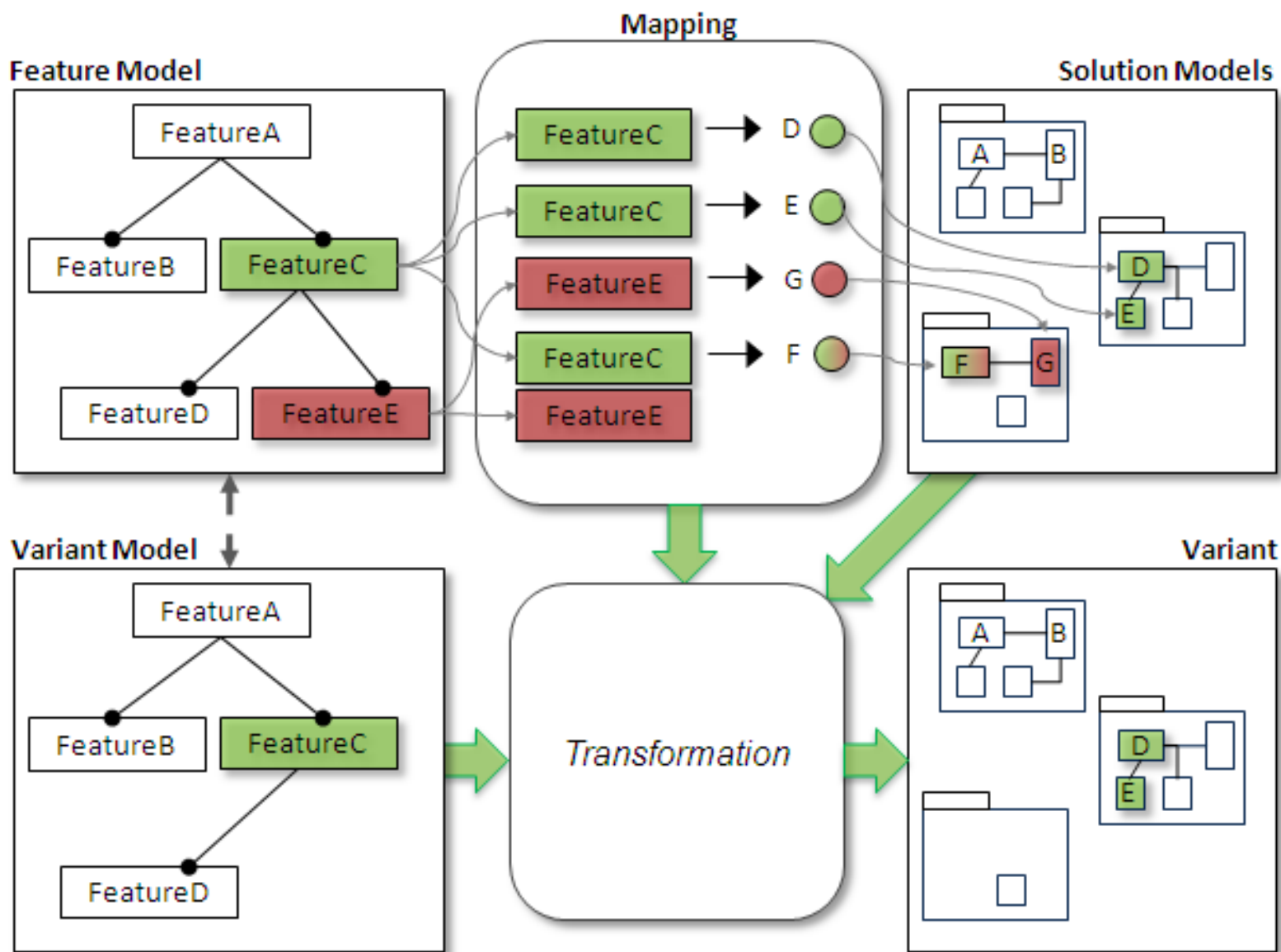
classDiagram
    class ContactList {
        +source
        +list
    }
    class Group {
        +target
        +source
    }
    class Address {
        +address
    }
    class Contact {
        +name
    }
    class Person {
        +forename
        +surname
    }
    class Company {
    }
    class Relationship {
        +role
    }
    ContactList "1" -- "*" Group : +source
    ContactList "1" -- "1" Contact : +list
    Group "*" -- "1" Group : +source
    Group "*" -- "1..*" Contact : +target
    Address "1" -- "1..*" Contact : +address
    Contact "1..*" -- "1" Contact : +contact
    Contact "1..*" -- "1" Relationship : +relationships
    Relationship "1..*" -- "1..*" Relationship : +relationships
    Person --|> Contact
    Company --|> Contact
    
```

Solution Space View

Feature	Element	Resource
Feature Relationships	<Association> Association6	ContactManagement/solution/ClassDiagram.uml
Feature Relationships	<Association> Association7	ContactManagement/solution/ClassDiagram.uml
Feature Relationships	<Class> Relationship	ContactManagement/solution/ClassDiagram.uml
Feature Relationships	<Property> role	ContactManagement/solution/ClassDiagram.uml

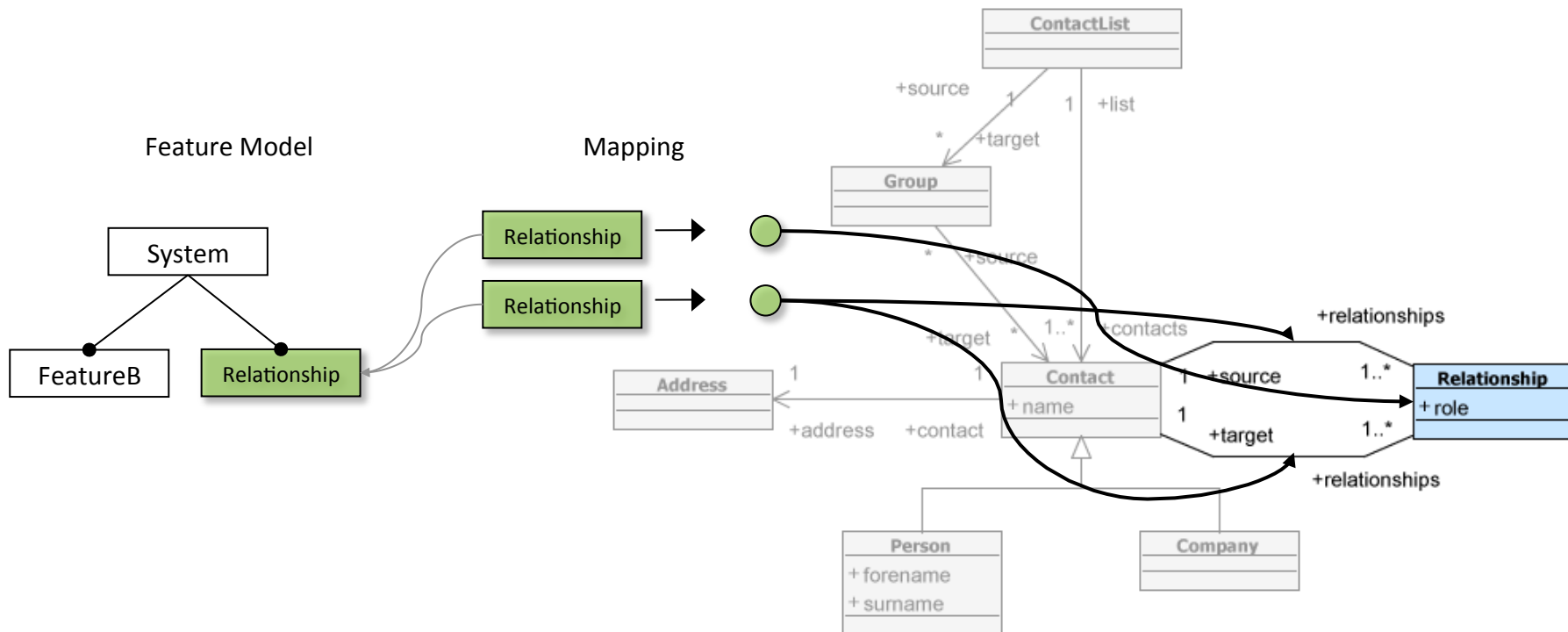
- We chose an explicit *Mapping Representation* in our tool **FeatureMapper**
- Mappings are stored in a mapping model that is based on a mapping metamodel



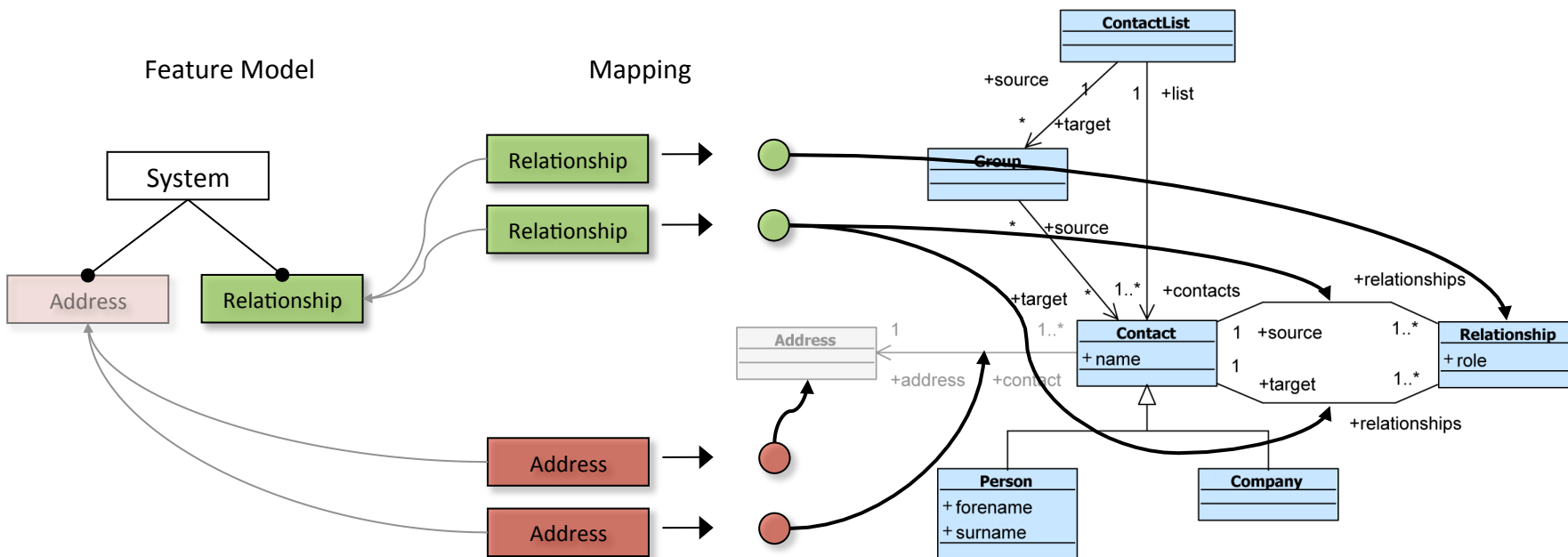


- **Visualisations play a crucial role in Software Engineering**
 - It's hard to impossible to understand a complex system unless you look at it from different points of view
- **In many cases, developers are interested only in a particular aspect of the connection between a feature model and realising artefacts**
 - How a particular feature is realised?
 - Which features communicate or interact in their realisation?
 - Which artefacts may be effectively used in a variant?
- **Solution of the FeatureMapper: MappingViews, a visualisation technique that provides four basic visualisations**
 - Realisation View
 - Variant View
 - Context View
 - Property-Changes View

- For one Variant Model, the realisation in the solution space is shown

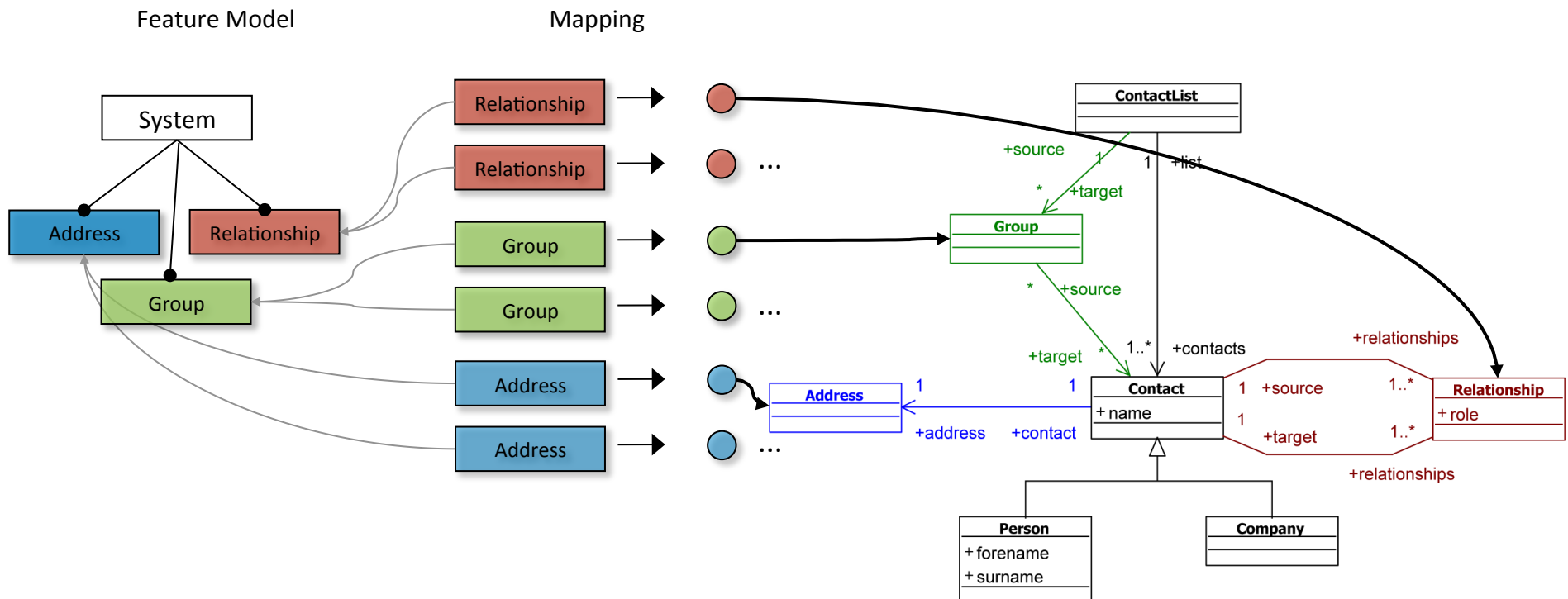


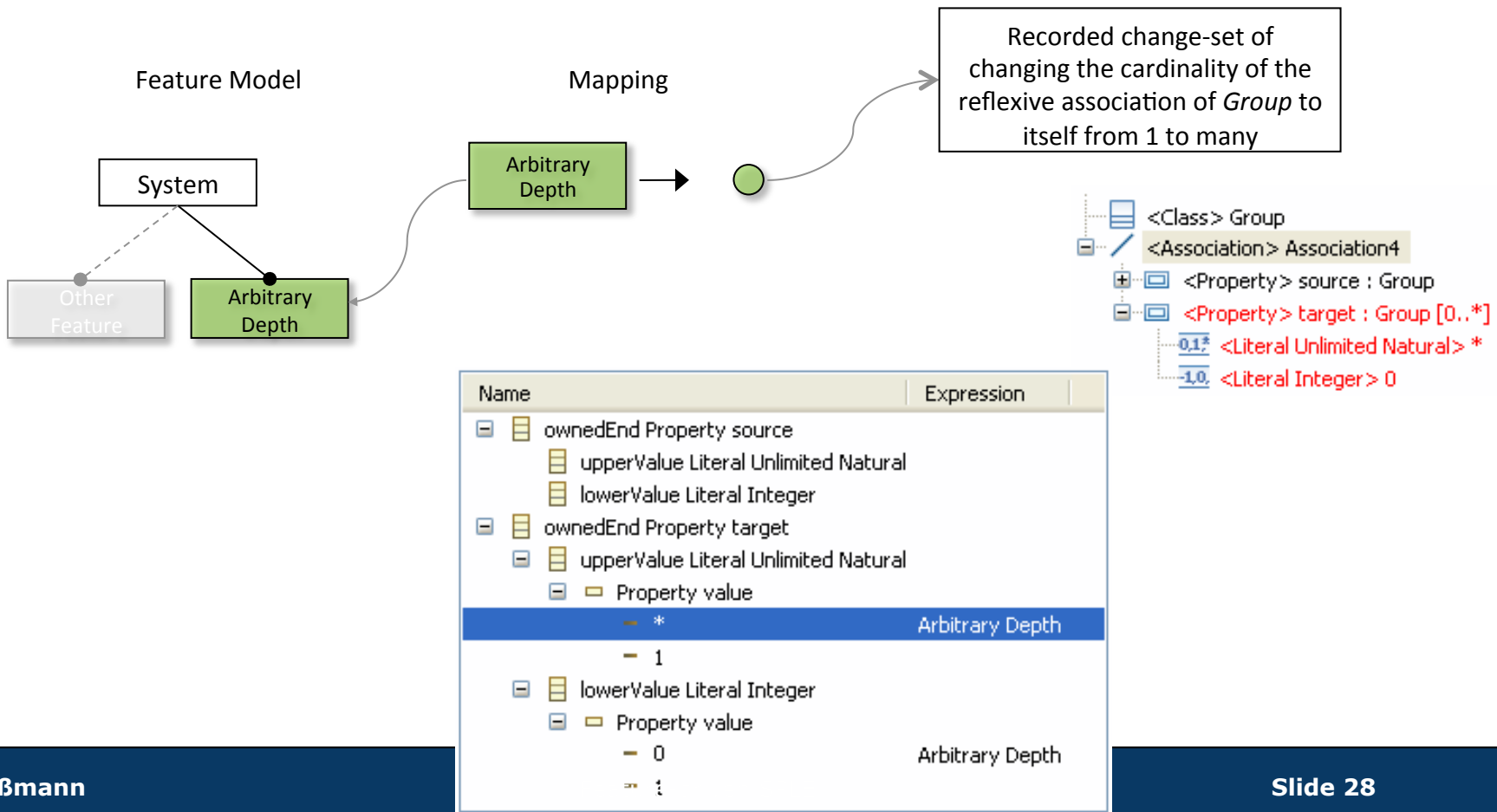
- The variant view shows different variant realisations (variant models) in parallel



➤ The Context View draws the variants with different colors

- Aspect-separation: each variant forms an aspect





- **Unified handling of modelling languages and textual languages by lifting textual languages to the modelling level with the help of EMFText**
- **All >80 languages from the EMFText Syntax Zoo are supported, including Java 5**
- **<http://emftext.org>**



➤ Aspect-related color markup of the code

The screenshot shows the Eclipse IDE interface with the following components:

- Project Explorer:** Shows a project structure with features like 'Feature Relationships' highlighted in blue.
- Code Editor:** Displays the source code for `Contact.java`. Several lines are highlighted in blue, indicating aspect-related color markup:


```

package org.featuremapper.examples.contactmanagement;

import java.util.LinkedHashSet;
import java.util.Set;

public class Contact {
    private String name;
    private Set<Relationship> relationships;

    public Contact(String name) {
        this.name = name;
        this.relationships = new LinkedHashSet<Relationship>();
    }

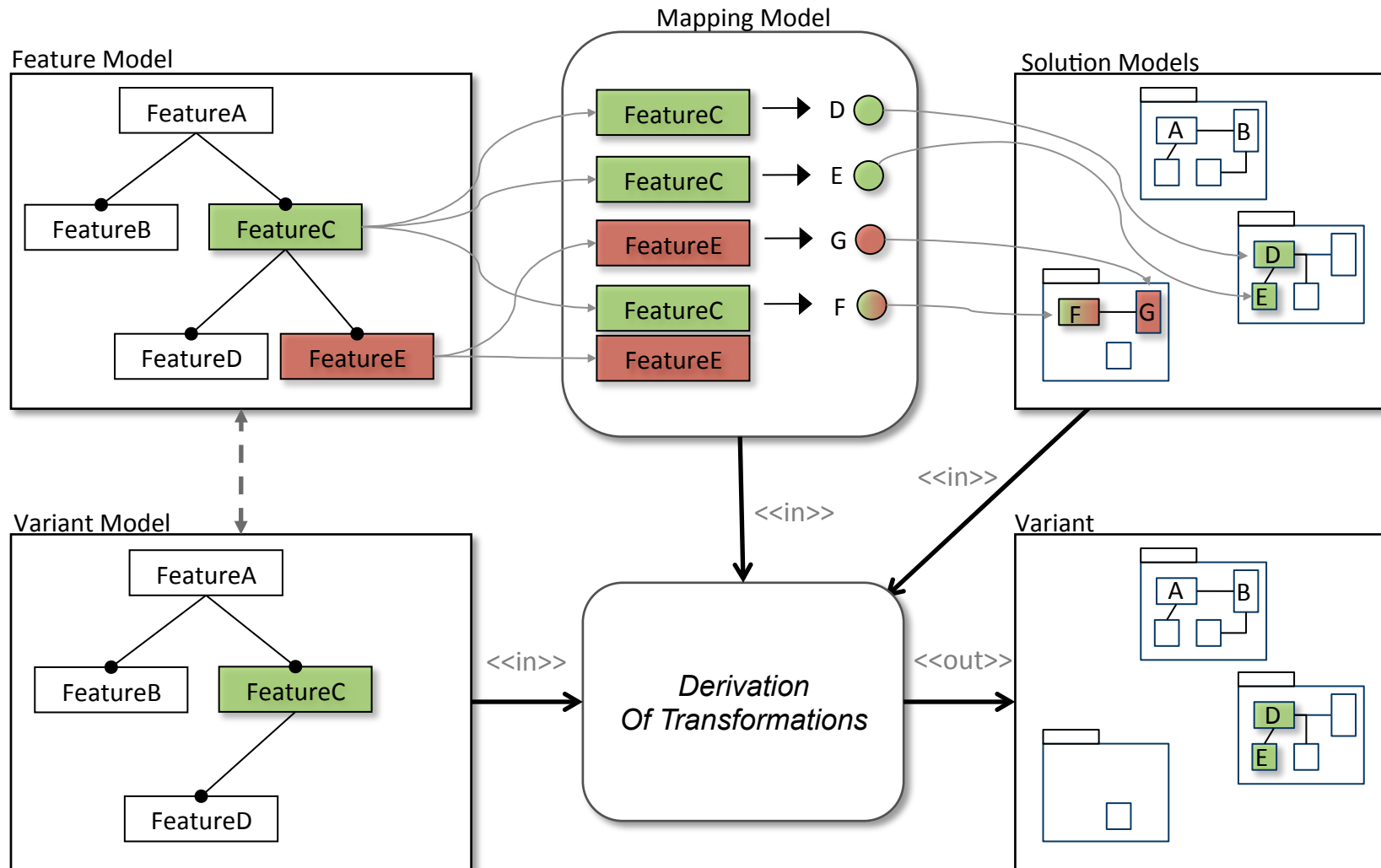
    public void addRelationship(Relationship relationship) {
        this.relationships.add(relationship);
    }

    public String toString() {
        final StringBuffer result = new StringBuffer();
        result.append("Name: " + name);
        result.append("Relationships: " + relationships);
        return result.toString();
    }
}

```
- Outline:** Shows the class structure with 'Class Contact' expanded to show methods like 'addRelationship' and 'toString'.
- Solution Space View:** A table showing the mapping between features and code elements.

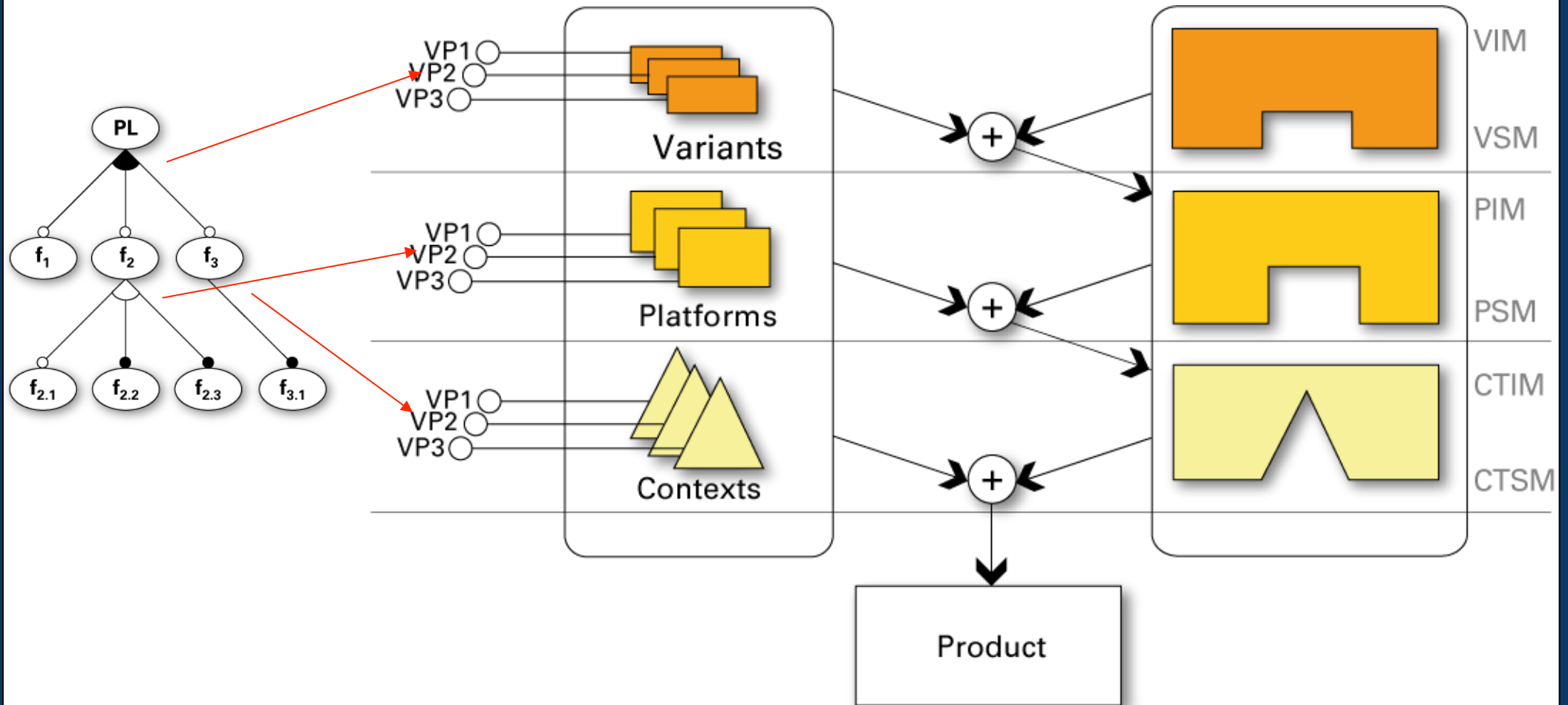
Feature	Element	Resource
Feature Relationships	Class Method toString	ContactManagementJava/s
Feature Relationships	Class Method getTarget	ContactManagementJava/s
Feature Relationships	Class Method getSource	ContactManagementJava/s
Feature Relationships	Class Method getRole	ContactManagementJava/s
Feature Relationships	Constructor Relationship	ContactManagementJava/s
Feature Relationships	Field role	ContactManagementJava/s
Feature Relationships	Field source	ContactManagementJava/s
- Current Expression:** Shows 'Feature Relationships' as the active expression.

➤ Transformations in the solution space build the product

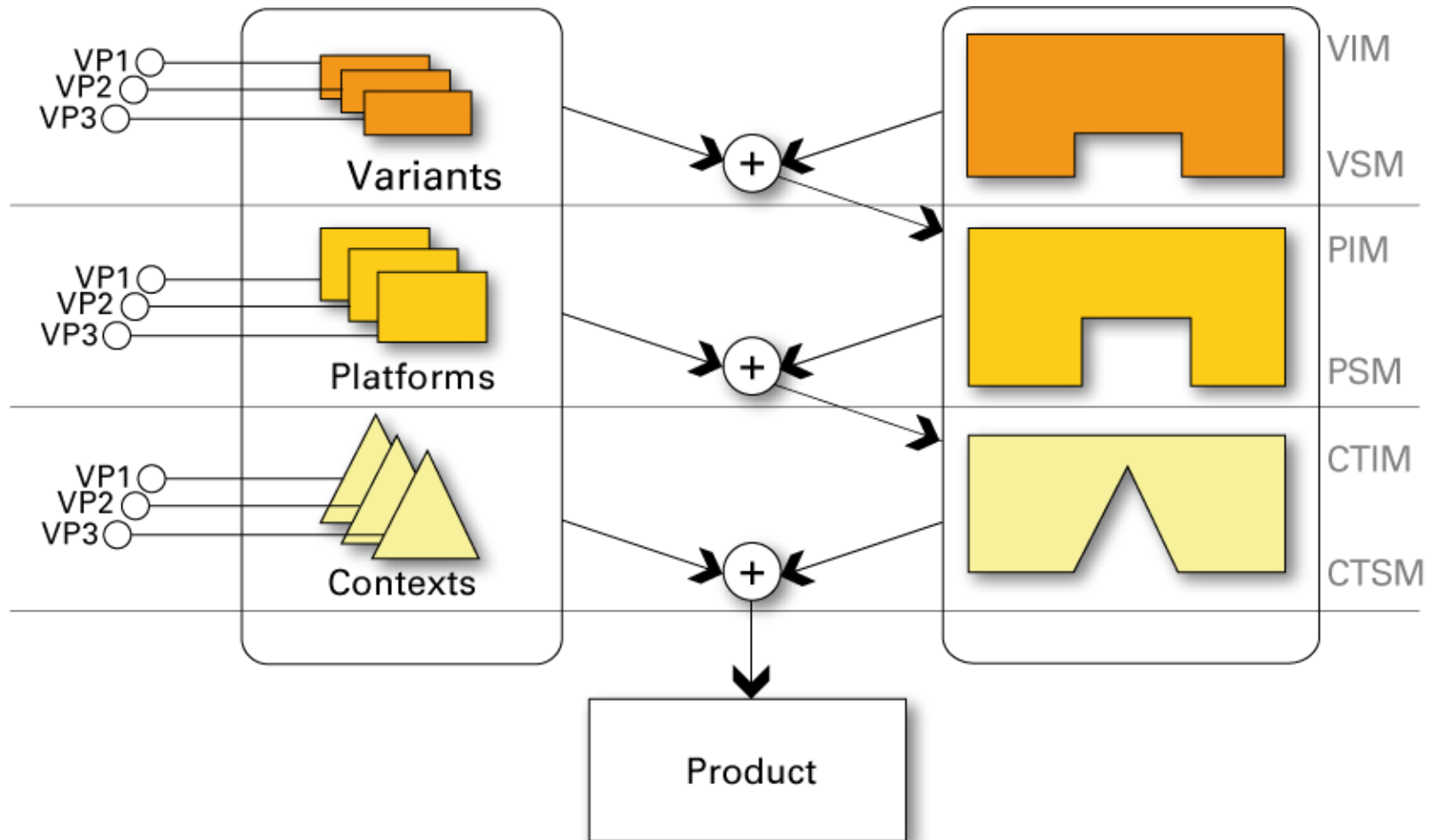


31.3 MULTI-STAGE CONFIGURATION

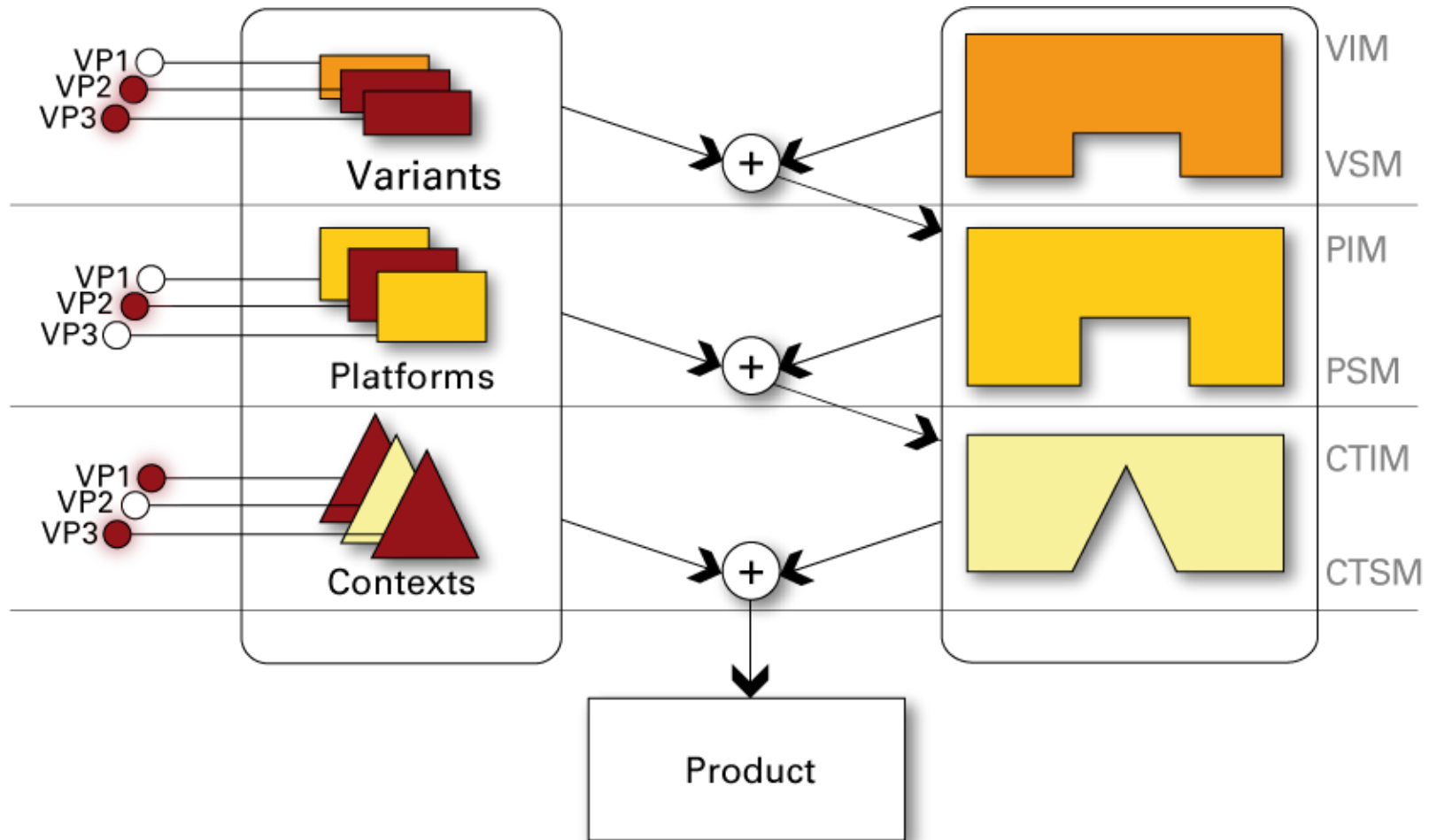
- Chose one variant on each level
- Feature Tree as input for the configuration of the model weavings



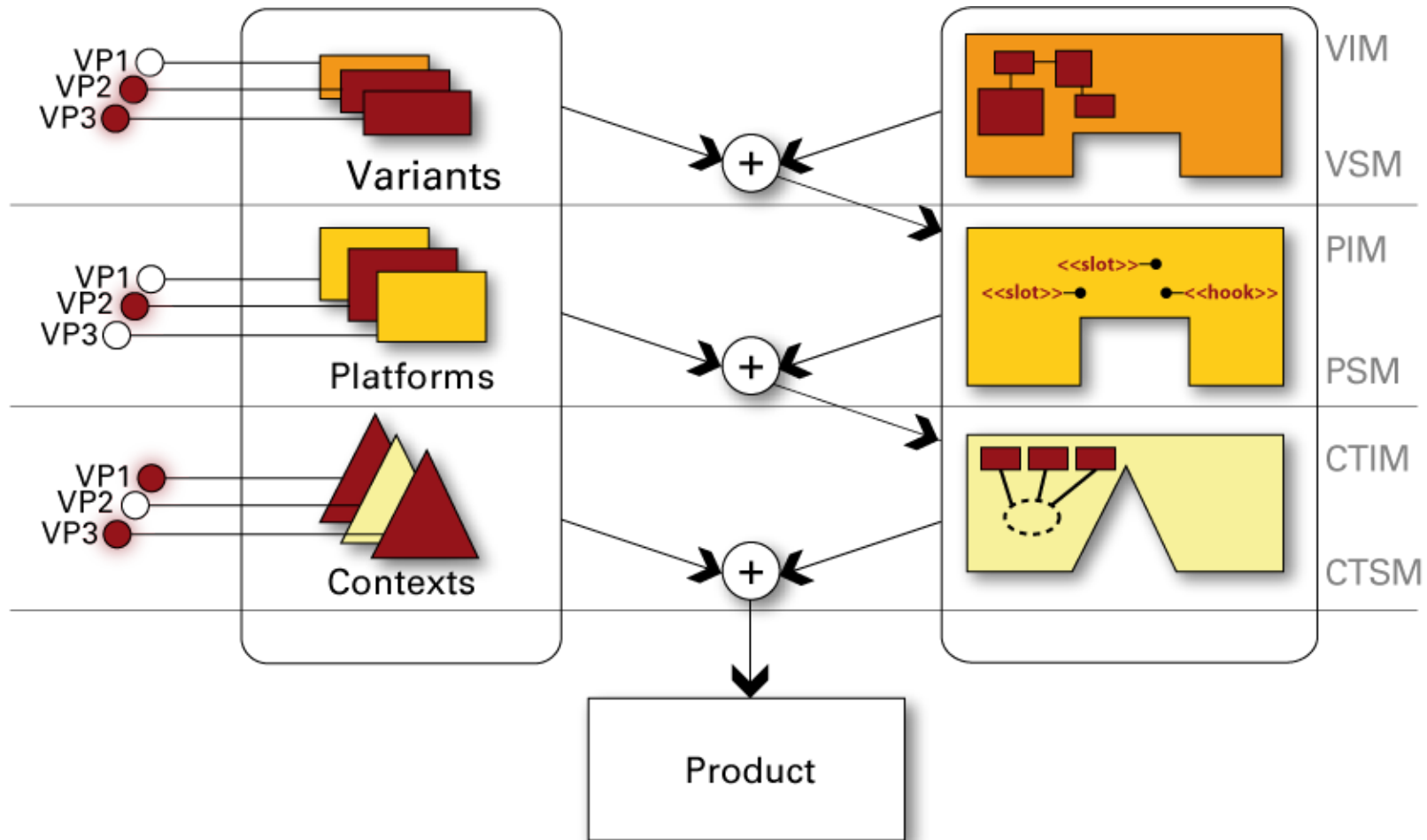
- **Goal: a staged MDSD-framework for PLE where each stage produces the software artefacts used for the next stage**



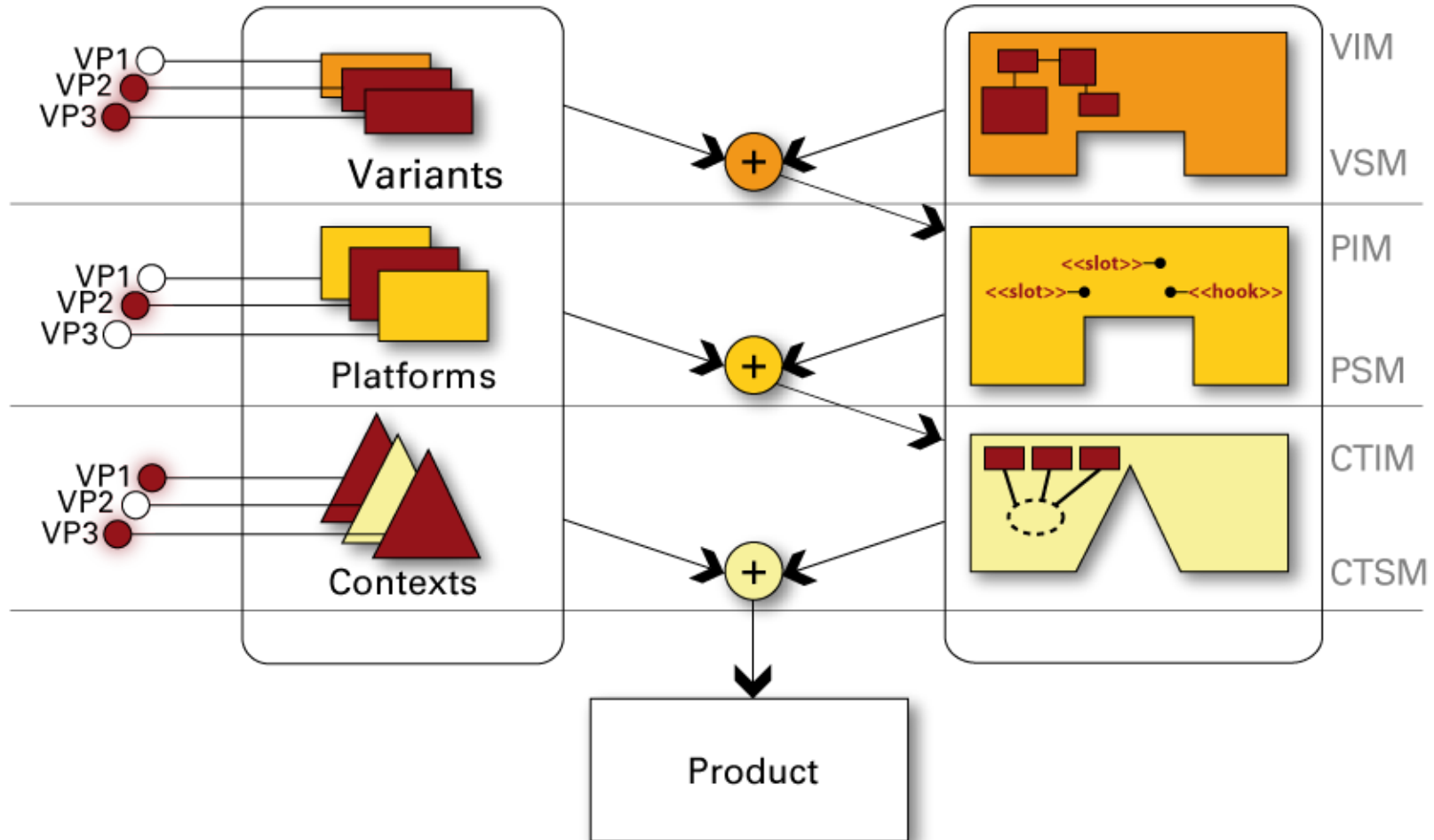
- **Characteristic feature 1:**
- **Variability on each stage**



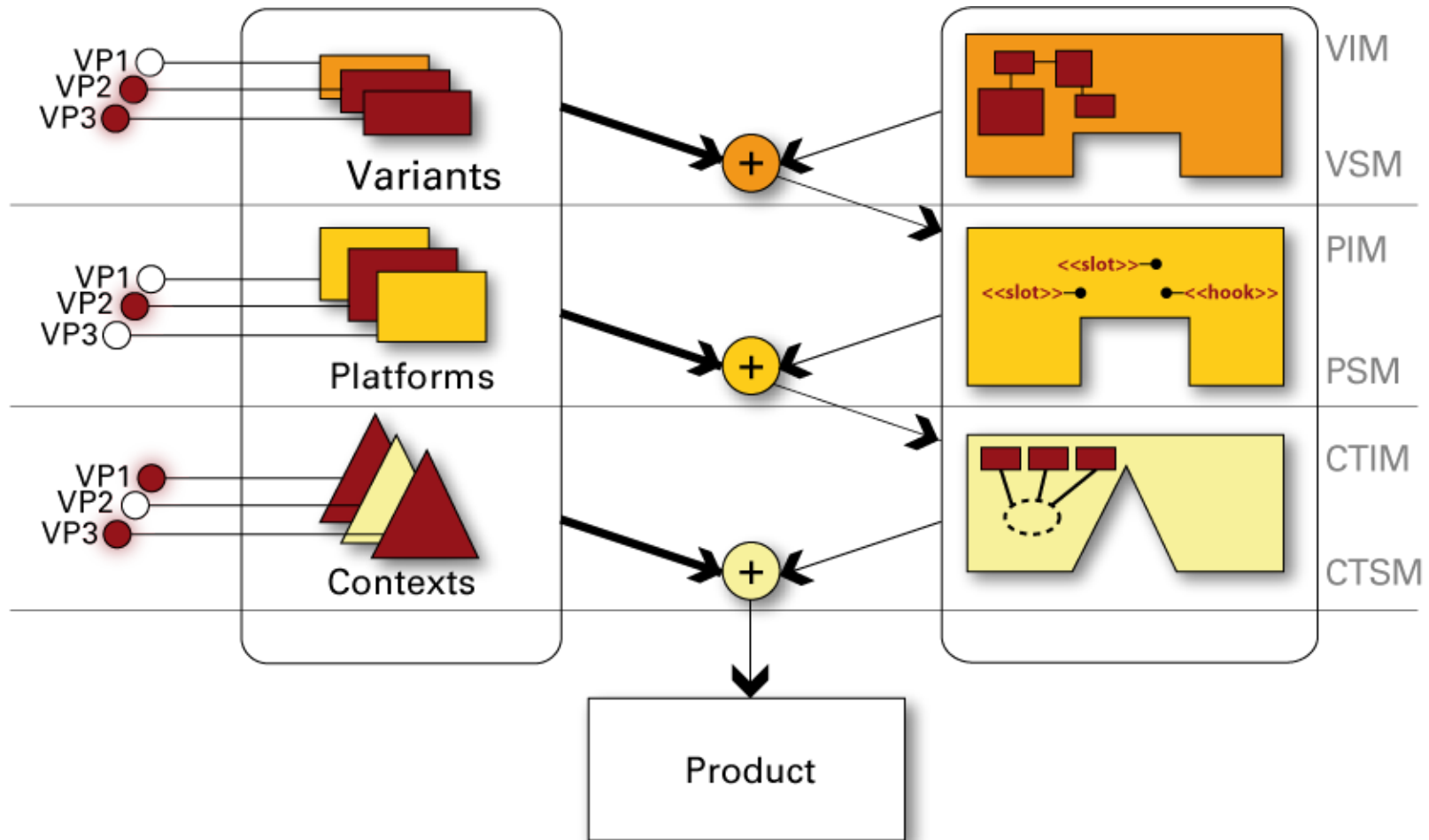
- **Characteristic feature 2:**
- **Different modelling languages, component systems and composition languages per stage**



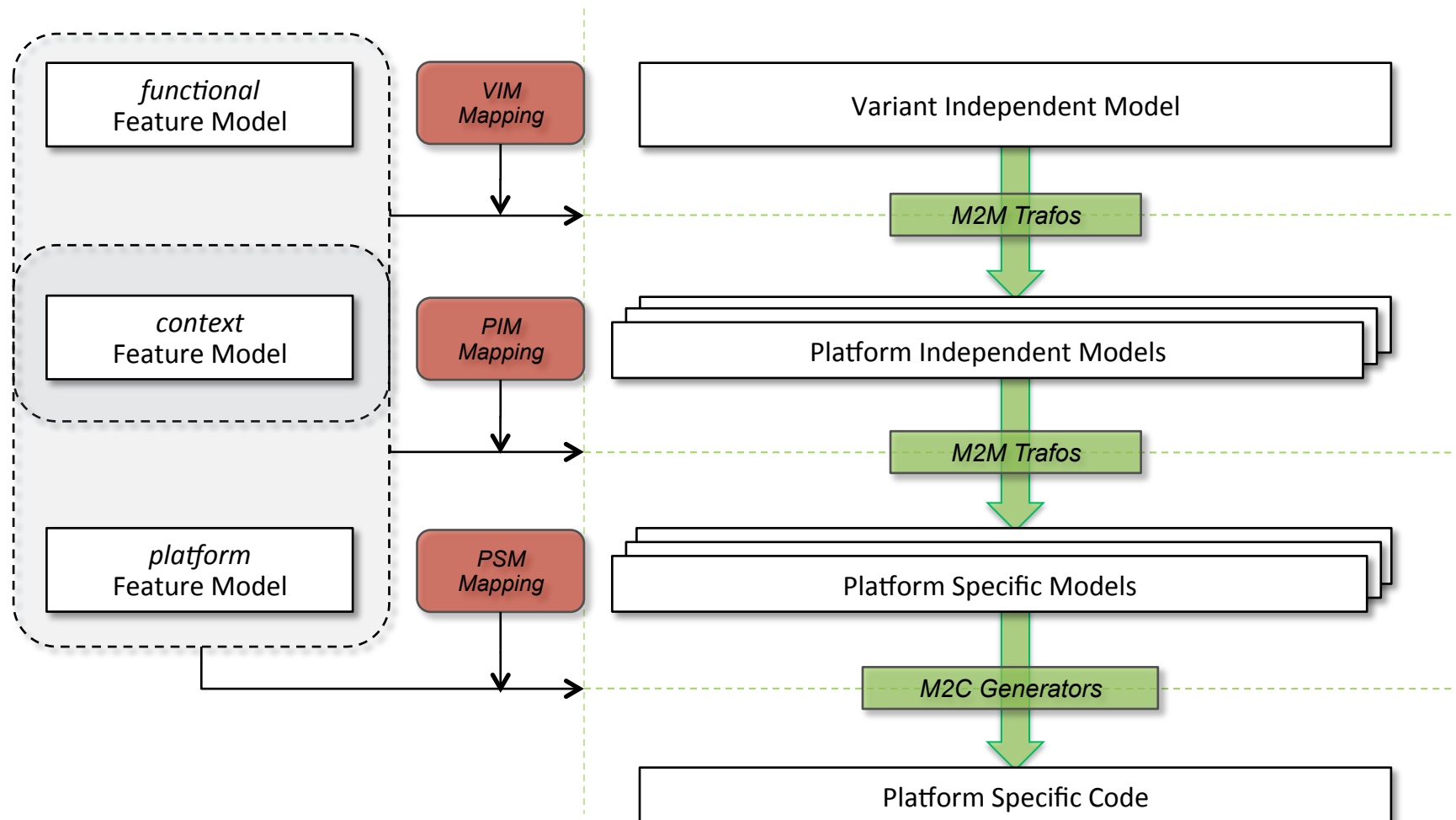
- **Characteristic feature 3:**
- **Different composition mechanisms per stage**



- **Characteristic feature 4:**
- **Composition mechanisms are driven by variant selection**

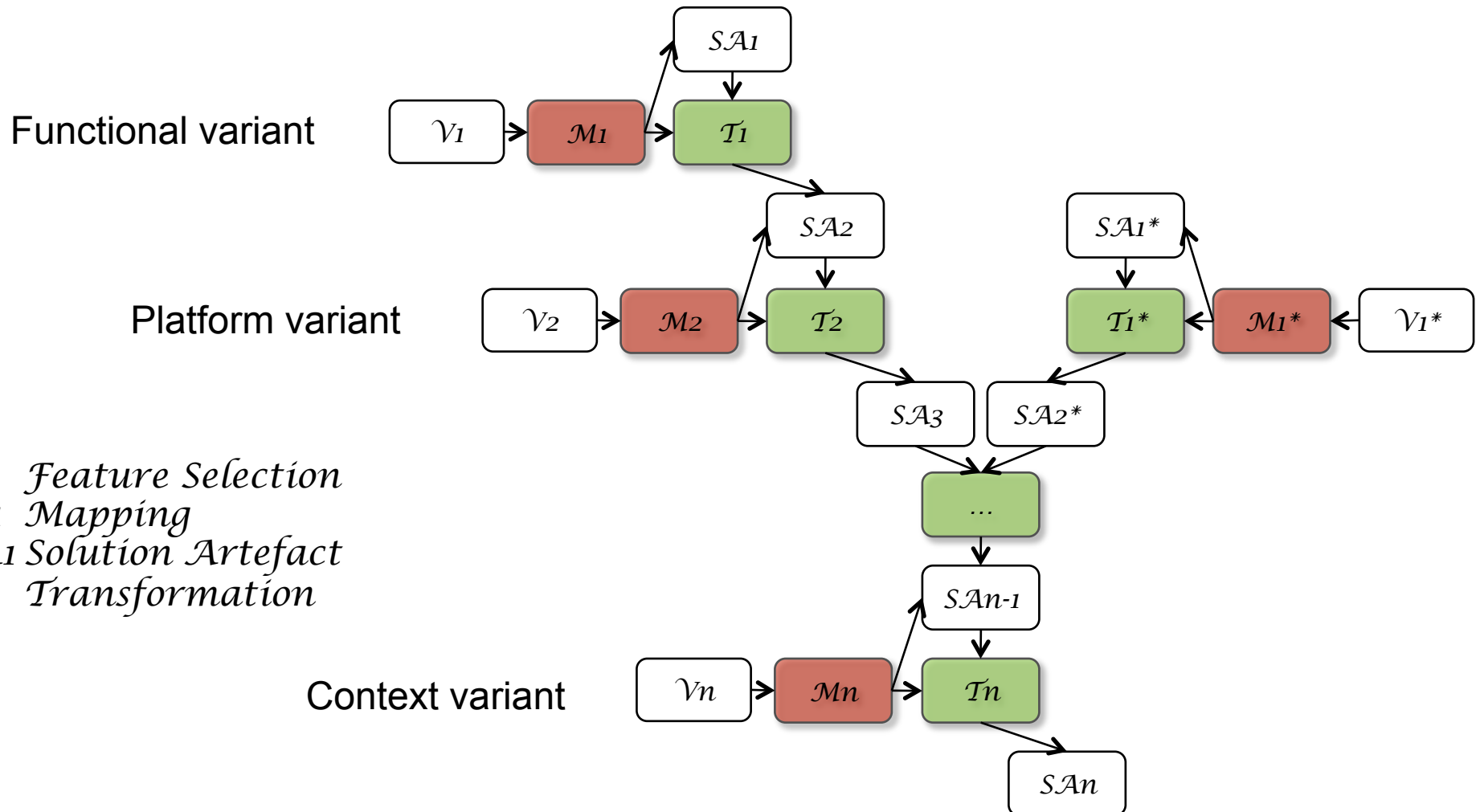


➤ **How do we compose transformations? Between different stages?**



➤ **TraCo encapsulates transformations into composable components**

- Arranges them with *composition programs* of parallel and sequential transformation steps (multi-threaded transformation)



1. Transformations are represented as composable components

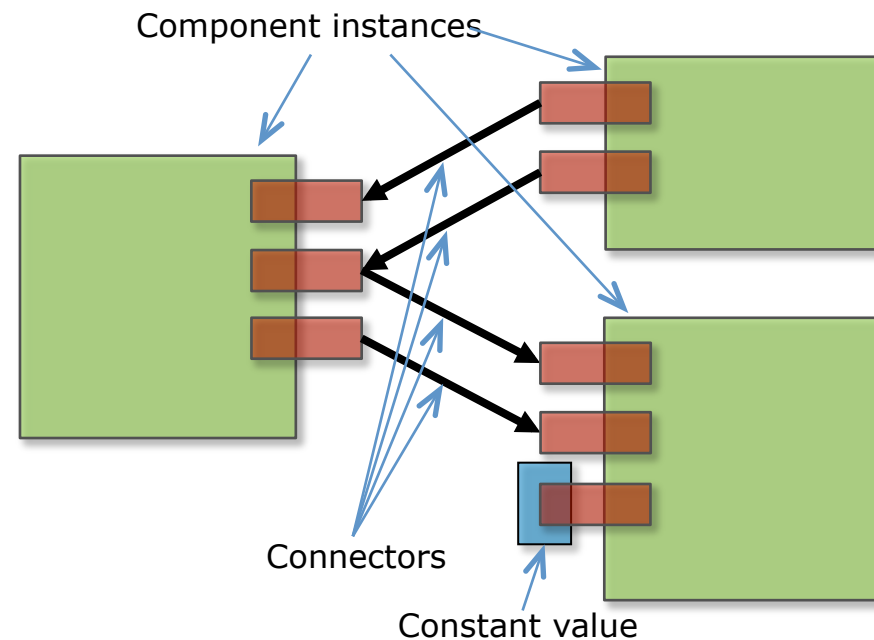
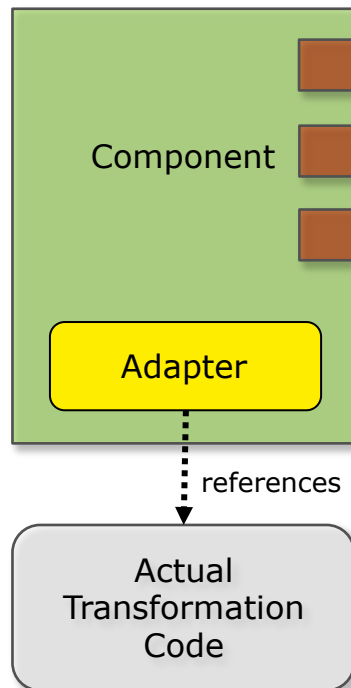
2. Definition and Composition of Transformation Steps

- A *Composition System* is needed (course CBSE): Allows for reuse of arbitrary existing transformation techniques

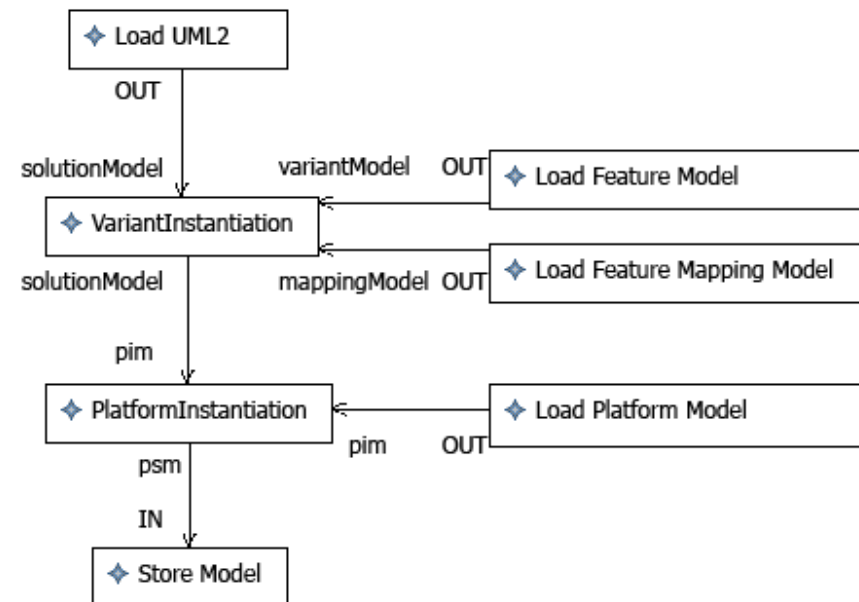
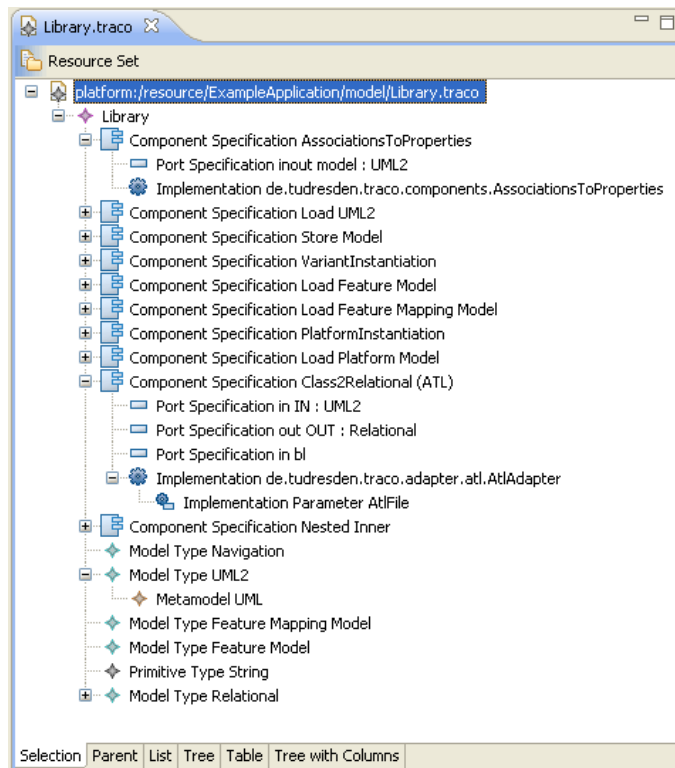
3. Validation of each transformation and composition step

- Type-checking
- Invariant- and constraint-checking
- Correctness of port and parameter binding
- Static and dynamic analysis

4. Execution of composition program



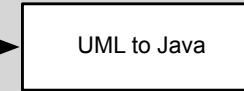
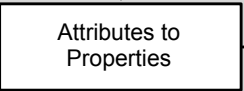
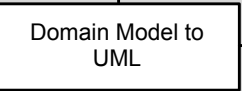
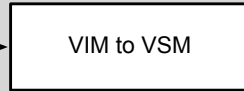
➤ Implemented in our tool TraCo



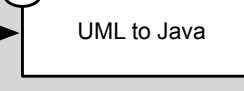
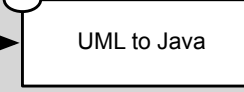
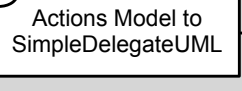
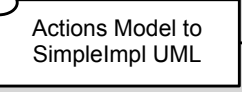
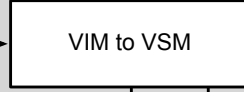
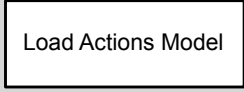
„Anything you can do, I do meta“ (Charles Simonyi)

- **The composition program shown in the last slide can be subject to transformation and composition**
- **If we build a product line with TraCo, platform variability can be realised by different transformation steps**
- **A TraCo composition program can be used with FeatureMapper**
 - Multi-Staged transformation steps
 - Even of composition programs
- **More about *metacomposition* in CBSE course**

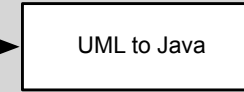
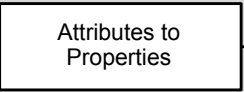
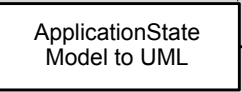
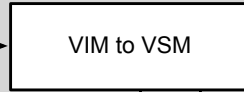
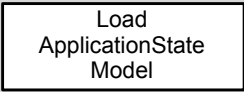
Domain



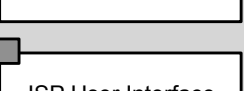
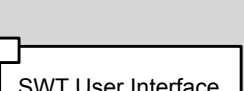
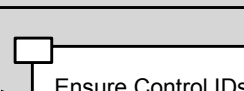
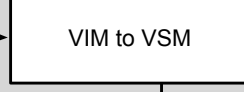
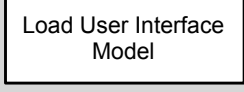
Actions



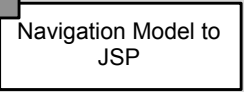
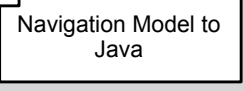
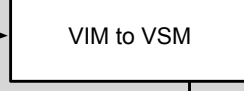
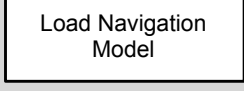
Application State



User Interface



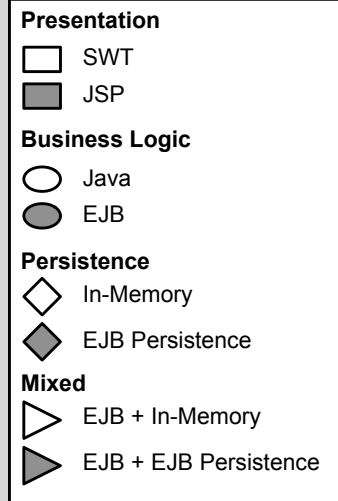
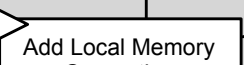
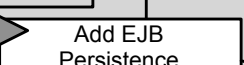
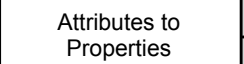
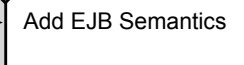
Navigation



Loading

Functional Variability

Platform Variability

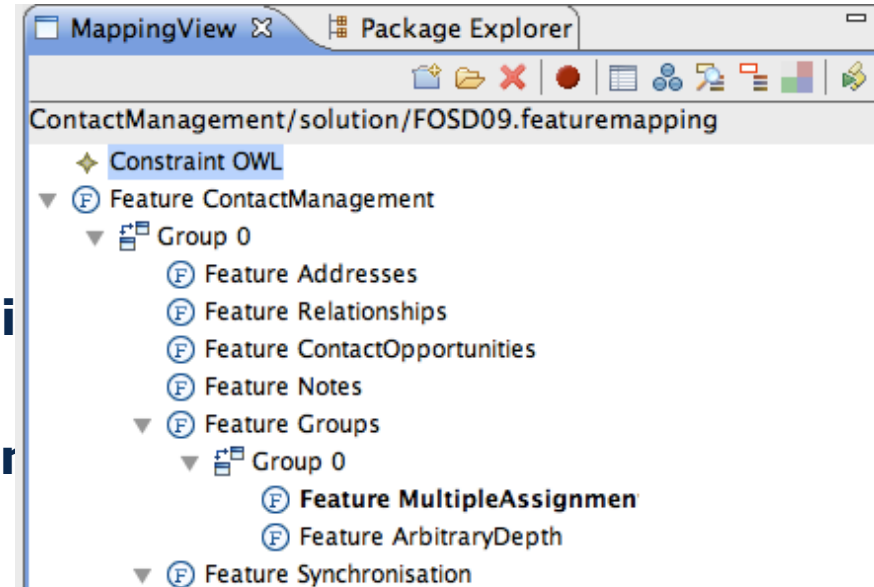


➤ **Motivation: Make sure that well-formedness of all participating models is ensured**

- Feature Model
- Mapping Model
- Solution Models

➤ **Well-formedness rules are described**

➤ **Constraints are enforced during runtime**



Feature	Element	Re:
▼ Feature Flood		
⚠ Feature Flood		
Feature Flood	<Property> handicap : HandicapKind [1..*]	
Feature Flood	<Association> A_<rescueMission>_<rope>	
Feature Flood	<Enumeration Literal> MENTAL	
Feature Flood	<Enumeration Literal> SURD	
Feature Flood	<Class> HandicappedVictim	

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

Property	Value
Constrained Features	Feature MultipleAssignment, Feature Highrise
Expression	conflicts
Language	OWL

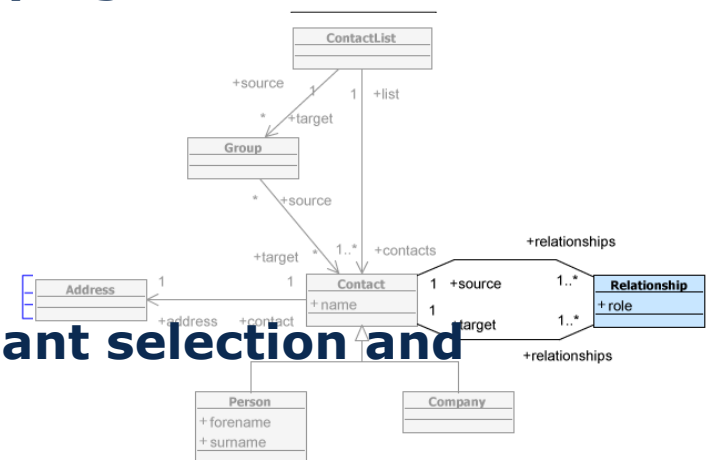
- **Simple Contact Management Application Software Product Line**
 - FeatureMapper used to map features to UML2 model elements
 - Both static and dynamic modelling

- **Simple Time Sheet Application Software Product Line**
 - FeatureMapper used to tailor ISC composition programs
 - ISC used as a universal variability mechanism in SPLE
 - Meta Transformation

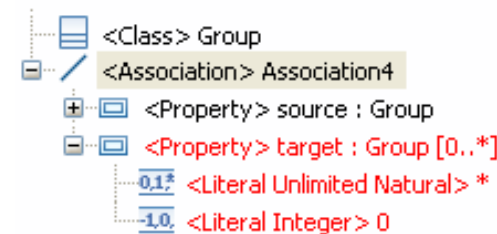
- **SalesScenario Software Product Line**
 - FeatureMapper used to tailor models expressed in Ecore-based DSLs
 - was developed in project **feasiPLe** (<http://www.feasiple.de>)

- **TAOSD AOM Crisis Management System**

- **Configuration of product lines with mapping of feature models to solution spaces**
- **Mapping of Features to models in Ecore-based languages using FeatureMapper**
- **Visualisations of those mappings using MappingViews**
 - Realisation View
 - Variant View
 - Context View
 - Property-Changes View
- **Derivation of solution models based on variant selection and mapping**
- **Multi-Staged derivation using TraCo**
- **Ensuring well-formedness of SPLs**



<http://featuremapper.org>





The End