TECHNISCHE UNIVERSITÄT DRESDEN

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30 Transformational Design with Essential Aspect Decomposition: Model-Driven Architecture (MDA)

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1. Model-Driven Architecture
2. Model Mappings
3. Model Merging and Weaving
4. MDSD with domain-specific tagging

References

- Obligatory:
  - www.omg.org/mda Model driven architecture.
  - MDA Guide. OMG (ed.). Reference document for MDA applications
- Optional:
  - J. Frankel. Model-driven architecture. Wiley. Excellent book on the concepts of MDA, including the MOF, model mappings.
  - Manfred Nagl, editor. Building tightly integrated software development environments: the IPSEN approach, volume 1170 of Lecture Notes in Computer Science. Springer-Verlag Inc., New York, NY, USA, 1996.
  - CIP Language Group. The Munich Project CIP, volume 1 of Lecture Notes in Computer Science. Springer-Verlag, 1984.
  - Bauer et al. The Munich project CIP. Volume 1: The wide spectrum language CIP-L, volume 183 of Lecture Notes in Computer Science. Springer-Verlag, Berlin, Germany, 1985.
  - F. L. Bauer, et al. The Munich Project CIP. Volume II: The Transformation System CIP-S. Springer-Verlag, LNCS 292, 1987.

Problem – Reuse in Product Lines (Product Families)

- Many products must be produced in variants for different platforms (portability problem):
  - Machines ranging from PDA over PC to host
  - Component models from .NET over CORBA to EJB
  - Technical spaces such as Java vs .NET vs. Python
- How to develop a product line with products for all these platforms?
- How to reuse common parts of models?

Problem: The Representation Schizophrenia

- Problem: **Design Aging**, one of the biggest problems in software maintenance
  - If an artifact has several representations, such as design, implementation, documentation, and code: always the code is modified, and the other become inconsistent
  - Usually, a design specification **ages** faster than implementation, because the programmers are tempted to change the implementation quickly, due to deadlines and customer requests
  - They "forget" to update the design
- Solution:
  - XP: Single-source principle
    - don't represent in other ways that code
    - "clean code that works"
  - MDA: Generate the code from models, enable a round-trip to solve the problem

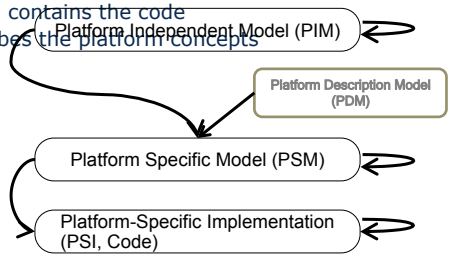
30.1 MODEL-DRIVEN ARCHITECTURE (MDA)

Remember: Refinement-based Modelling

- Refinement-based design and transformative design (with GRS) are an old idea.
  - Broadband languages, such as CIP or IPSEN did this in the 70s already
- Refinement starts with some simple model
- Apply refinement steps:
  - Elaborate (more details – change semantics)
    - Add platform-specific details
  - Semantics-preserving operations
    - Restructure (more structure, but keep requirements and delivery, i.e., semantics)
      - Split (decompose, introduce hierarchies, layers, reducibility)
      - Coalesce (rearrange)
    - TransformDomains (change representation, but keep semantics)

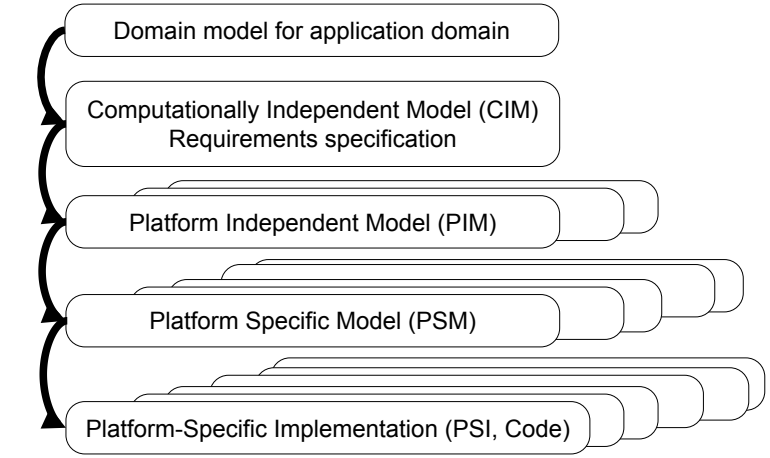
Model-Driven Architecture (MDA)

- MDA http://www.OMG.org/mda is a refinement- and transformation-based development method for product families (product lines). It uses Essence-Administration-Infrastructure (EAI) aspect-decomposition
- Split the all design models into
  - **Platform-independent model**: The PIM focuses on *essence,* the logical architecture and the *administration* (consistency)
  - **Platform-specific extension:** containts the infrastructure code for a platform
  - **Platform-specific model**: The PSM adds platform-specific details and timing constraints (infrastructure)
  - **Platform-specific implementation** contains the code
  - **Platform description model** describes the platform concepts
- Advantages
  - Separation of concerns: Platform-independent vs platform-dependent issues
  - Portability
  - Automation: derive implementation models from design models (semi-) automatically



MDA Describes Product Lines

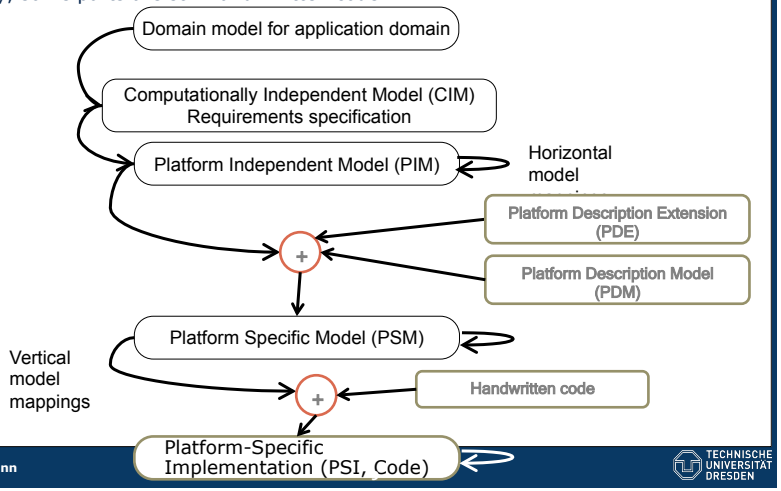
- The upper levels of the platform stack form *transformational frameworks*



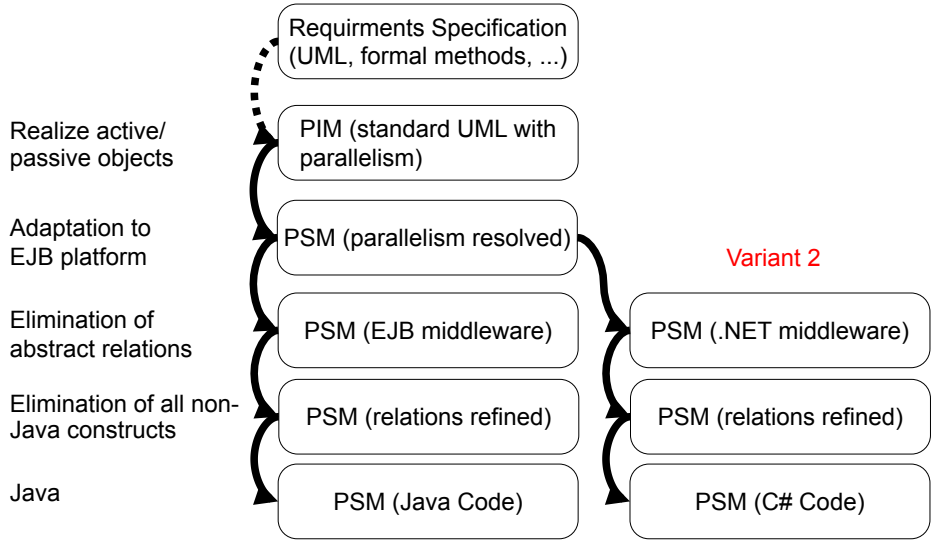
The products of the product line

Model Mappings and Model Weavings

- **Model mappings** connect models horizontally (on the same level) or vertically (crossing levels).
  - From a model mapping, a simple transformation can be infered
- **Model weavings** weave two input models to an output model
  - Usually, some parts are still hand-written code

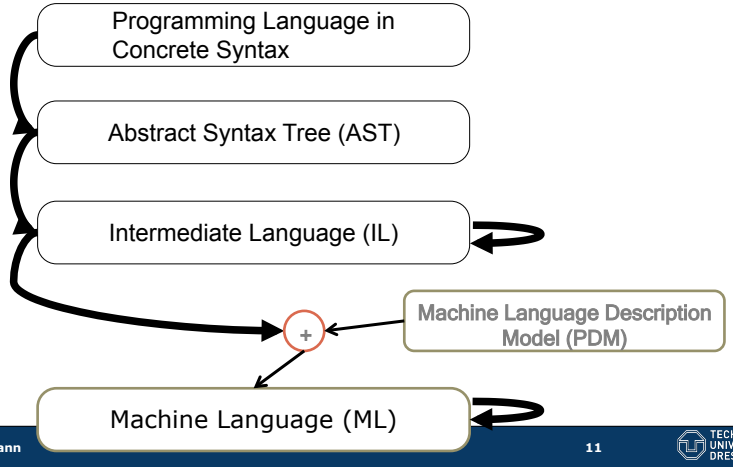


Example: MDA Performed by Hand



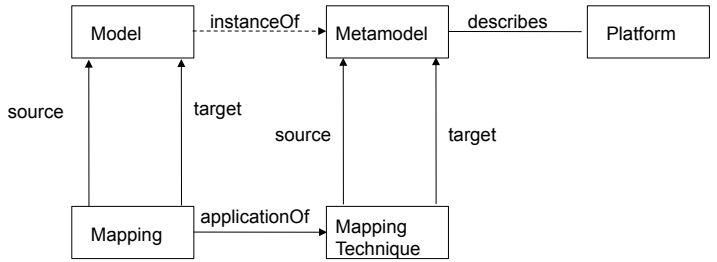
Example: Compilers Are Simple, but Automatic MDA Tools

- Metamodels are language descriptions
- Models are intermediate representations
- Platform specific (abstract syntax tree)
- Platform dependent (binary code)



What are Model Mappings?

- Remember Model:
  - "A model is a representation of a part of a function of a system, its structure, or behavior"
- Model mappings are transformations from an upper to a lower model
  - The mappings are automatic or semi-automatic: step-wise refinement of the model by transformation



What Are Platforms?

- **Platforms** are *concerns (aspects),* describing the environment on which a system runs
  - Platforms slice a system into platform-independent (aspect-independent) and platform-dependent parts (aspect-related)
- Platforms define *variability levels* of a system, with variants that produce a variant of the specification
- Possible platforms:
  - Abstract machines
    - Libraries, such as JDK, .NET
  - Implementation languages
    - Java, Eiffel, C#
  - Component models
    - CORBA, Enterprise Java Beans (EJB), .NET-COM+, etc.
  - Ontology of a domain (e.g., medicine)
  - Constraints of the system
    - Time
    - Memory
    - Energy

Benefit of MDA

- MDA sees the system development process as a sequence of transformation steps from requirements to code
  - MDA is an architectural style for transformational frameworks
- Separation of platform information (separation of concerns) reduces dependencies on platform
  - Middleware (.NET, Corba, DCOM, Beans)
  - Platform specific details (resource constraints, memory handling)
  - Platforms in embedded and realtime systems
  - Domain
- Reuse of PIM for many platforms
  - The PIM is a *generic framework* for a product family
  - A *transformational* framework, not an object-oriented framework
- MDA provides generic frameworks for designs and models
  - Parameterization with model mappings

30.2 MODEL MAPPINGS

Different Kinds of Mappings

- The MDA Guide suggests several *MDA patterns,* i.e., mapping patterns between PIM and PSM:
- **Instantiation**: binding the formal parameters of a template (instantiation of templates, framework instantiation) [see Design Patterns and Frameworks]
- **Isomorphic mapping:** expand a tag in a PIM to n elements of a PSM (1:1 mapping)
  - Important to map a element of a PIM to several elements of a PSM
  - The extension information of a PSM can be expressed as one stereotype in a PIM (marked PIM)
- **Homomorphic mapping:** expand a tag in a PIM to n elements of a PSM (1:n mapping)
  - Important to map a element of a PIM to several elements of a PSM
  - The extension information of a PSM can be expressed as one stereotype in a PIM (marked PIM)
- **Concept transformation mapping:** Change a concept of a PIM into another concept in a PSM
  - For instance, a PIM method to a PSM Command object
- **Aspect mappings:** aspects are woven into the core PIM
  - For instance, with a GRS

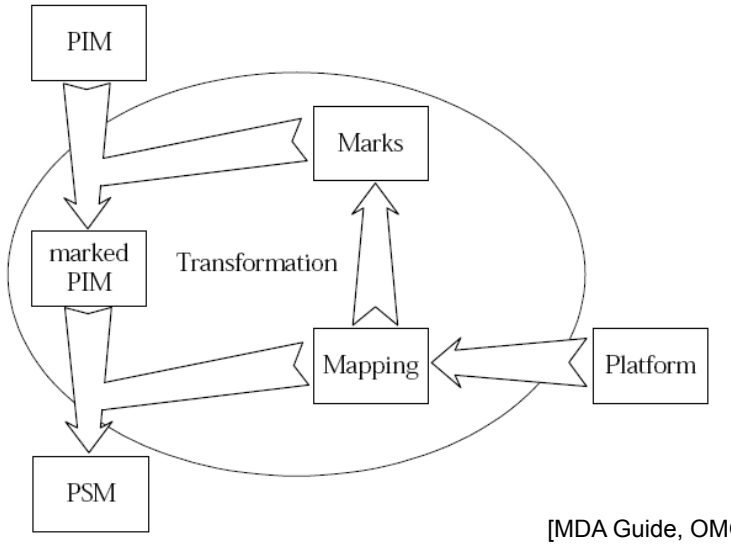
Morphic Mappings on Marked PIMs

- **1:1 or 1:n mappings (isomorphic mappings, marked PIMs)** are important
  - They introduce an exclusively-owns relationship from 1 element of the PIM to n elements in the PSM
    - Supported by many UML and MDA tools
  - They partition the PIM and the PSM: The border of a partition is demarcated by the PIM tag
  - This serve for clear responsibilities, on which level a partition is edited

What Are UML Profiles?

- A **(UML) profile** is a metamodel describing a platforms or a domain
  - Technically, a profile is a set of new stereotypes and tagged values
  - Stereotypes correspond to metaclasses
  - A profile has a metamodel that extends the UML metamodel
  - Stereotypes are metaclasses in this metamodel that are derived from standard UML metaclasses
- Examples platform profiles:
  - EDOC Enterprise Distributed Objects Computing
  - Middleware: Corba, .NET, EJB
  - Embedded and realtime systems: time, performance, schedulability
- A *profile* can describe a domain model
  - or ontology, if domain is large enough
  - A *profile* can be the core of a domain specific language (DSL)
  - With own vocabulary, every entry in metamodel is a term
- Examples:
  - Banking, insurances, cars, airplanes, …

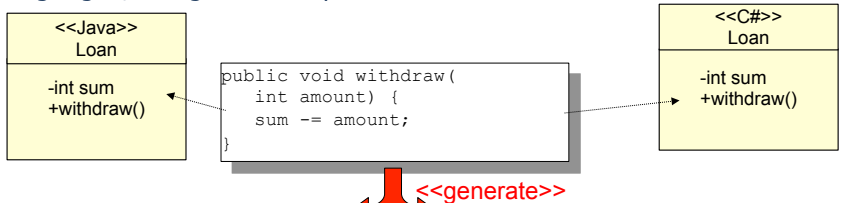
Marking of a PIM with Stereotypes



[MDA Guide, OMG]

Example of a Marked PIM

- Different class implementations in a PSM, refining to different languages, using different patterns

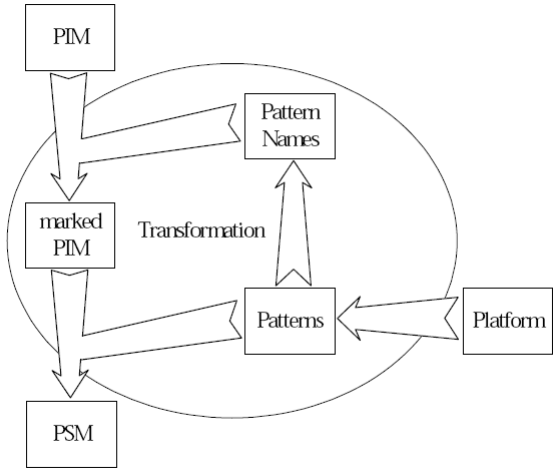



```
// Java implementation as a decorator
class Loan extends Account {
  // decorator backlink
  Account upper;

  private int sum;
  public void withdraw(
   int amount) {
   sum -= amount;
}
```

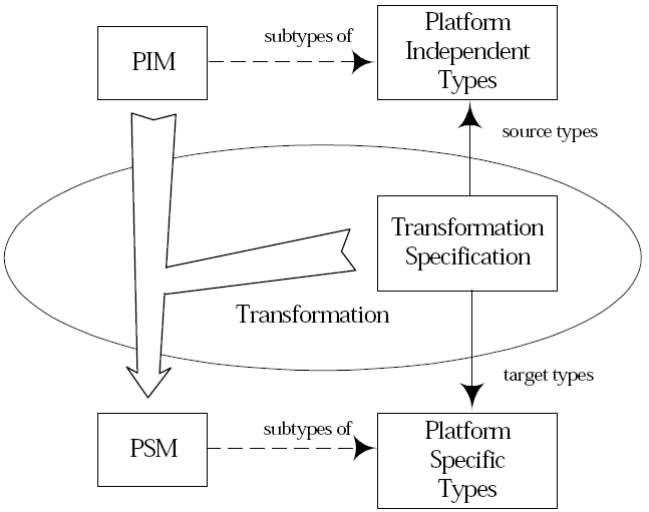
```
// C# implementation: a partial class
class Loan partial Account {
  private int sum;
  public void withdraw(
   int amount) {
   sum -= amount;
}
```

Pattern Transformation



[MDA Guide, OMG]

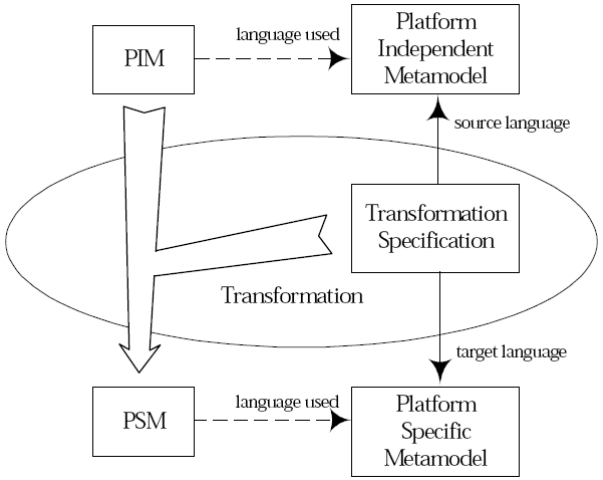
Model Transformation from PIM to PSM



[MDA Guide, OMG]

Meta Model Transformation

- If the metamodel is changed in a vertical transformation, we speak of a **exogeneous transformation**

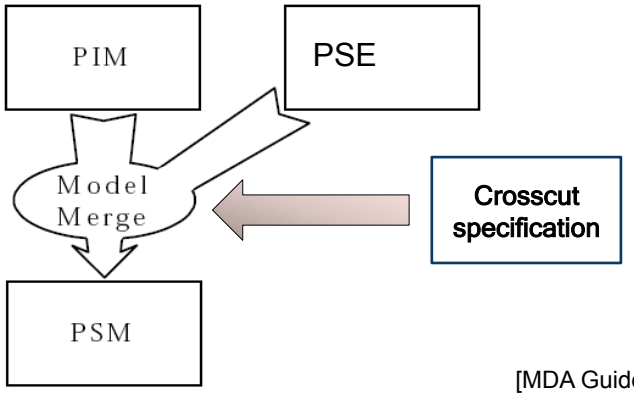


[MDA Guide, OMG]

30.3 MODEL WEAVING

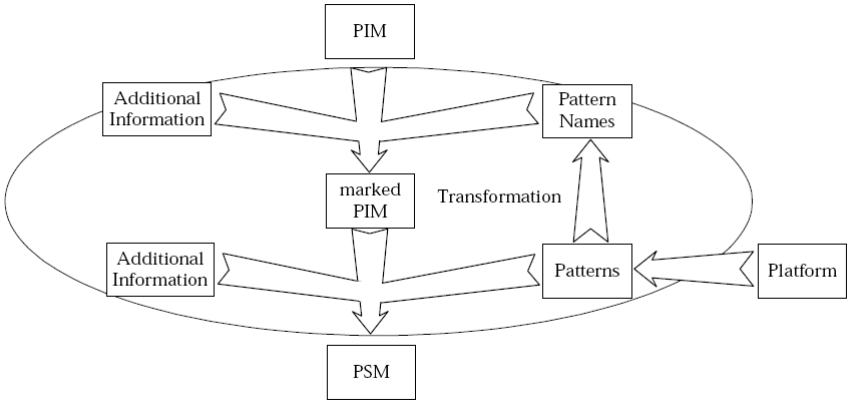
Model Merging and Weaving

- **Model merging** enters an extension into a core model, i.e., a PSE into a PIM
- **Model weaving** uses a crosscut specification how to do this



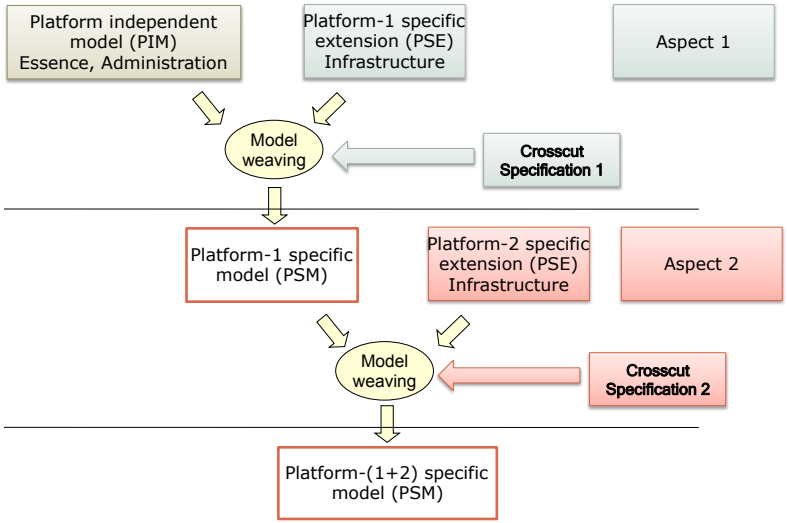
[MDA Guide, OMG]

Additional Information



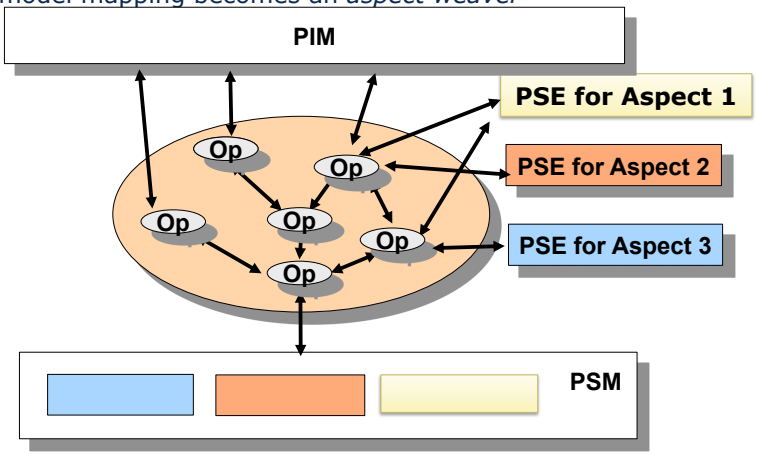
[MDA Guide, OMG]

Adding Platform-Specific Extensions to Platform-Independent Models



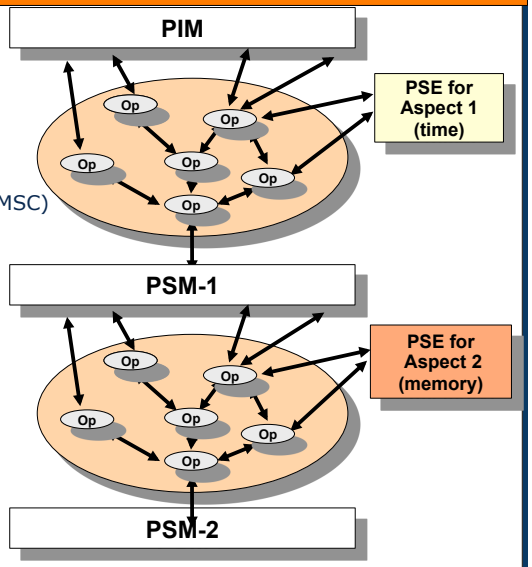
When Can We Semi-Automatically Enrich A PIM to a PSM?

- Describe *platform specific extension (PSE)* as *aspects* or *views*
- The PIM is the *core, t*he PSM the *weaved system*
- The model mapping becomes an *aspect weaver*

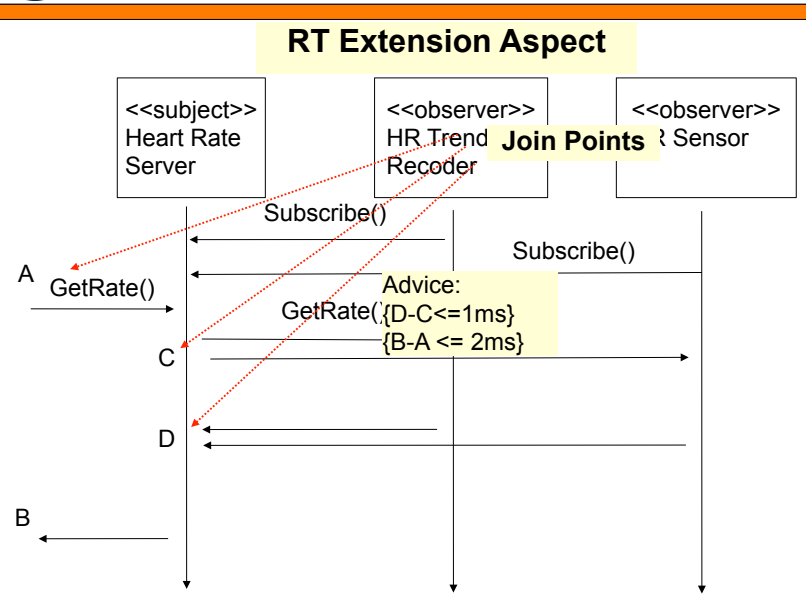


MDA With Several Layers for Resource-Constrained Systems

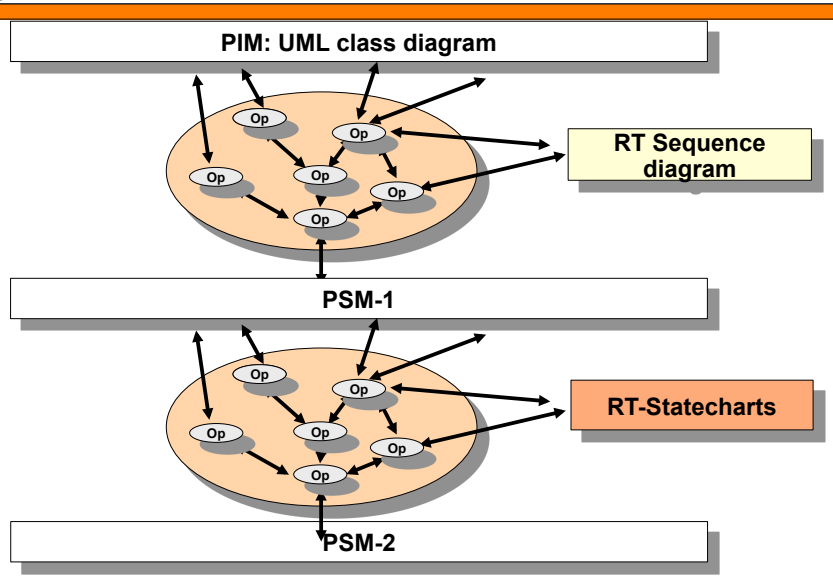
- HIDOORS EU Projekt (High Integrity Distributed Object-Oriented Real-Time Systems), http://www.hidoors.org
- MDA for RT-UML
  - Realtime sequence diagrams (MSC)
  - UML realtime statecharts
- Transformation into timed automata of Uppaal model checker



RT Sequence Diagram (UML)

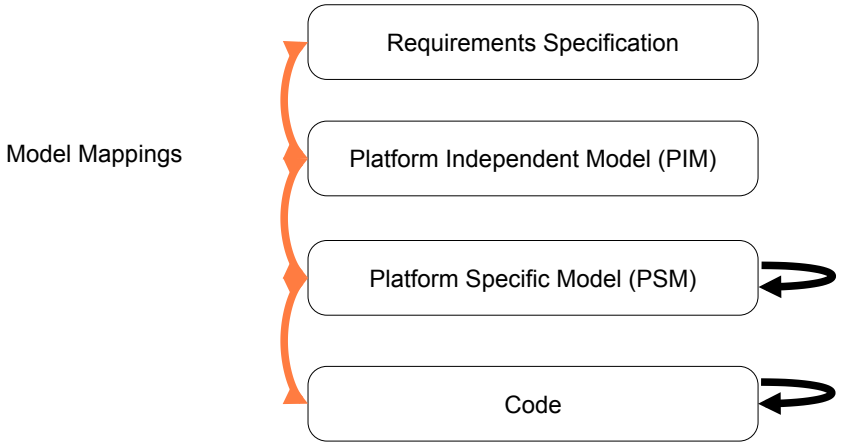


RT-SD und RT-Statecharts are Platform Specific Aspects

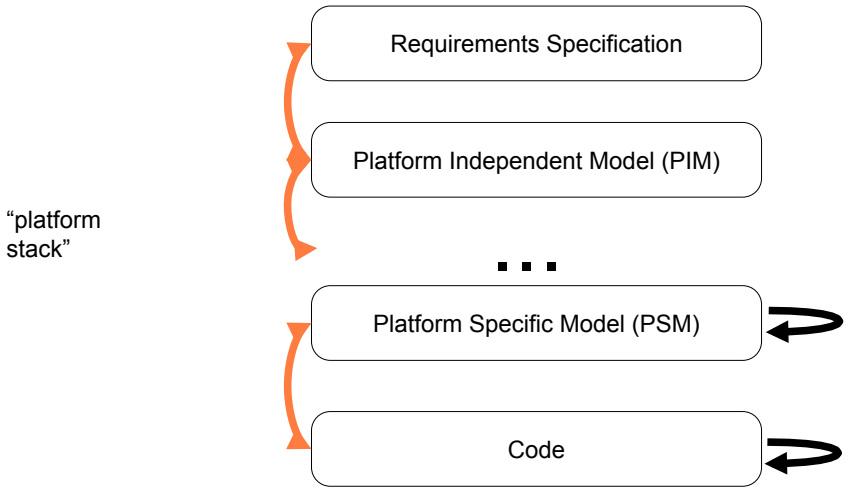


Problem: Full MDA Needs Roundtrip

- Otherwise, the models age (design aging)
- This is still an unsolved problem



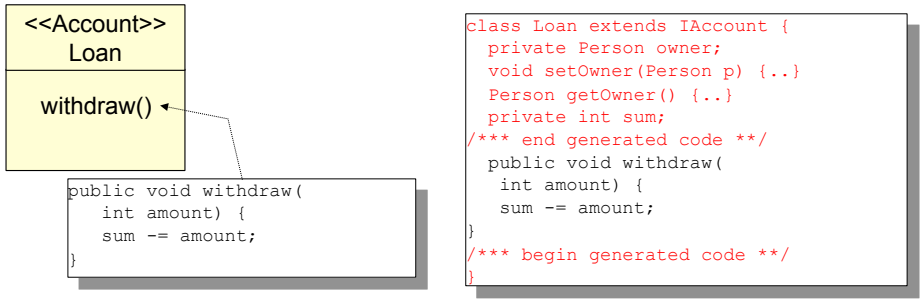
Problem 2: MDA Needs More Levels (Multi-Stage MDA)



30.4 DOMAIN-SPECIFIC MARKING

Model-Driven Software Development (MDSD) with Domain Specific Marking

- **Model-based software development (MDSD, MDD)** tags UML diagrams with *domain profiles*
  - From the profile stereotypes and tags, domain-specific code is generated
  - set/get, standard functions, standard attributes
  - compliance functions for component models
- <!--In contrast, MDA profile tags are platform-specific-->



The End

- MDA(R) is a trademark of OMG