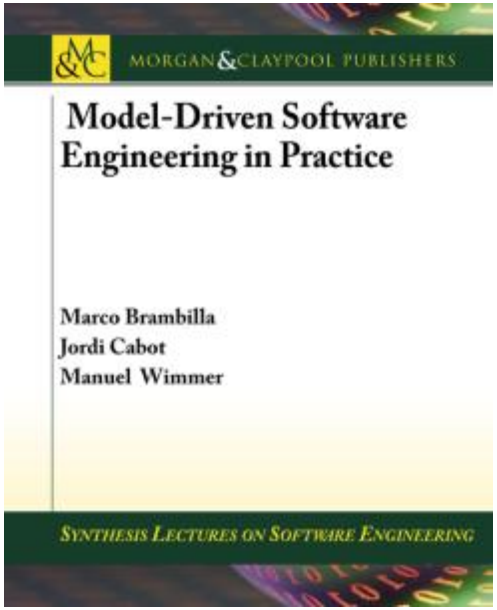
Chapter #2

MDSE PRINCIPLES

Teaching material for the book
Model-Driven Software Engineering in Practice
by Marco Brambilla, Jordi Cabot, Manuel Wimmer.
Morgan & Claypool, USA, 2012.


MORGAN & CLAYPOOL PUBLISHERS
Model-Driven Software Engineering in Practice
Marco Brambilla
Jordi Cabot
Manuel Wimmer
SYNTHESIS LECTURES ON SOFTWARE ENGINEERING

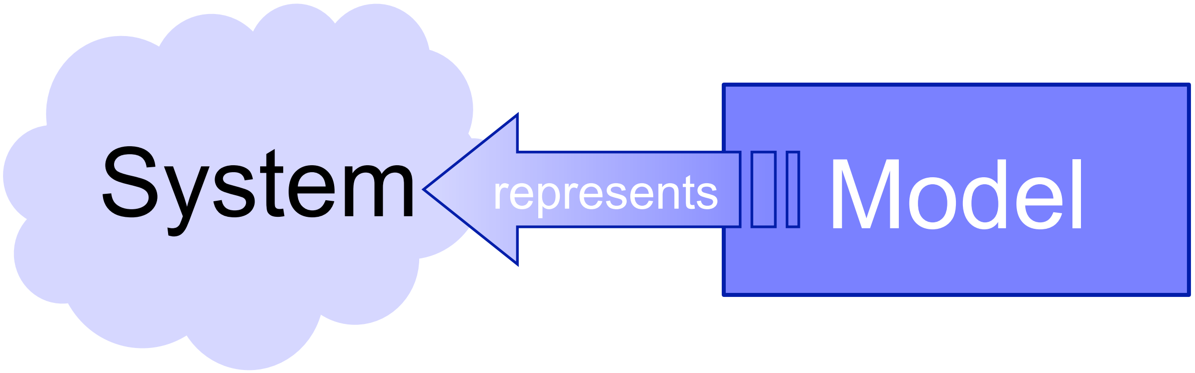
MDSE Principles

Contents

- Concepts
- Approaches
- Adoption

Models

What is a model?



System

represents

Model

Mapping Feature	A model is based on an original (=system)
Reduction Feature	A model only reflects a (relevant) selection of the original‘s properties
Pragmatic Feature	A model needs to be usable in place of an original with respect to some purpose

Purposes:

- descriptive purposes
- prescriptive purposes

MDSE aim at large

- MDSE considers models as first-class citizens in software engineering
- The way in which models are defined and managed is based on the actual needs that they will address.
- MDSE defines sound engineering approaches to the definition of
  - models
  - transformations
  - development process.

Concepts

Principles and objectives

- **Abstraction** from specific realization technologies
  - Requires modeling languages, which do not hold specific concepts of realization technologies (e.g., Java EJB)
  - Improved **portability** of software to new/changing technologies – model once, build everywhere
  - **Interoperability** between different technologies can be automated (so called Technology Bridges)

- **Automated code generation** from abstract models
  - e.g., generation of Java-APIs, XML Schemas, etc. from UML
  - Requires expressive und precise models
  - Increased **productivity** and **efficiency** (models stay up-to-date)

- **Separate development** of application and infrastructure
  - Separation of application-code and infrastructure-code (e.g., Application Framework) increases **reusability**
  - **Flexible** development cycles as well as **different development roles possible**

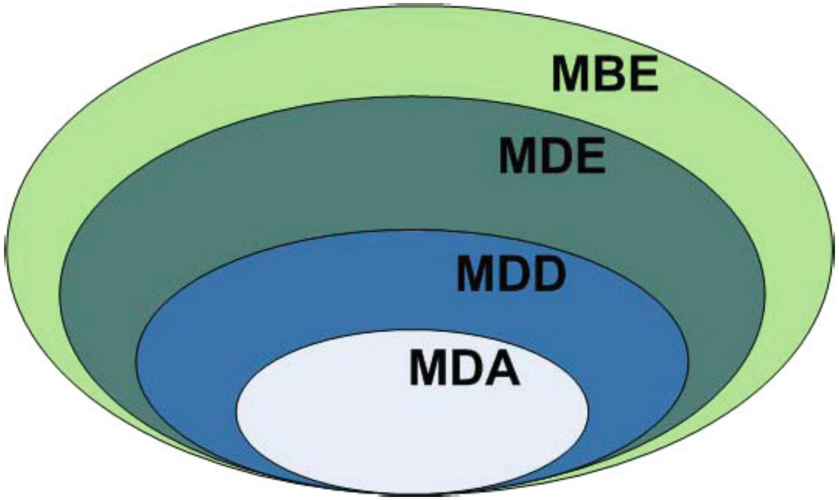
MDSE methodology ingredients

- **Concepts:** The components that build up the methodology
- **Notations:** The way in which concepts are represented
- **Process and rules:** The activities that lead to the production of the final product
- **Tools:** Applications that ease the execution of activities or their coordination

MDSE Equation

Models + Transformations = Software

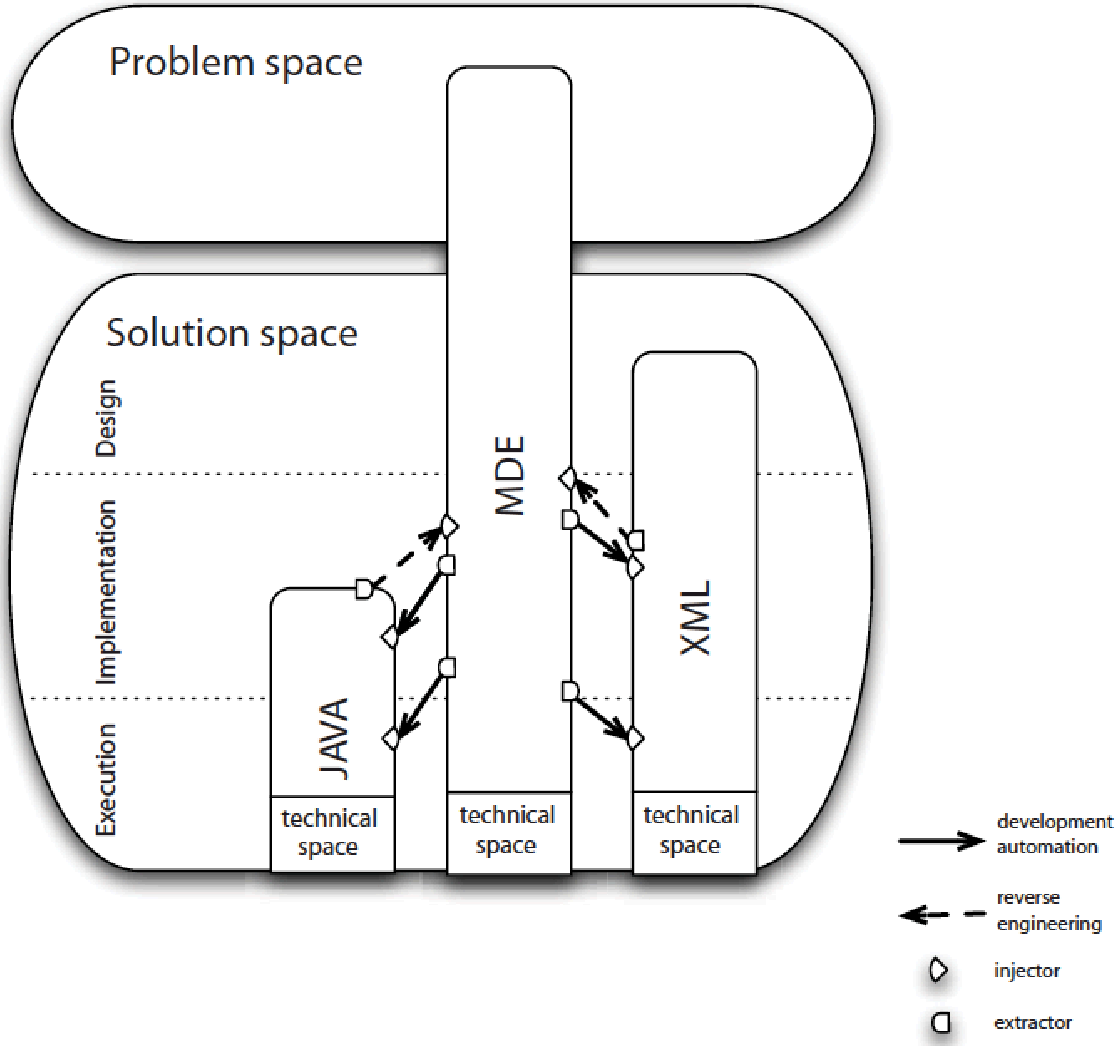
The MD* Jungle of Acronyms



- **Model-Driven Development (MDD)** is a development paradigm that uses models as the primary artifact of the development process.
- **Model-driven Architecture (MDA)** is the particular vision of MDD proposed by the Object Management Group (OMG)
- **Model-Driven Engineering (MDE)** is a superset of MDD because it goes beyond of the pure development
- **Model-Based Engineering** (or “model-based development”) (**MBE**) is a softer version of ME, where models do not “drive” the process.

Target of MDSE

- The **Problem Domain** is defined as the field or area of expertise that needs to be examined to solve a problem.
- The **Domain Model** is the conceptual model of the problem domain
- **Technical Spaces** represent specific working contexts for the specification, implementation, and deployment of applications.



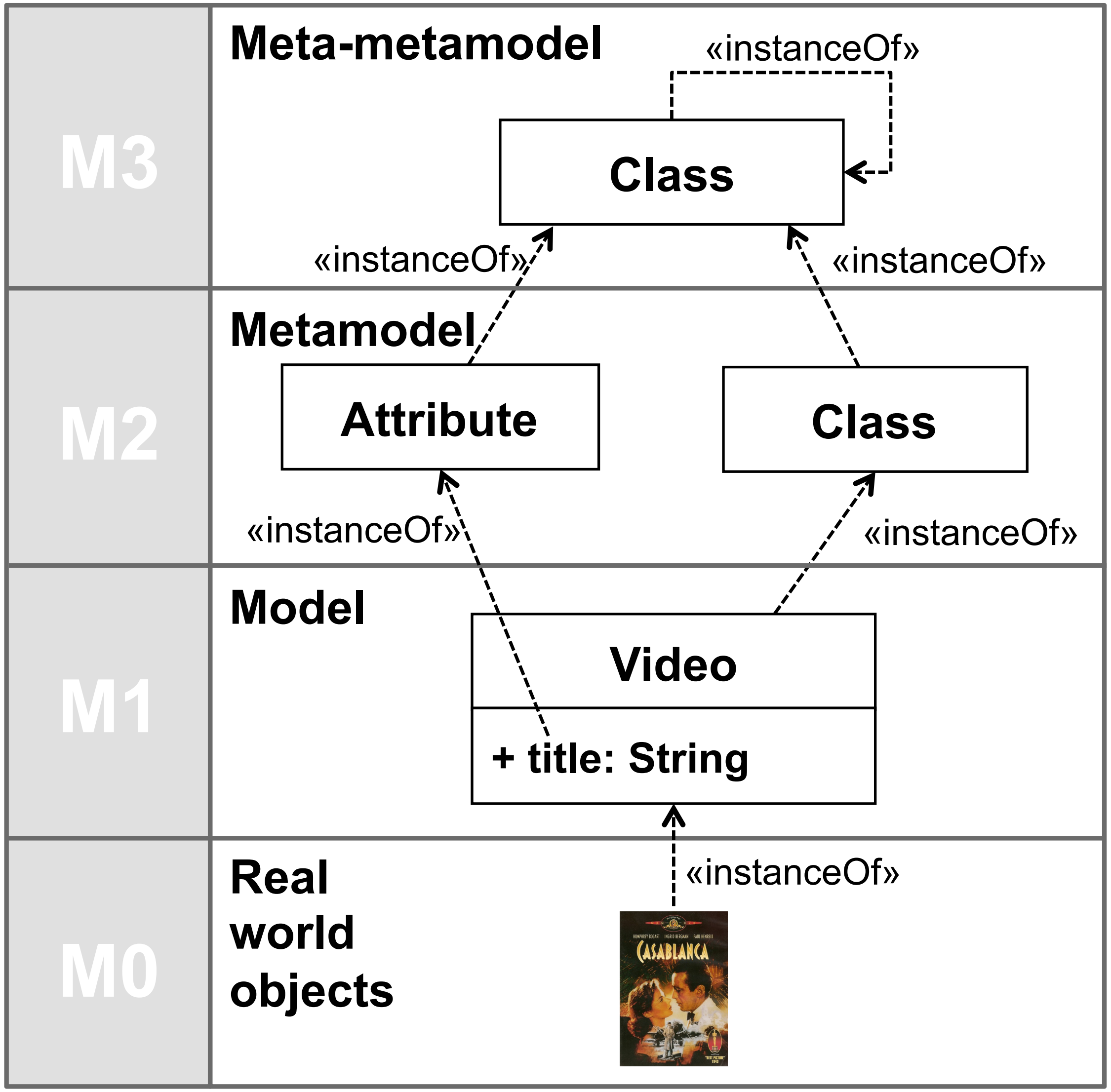
Modeling Languages

- **Domain-Specific Modeling Languages (DSMLs, DSLs):** languages that are designed specifically for a certain domain or context
- DSLs have been largely used in computer science.
- Examples: HTML, Logo, VHDL, Mathematica, SQL

- **General Purpose Modeling Languages** (GPMLs, GMLs, or GPLs): languages that can be applied to any sector or domain for (software) modeling purposes
- The typical examples are: UML, Petri-nets, or state machines

Metamodeling

- To represent the models themselves as "instances" of some more abstract models.
- **Metamodel** = yet another abstraction, highlighting properties of the model itself
- Metamodels can be used for:
  - defining new languages
  - defining new properties or features of existing information (metadata)

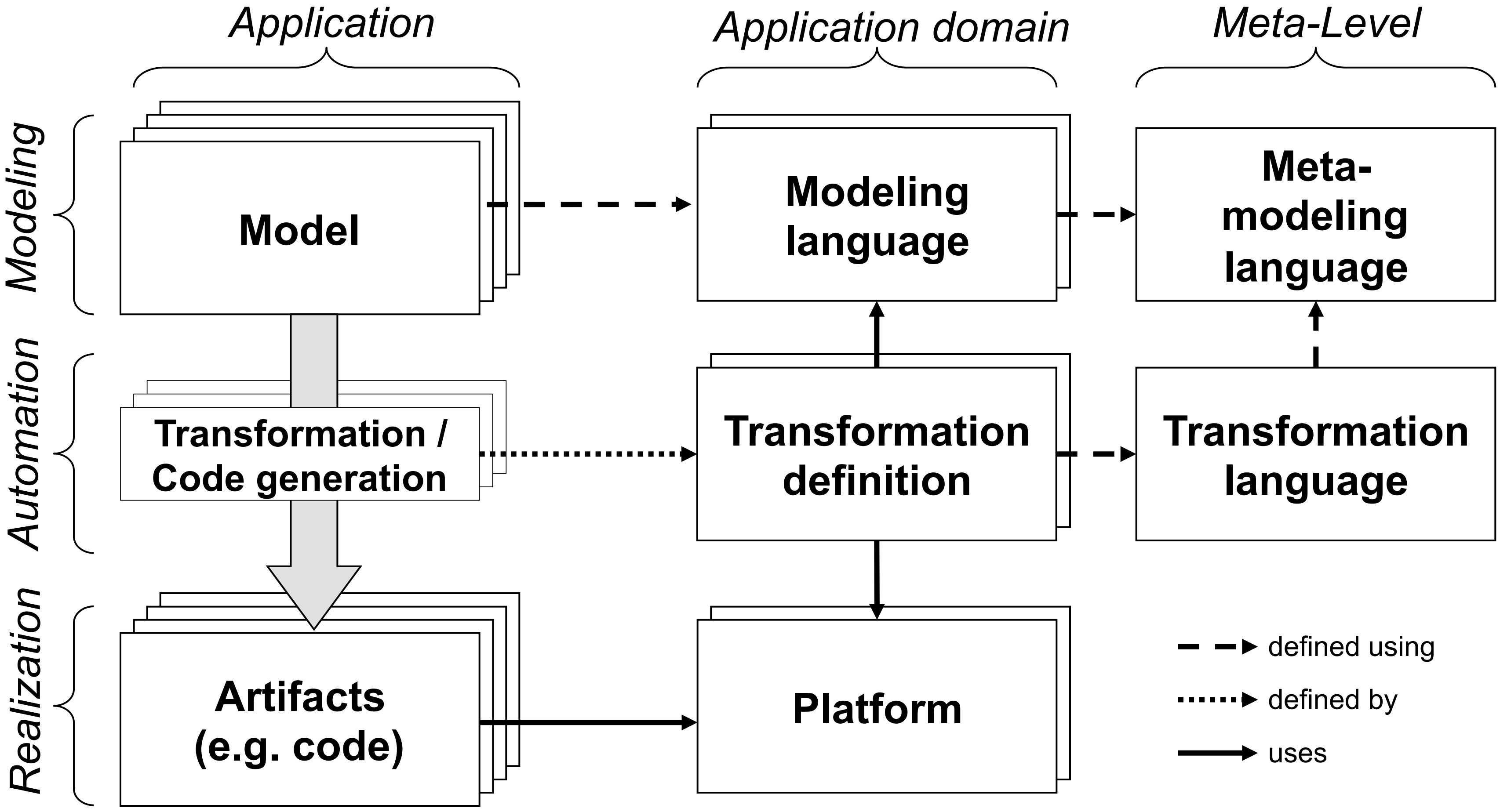


Model Transformations

- Transforming items
- MDSE provides appropriate languages for defining model transformation rules
- Rules can be written manually from scratch by a developer, or can be defined as a refined specification of an existing one.
- Alternatively, transformations themselves can be produced automatically out of some higher level mapping rules between models
  - defining a mapping between elements of a model to elements to another one (**model mapping or model weaving**)
  - automating the generation of the actual transformation rules through a system that receives as input the two model definitions and the mapping
- Transformations themselves can be seen as models!

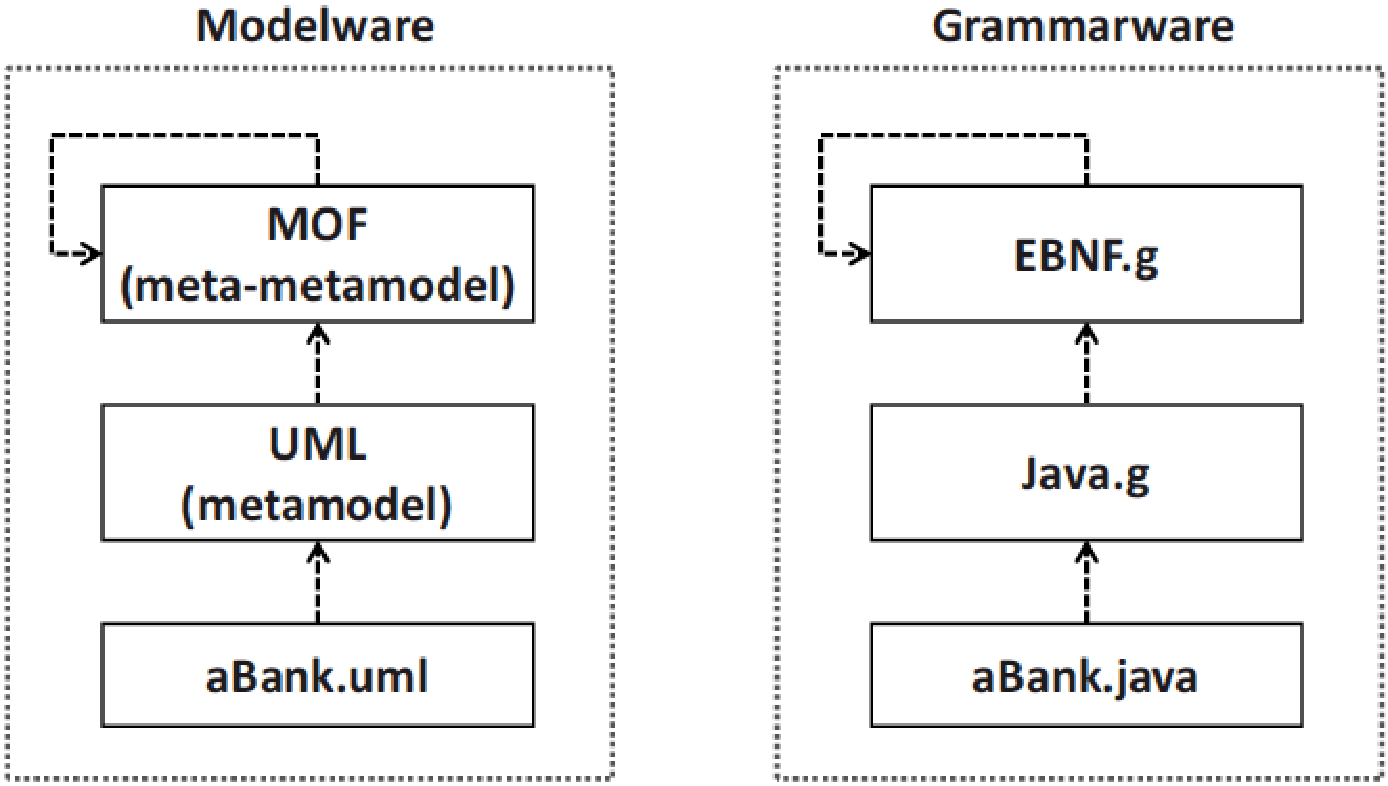
Concepts

Model Engineering basic architecture



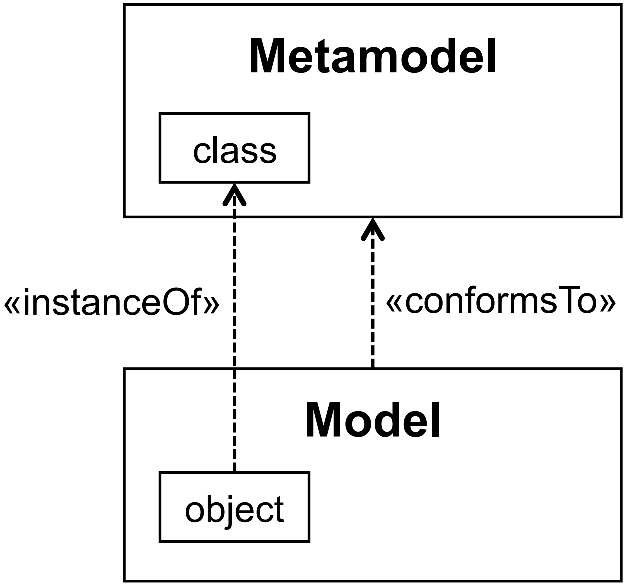
Modelware vs. Grammarware

- Two technical spaces



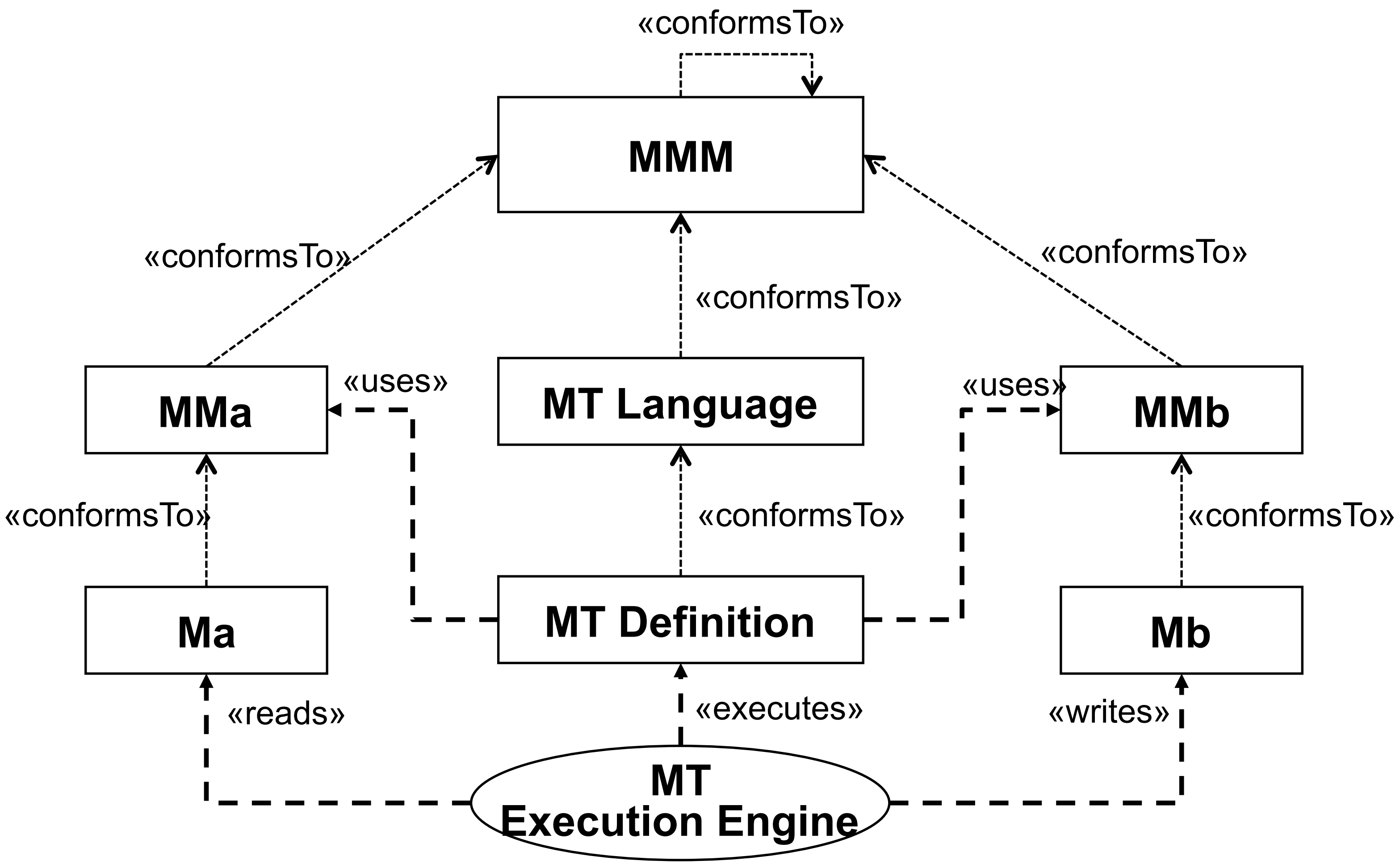
InstanceOf vs. ConformsTo

- Conformance is between models
- Instantiation is between model elements



Model Transformations

MOF and transformation setting



Types of models

- **Static models:** Focus on the static aspects of the system in terms of managed data and of structural shape and architecture of the system.
- **Dynamic models:** Emphasize the dynamic behavior of the system by showing the execution.

- Just think about UML!

Concepts

Consequences or Preconditions

- Modified **development process**
  - Two levels of development – application and infrastructure
    - Infrastructure development involves modeling language, platform (e.g., framework) and transformation definition
    - Application development only involves modeling – efficient reuse of the infrastructure(s)
  - Strongly simplified application development
    - Automatic code generation replaces programming
    - Working on code level (implementation, testing, maintenance) becomes unnecessary
    - *Under which conditions is this realistic … or just futuristic?*
- New **development tools**
  - Tools for language definition, in particular meta modeling
  - Editor and engine for model transformations
  - Customizable tools like model editors, repositories, simulation, verification, and testing tools

Approaches

Overview

- Considered Approaches
  - Computer Aided Software Engineering (CASE)
  - Executable UML
  - Model Driven Architecture (MDA)
  - Architecture Centric Model Driven Software Development (AC-MDSD)
  - MetaCASE
  - Software Factories

- Distinguishing features
  - Special objectives and fields of application
  - Restrictions or extensions of the basic architecture
  - Concrete procedures
  - Specific technologies, languages, tools

Approaches

CASE

[http://www.ca.com/us/devcenter/ca-gen.aspx/]

- **Historic** approach (end of 20th century)
- **Example**: Computer Associates' AllFusion Gen
  - Supports the Information Engineering Method by James Martin, different diagram types
  - Fully automated code generation for one architecture (3-Tier) and plenty of execution platforms (Mainframe, Unix, .NET, J2EE, different databases, …)
  - Advantage/Disadvantage: no handling with the target platform required/possible
- Different **implementation versions of the basic architecture**
  - Meta-Level often not supported / not accessible
  - Modeling language often fixed, tool specific versions
  - Execution platform often not considered or fixed
- **Advantages**
  - Productivity, development and maintenance costs, quality, documentation
- **Disadvantages**
  - Proprietary (version of a) modeling language
  - Tool interoperability non-existent
  - Strongly dependent on the tool vendor regarding execution platforms, further development
  - Tools are highly complex

Approaches

Executable UML

- “CASE with UML”
  - **UML-Subset**: Class Diagram, State Machine, Package/Component Diagram, as well as
  - UML Action Semantic Language (ASL) as programming language
- **Niche product**
  - Several specialized vendors like Kennedy/Carter
  - Mainly used for the development of Embedded Systems
- One **part of the basic architecture** implemented
  - Modeling language is predetermined (**xUML**)
  - Transformation definitions can be adapted or can be established by the user (via ASL)
- **Advantages** compared to CASE
  - Standardized modeling language based on the UML
- **Disadvantages** compared to CASE
  - Limited extent of the modeling language

[S.J. Mellor, M.J. Balcer: Executable UML: a foundation for model-driven architecture. Addison-Wesley, 2002]

Approaches

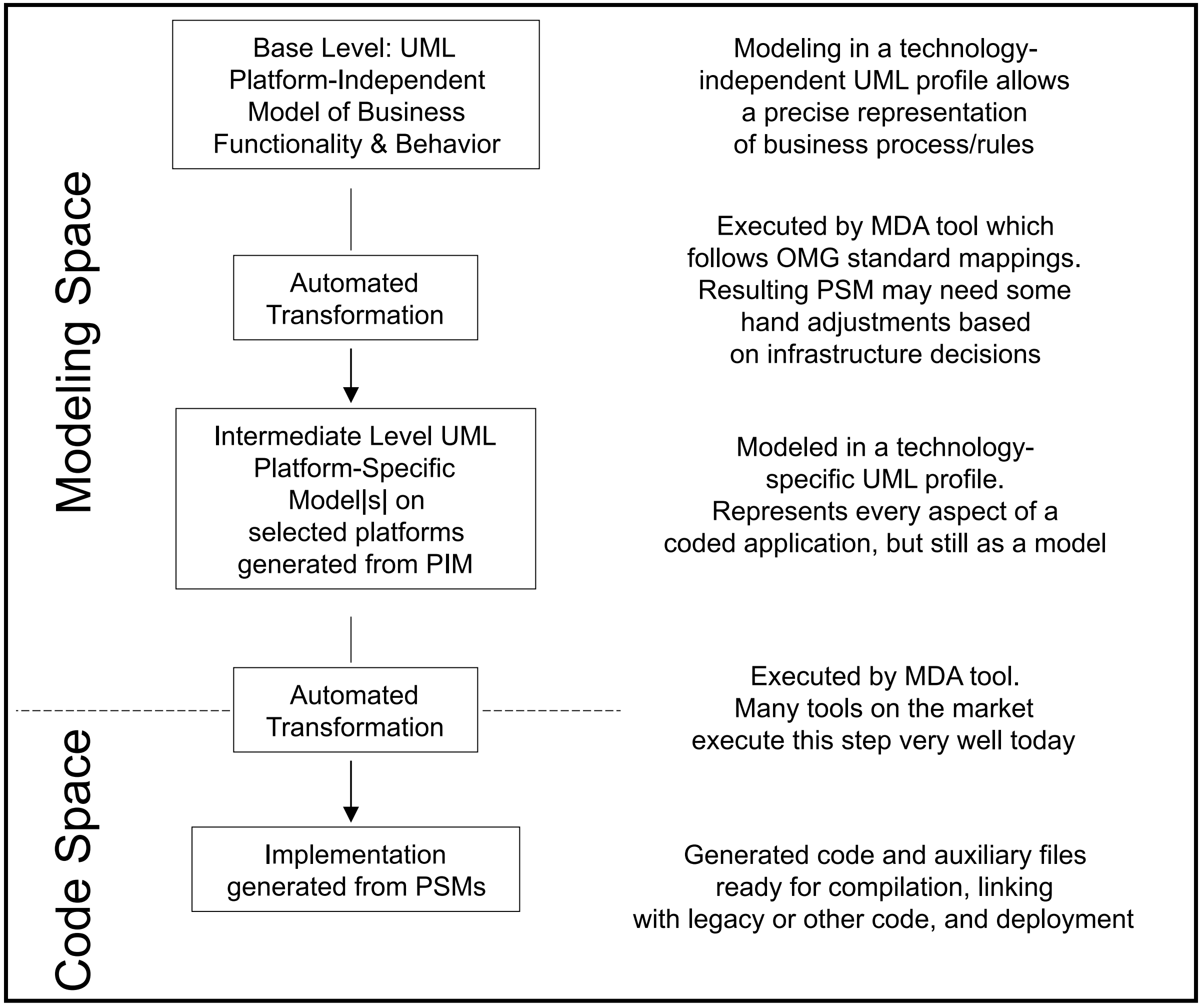
MDA

- **Interoperability** through platform independent models
  - Standardization initiative of the Object Management Group (**OMG**), based on OMG Standards, particularly **UML**
  - Counterpart to CORBA on the modeling level: interoperability between different platforms
  - Applications which can be installed on different platforms → portability, no problems with changing technologies, integration of different platforms, etc.
- **Modifications to the basic architecture**
  - Segmentation of the model level
    - **Platform Independent** Models (PIM): valid for a set of (similar) platforms
    - **Platform Specific** Models (PSM): special adjustments for one specific platform
  - Requires model-to-model transformation (PIM-PSM; cf. QVT) and model-to-code transformation (PSM-Code)
  - Platform development is not taken into consideration – in general industry standards like J2EE, .NET, CORBA are considered as platforms

[www.omg.org/mda/]

Approaches

MDA development cycle



Modeling Space
Base Level: UML Platform-Independent Model of Business Functionality & Behavior
Automated Transformation
Intermediate Level UML Platform-Specific Model|s| on selected platforms generated from PIM
Code Space
Automated Transformation
Implementation generated from PSMs

Modeling in a technology-independent UML profile allows a precise representation of business process/rules

Executed by MDA tool which follows OMG standard mappings. Resulting PSM may need some hand adjustments based on infrastructure decisions

Modeled in a technology-specific UML profile. Represents every aspect of a coded application, but still as a model

Executed by MDA tool. Many tools on the market execute this step very well today

Generated code and auxiliary files ready for compilation, linking with legacy or other code, and deployment

Modeling Levels

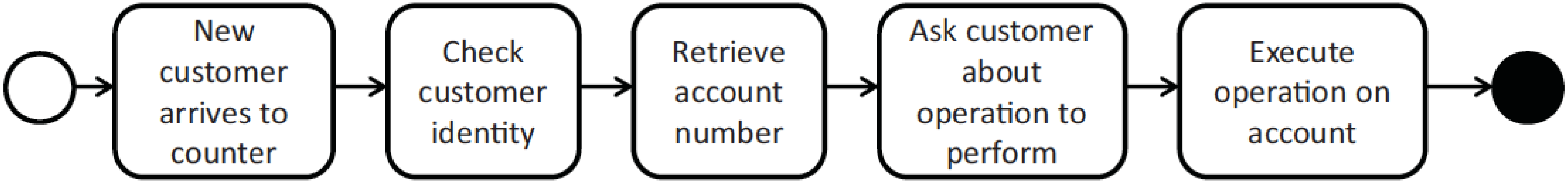
CIM, PIM, PSM

- **Computation independent models** (CIM): describe requirements and needs at a very abstract level, without any reference to implementation aspects (e.g., description of user requirements or business objectives);
- **Platform independent models** (PIM): define the behavior of the systems in terms of stored data and performed algorithms, without any technical or technological details;
- **Platform-specific models** (PSM): define all the technological aspects in detail.

Modeling levels

CIM

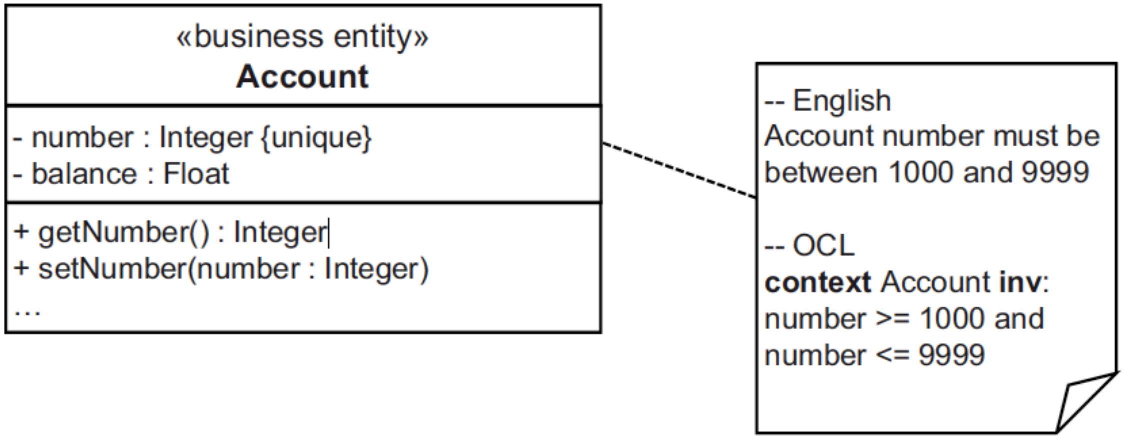
- Eg., business process


New customer arrives to counter
Check customer identity
Retrieve account number
Ask customer about operation to perform
Execute operation on account

Modeling levels

MDA Platform Independent Model (PIM)

- Specification of structure and behaviour of a system, abstracted from technological details



«business entity»
Account

- number : Integer {unique}
- balance : Float

+ getNumber() : Integer
+ setNumber(number : Integer)
...

-- English
Account number must be between 1000 and 9999

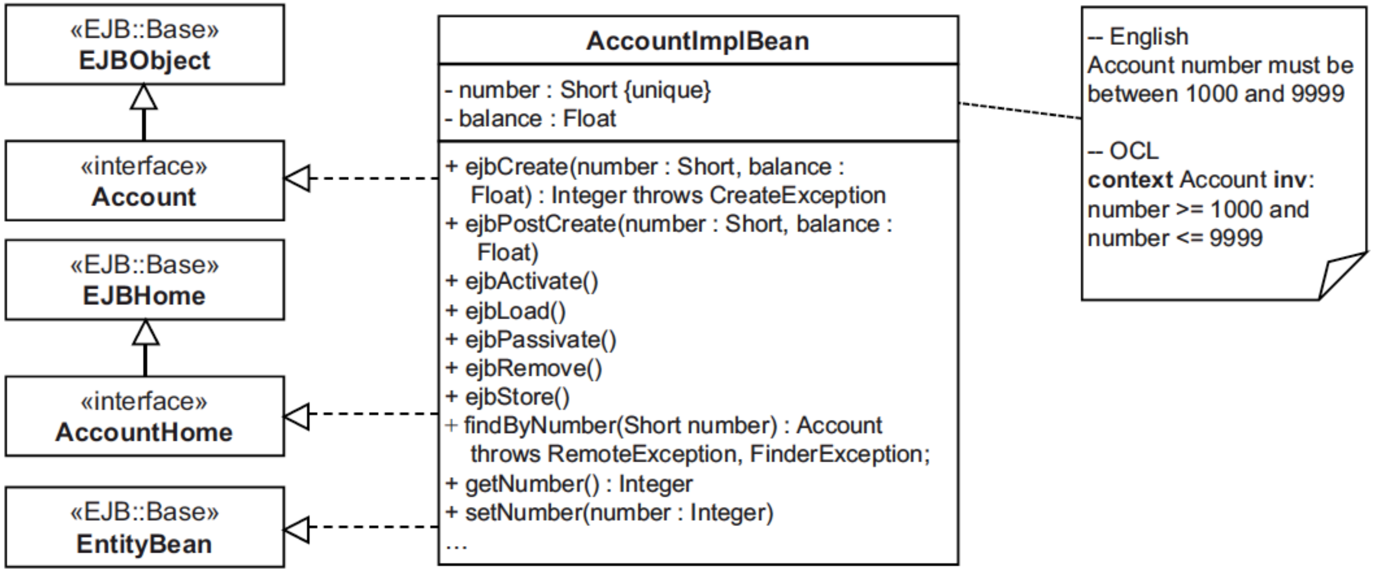
-- OCL
context Account **inv**:
number >= 1000 and
number <= 9999

- Using UML(optional)

- Abstraction of structur and behaviour of a system by PIM simplifies the following:
  - Validation of correctness of the model
  - Creation of implementations on different platforms
  - Tool support during implementation

Modeling levels

MDA Platform Specific Model (PSM)



«EJB::Base»
EJBObject

«interface»
Account

«EJB::Base»
EJBHome

«interface»
AccountHome

«EJB::Base»
EntityBean

AccountImplBean

- number : Short {unique}
- balance : Float

```
+ ejbCreate(number : Short, balance :
    Float) : Integer throws CreateException
+ ejbPostCreate(number : Short, balance :
    Float)
+ ejbActivate()
+ ejbLoad()
+ ejbPassivate()
+ ejbRemove()
+ ejbStore()
+ findByNumber(Short number) : Account
    throws RemoteException, FinderException;
+ getNumber() : Integer
+ setNumber(number : Integer)
...
```

-- English
Account number must be
between 1000 and 9999

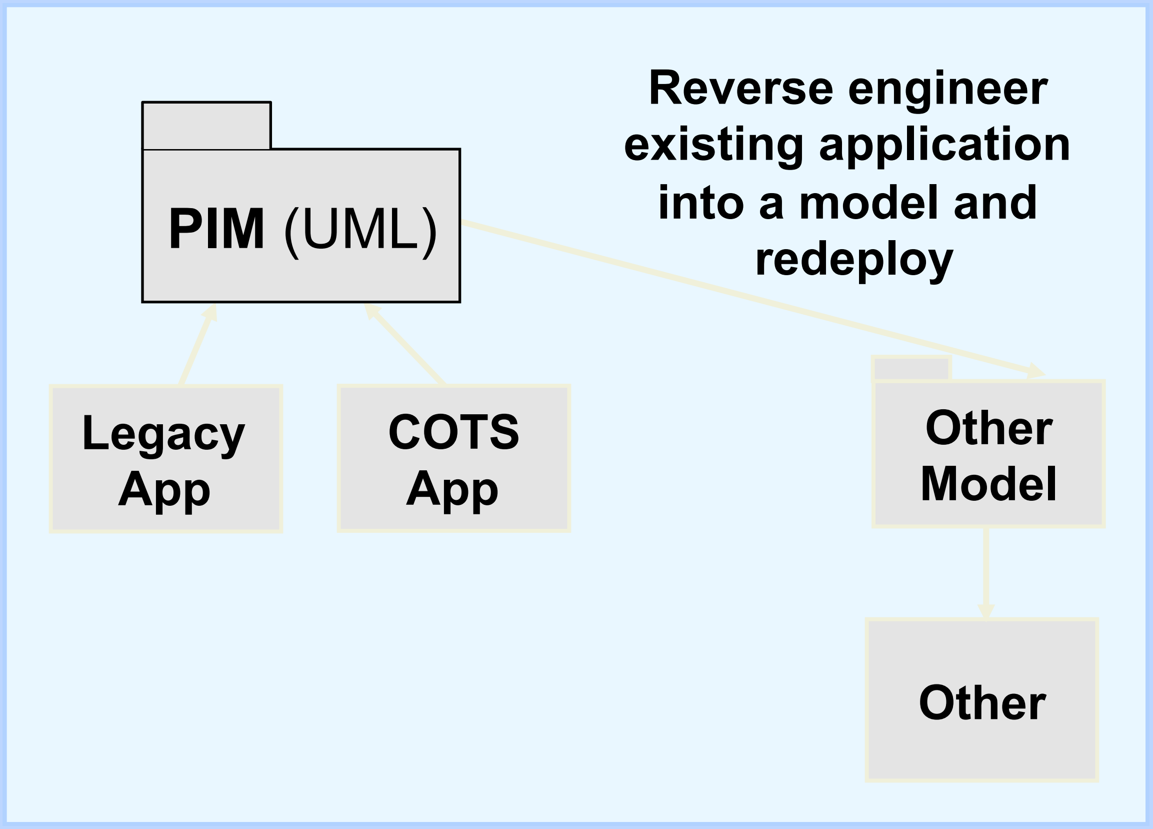
-- OCL
context Account **inv**:
number >= 1000 and
number <= 9999

- Specifies how the functionality described in the PIM is realized on a certain platform
- Using a UML-Profile for the selected platform, e.g., EJB

Approaches

MDA Reverse Engineering / Roundtrip Engineering

- Re-integration onto new platforms via reverse engineering of an existing application into a PIM und subsequent code generation
- MDA tools for reverse engineering automate the model construction from existing code



Reverse engineer existing application into a model and redeploy

Approaches

Excursus: OMG Standards

- CORBA - Common Object Request Broker Architecture
  - Language- and platform-neutral interoperability standard (similar to WSDL, SOAP and UDDI)
- UML - Unified Modeling Language
  - Standardized modeling language, industry standard
- CWM - Common Warehouse Metamodel
  - Integrated modeling language for data warehouses
- MOF – Meta Object Facility
  - A standard for metamodels and model repositories
- XMI - XML Metadata Interchange
  - XML-based exchange of models
- QVT – Queries/Views/Transformations
  - Standard language for model-to-model transformations

Approaches

MDA with UML

- Problems when using **UML** as PIM/PSM
  - Method bodies?
  - Incomplete diagrams, e.g. missing attributes
  - Inconsistent diagrams
  - *For the usage of the UML in Model Engineering special guidelines have to be defined and adhered to*
- Different requirements to **code generation**
  - get/set methods
  - Serialization or persistence of an object
  - Security features, e.g. Java Security Policy
  - *Using adaptable code generators or PIM-to-PSM transformations*
- **Expressiveness** of the UML
  - UML is mainly suitable for “generic” software platforms like Java, EJB, .NET
  - Lack of support for user interfaces, code, etc.
  - *MDA tools often use proprietary extensions*

Approaches

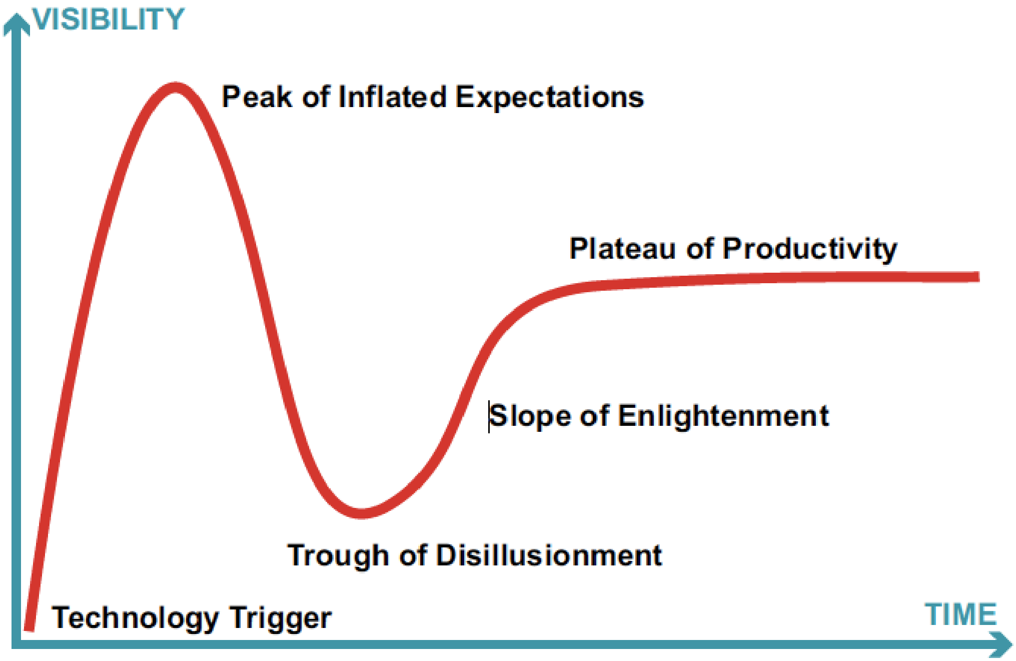
MDA

- Many **UML tools** are expanded to MDA tools
  - UML profiles and code generators
  - Stage of development partly still similar to CASE: proprietary UML profiles and transformations, limited adaptability
- **Advantages** of MDA
  - Standardization of the Meta-Level
  - Separation of platform independent and platform specific models (reuse)
- **Disadvantages** of MDA
  - No special support for the development of the execution platform and the modeling language
  - Modeling language practically limited to UML with profiles
  - Therefore limited code generation (typically no method bodies, user interface)

MDSE industry

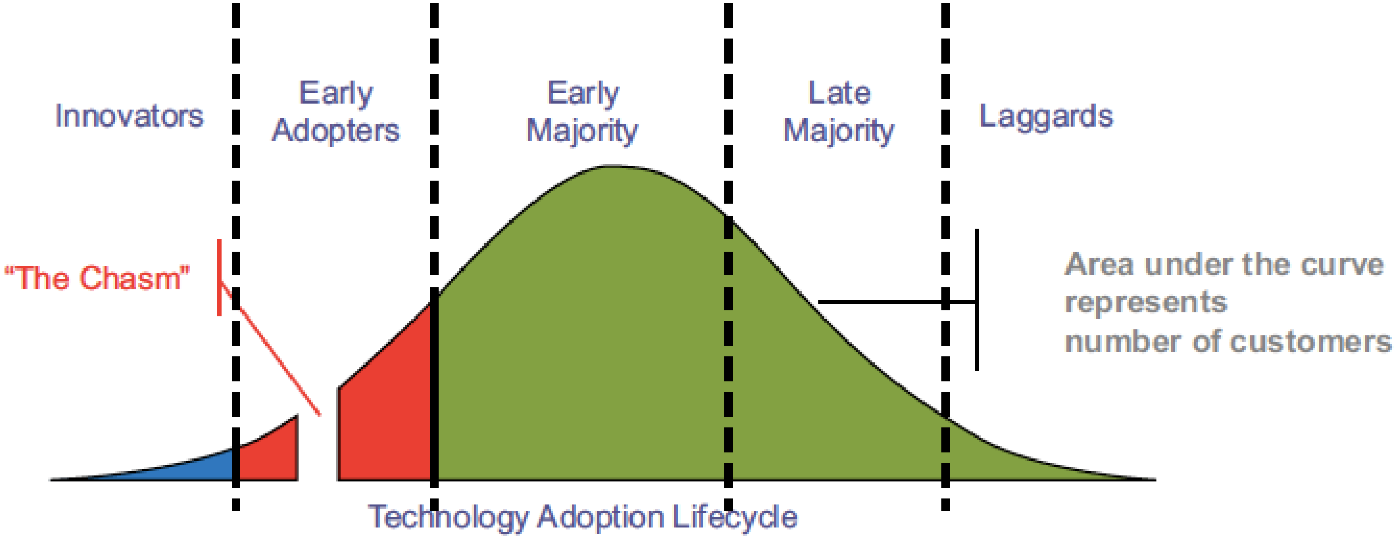
Adoption and acceptance (hype)

- Not yet mainstream in all industries
- Strong in core industry (defense, avionics, …)



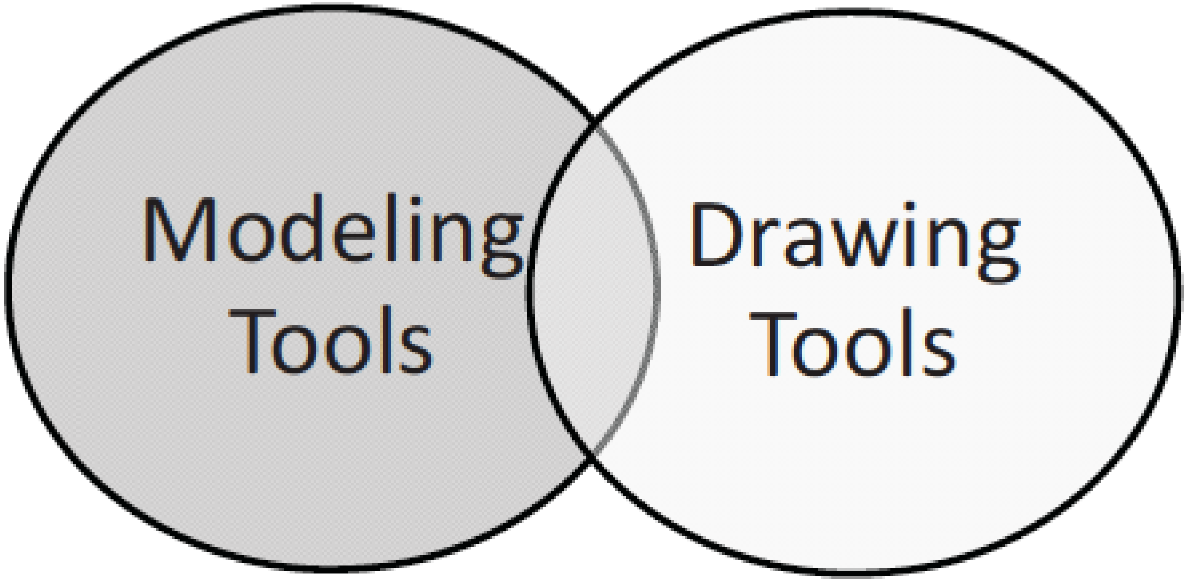
MDSE Industry (2)

Adoption Lifecycle



Tool support

- Drawing vs. modeling



Approaches

AC-MDSD

- Efficient reuse of architectures
  - Special attention to the efficient reuse of infrastructures/frameworks (= architectures) for a series of applications
  - Specific procedure model
    - Development of a reference application
    - Analysis in individual code, schematically recurring code and generic code (equal for all applications)
    - Extraction of the required modeling concepts and definition of the modeling language, transformations and platform
  - Software support (www.openarchitectureware.org)
- Basic architecture almost completely covered
  - When using UML profiles there is the problem of the method bodies
  - The recommended procedure is to rework these method bodies not in the model but in the generated code
- Advantages compared to MDA
  - Support for platform- and modeling language development
- Disadvantages compared to MDA
  - Platform independence and/or portability not considered

Approaches

MetaCASE/MetaEdit+

- Free configurable CASE
  - Meta modeling for the development of domain-specific modeling languages (**DSL**s)
  - **The focus** is on the ideal support of the **application area**, e.g. mobile-phone application, traffic light pre-emption, digital clock – Intentional Programming
  - Procedural method driven by the DSL development
- Support in particular for the **modeling level**
  - Strong Support for meta modeling, e.g. graphical editors
  - Platform development not assisted specifically, the usage of components and frameworks is recommended
- **Advantages**
  - Domain-specific languages
- **Disadvantages**
  - Tool support only focuses on graphical modeling

[www.metacase.com]

Approaches

Software Factories

- **Series production** of software products
  - Combines the ideas of different approaches (MDA, AC-MDSD, MetaCASE/DSLs) as well as popular SWD-technologies (patterns, components, frameworks)
  - Objective is the automatically processed development of software product series, i.e., a series of applications with the same application area and the same infrastructure
  - The SW-Factory as a marketable product
- Support of the **complete basic architecture**
  - Refinements in particular on the realization level, e.g. deployment
- **Advantages**
  - Comprehensive approach
- **Disadvantages**
  - Approach not clearly delimited (similar MDA)
  - Only little tool support

[J. Greenfield, K. Short: Software Factories. Wiley, 2004]

Eclipse and EMF

- Eclipse Modeling Framework
- Full support for metamodeling and language design
- Fully MD (vs. programming-based tools)
- Used in this course!

Conclusion

Modeling in the last century

- Critical Statements of Software Developers
- »When it comes down to it, the real point of software development is cutting code«
- »Diagrams are, after all, just pretty pictures«
- »No user is going to thank you for pretty pictures; what a user wants is software that executes«

M. Fowler, ”UML Distilled”, 1st edition, Addison Wesley, 1997

Conclusion

Modeling in the new millennium – Much has changed!

- »When it comes down to it, the real point of software development is cutting code«
  - To model or to program, that is not the question!
  - Instead: Talk about the right abstraction level

- »Diagrams are, after all, just pretty pictures«
  - Models are not just notation!
  - Instead: Models have a well-defined syntax in terms of metamodels

- »No user is going to thank you for pretty pictures; what a user wants is software that executes«
  - Models and code are not competitors!
  - Instead: Bridge the gap between design and implementation by model transformations

M. Fowler, ”UML Distilled”, 1st edition, Addison Wesley, 1997
(revisited in 2009)

MORGAN & CLAYPOOL PUBLISHERS

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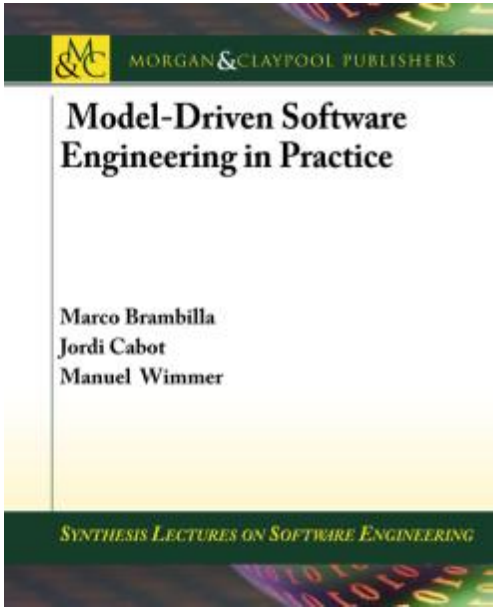

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