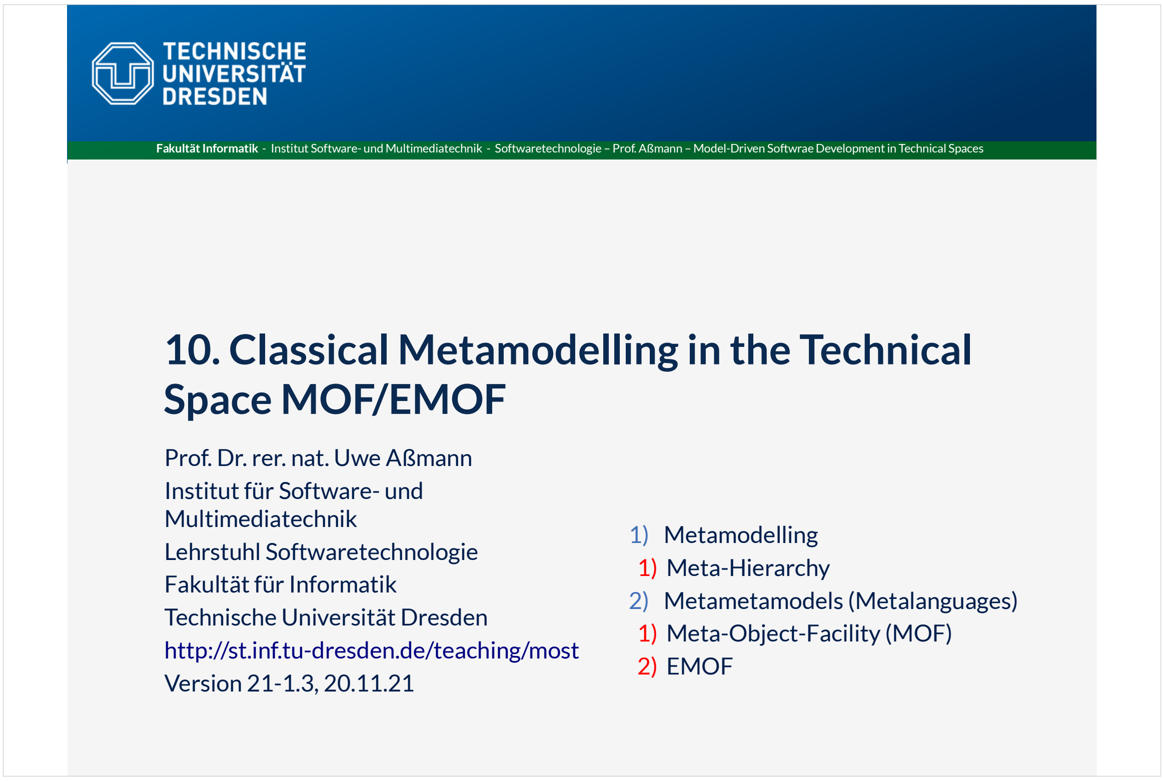

10. Classical Metamodelling in the Technical Space MOF/EMOF

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

Version 21-1.3, 20.11.21

1) Metamodelling
   1) Meta-Hierarchy
2) Metametamodels (Metalanguages)
   1) Meta-Object-Facility (MOF)
   2) EMOF

Obligatory Literature

- Kurtev, I., Bezivin, J., Aksit, M.: Technological Spaces: An Initial Appraisal. In: International Symposium on Distributed Objects and Applications, DOA Federated Conferences, Industrial track, Irvine. (2002)
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- Ed Seidewitz. What models mean. IEEE Software, 20:26-32, September 2003.
  - http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1231147&tag=1

Other Literature

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    - http://www.springer.com/computer/swe/book/978-3-642-00281-6?cm_mmc=Google-_-Book%20Search-_-Springer-_-0
- [MOF] Metaobject Facility. OMG. 1.4 and 2.0. www.omg.org
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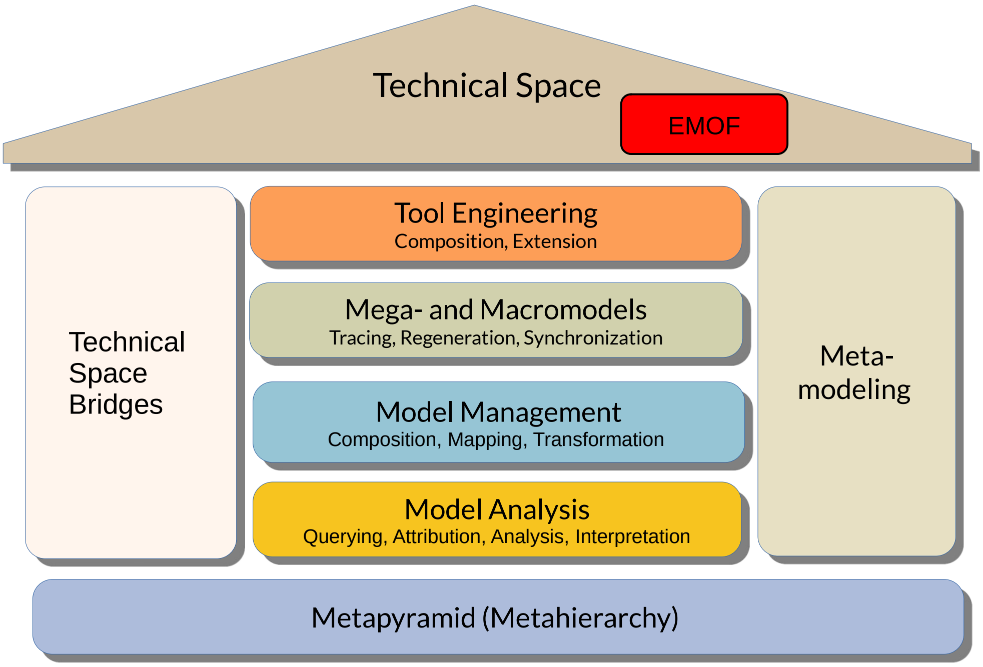
- [Favre] Jean-Marie Favre. Foundations of model (driven) (reverse) engineering: Models. Technical report, ADELE Team, Laboratoire LSR-IMAG Université Joseph Fourier, Grenoble, France, 20010. vol. 1-3.
- [Flatscher] Rony Flatscher. Metamodeling in EIA/CDIF - meta-metamodel and metamodels. ACM Trans. Model. Comput. Simul, 12(4):322-342, 2002.
- [Kendall] D. T. Chang and E. Kendall. Metamodels for RDF Schema and OWL. Proceedings of the First International Workshop on the Model-Driven Semantic Web (MDSW 2004), Monterey, USA, September 21, 20010.

Q10: The House of a Technical Space



Technical Space

EMOF

Technical Space Bridges

Tool Engineering
Composition, Extension

Mega- and Macromodels
Tracing, Regeneration, Synchronization

Model Management
Composition, Mapping, Transformation

Model Analysis
Querying, Attribution, Analysis, Interpretation

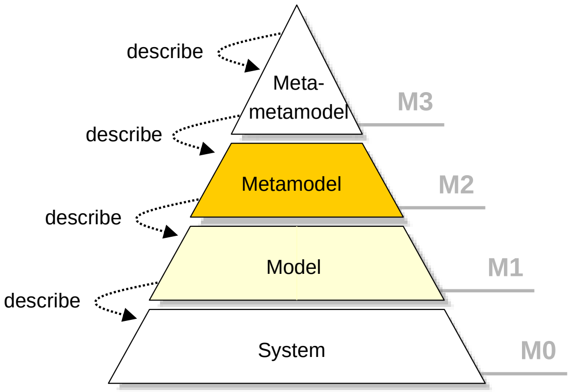
Meta-modeling

Metapyramid (Metahierarchy)

10.1 Metamodelling in the Classical Metapyramid

The Metamodel Hierarchy (Metapyramid, Metahierarchy)

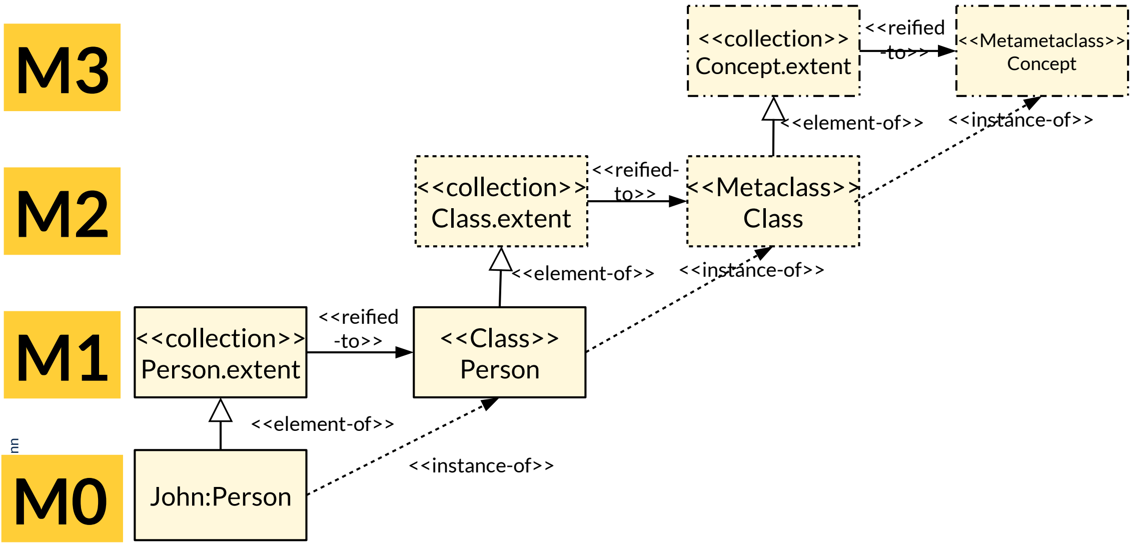
- Models are widely used in engineering disciplines
  - Need for **tool support** that enables model-editing
- Domain experts want **domain specific languages** (DSL)
  → domain specific models with types from the domain lifted from M1 to M2
- Do not build model editors from scratch each time
  → **reuse** functionality
  → use meta-information



[F. Klar, TU Darmstadt]

Remember: The Clabject Metahierarchy and Metapyramids

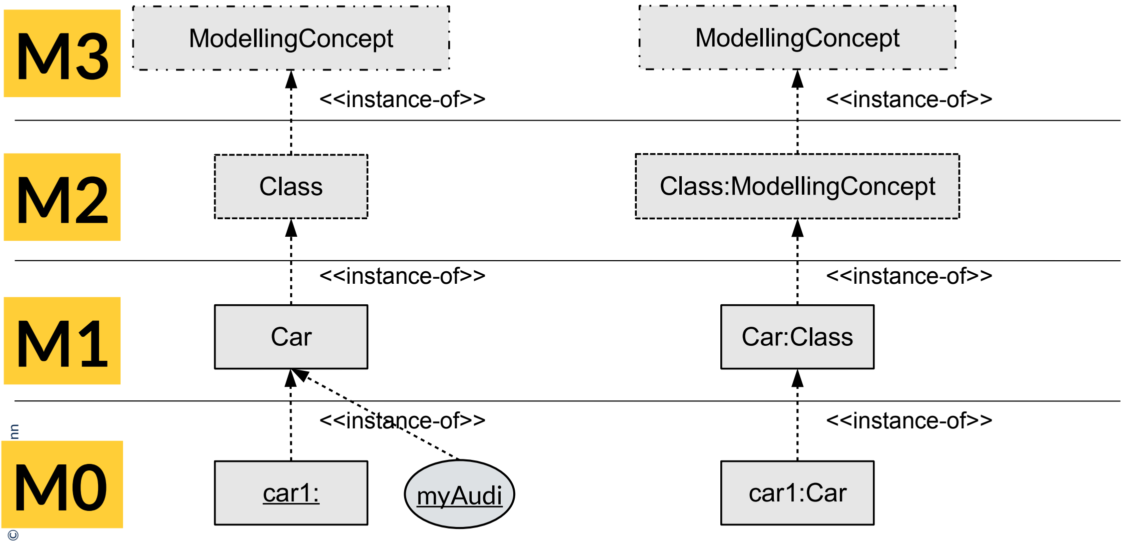
- We call a hierarchy of instance-of relationships a ***metahierarchy***.
- A ***metapyramid*** is a network of element-of, reified-to, and instance-of relationships



Notation

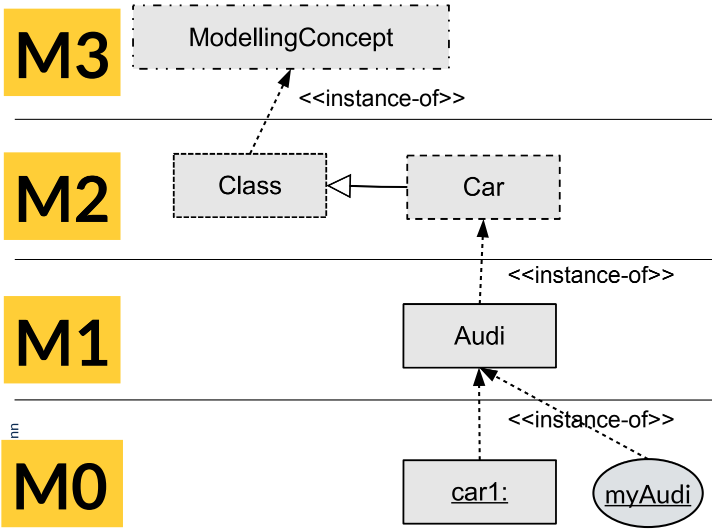
Clabject Hierarchy

- We write metaclasses (clabjects) with dashed lines, metametaclasses (clabjects) with dotted-dashed lines



Lifting a Domain Concept to a Language Concept

- Advantages: support of domain-specific semantics by language semantics
- Which domain semantics has the concept `Car`?



Models in Software Engineering

Models define abstractions of realities.

- **Process models (Workflow models)** define workflows and other processes
- **Domain models** describe a domain of the world, or a problem domain from the world of the customer
- **System models** specify systems or artefacts:
  - **Software models** define the structure of code
  - **Architecture models** define computational units, distribution, runtime issues, design patterns or architectural styles
  - **Data models** define die structure of materials and the data (e.g. relational model)

Metamodels define types for model elements. They define the *structure* of models. Their instances are models.

- **Process metamodels** define concepts for workflows
- **Domain metamodels** define concepts of domains
- **System metamodels** define concepts of systems
- **Programming Language Metamodels** define concepts of programming languages
- **Modeling Language Metamodels** define concepts of modeling languages
- **Domain-specific language (DSL) metamodels** define concepts of DSL
- **Pattern Language Metamodels** define stereotypes for classes
- **Data metamodels** define concepts for materials

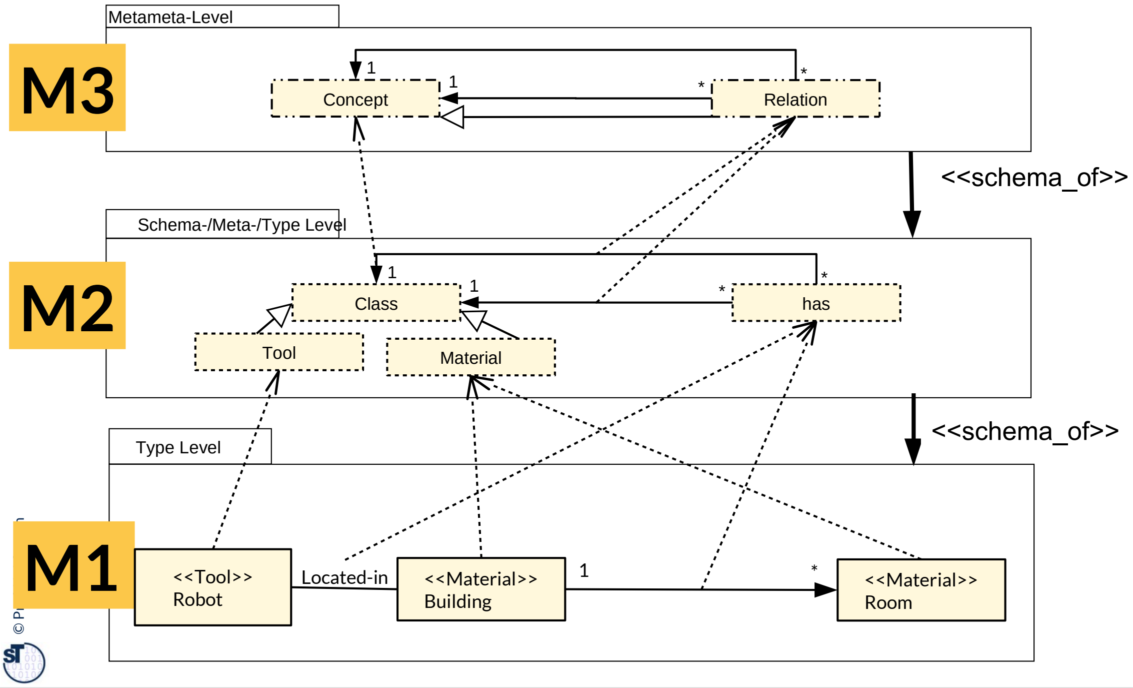
10.2 Metametamodels on M3

The Metametamodel (Metalanguage)

- Def.: A ***Metametamodel (MMM, Metalanguage)*** is a structural graph schema of a language
  - Defines types for the concepts of a language (the metaclasses on M2)
    - Contains the modeling concepts for languages
  - Structural – no behavior
  - Contains **wellformedness rules** for the graphs on M2
  - Via its **multiplicity constraints**, the metametamodel defines the form of data structure on M0 (sequence, list, table, tree, link tree, reducible graph, graph)
  - Should be minimalistic

Problem: All tools and materials heavily depend on the MMM of the technical space

Objects, their Clabjects in Models and Metamodels



Tower of Babel Problem

Tragically, no uniform metametamodell has appeared... (tower of babel)

Tools depend on their MMM

[Jan-Pieter Breughel (wikipedia)]

Metametamodels - Overview

- A ***metametamodel*** describes the context-free and -sensitive structure of a **metalanguage**. It can be augmented with wellformedness rules of the metalanguage.

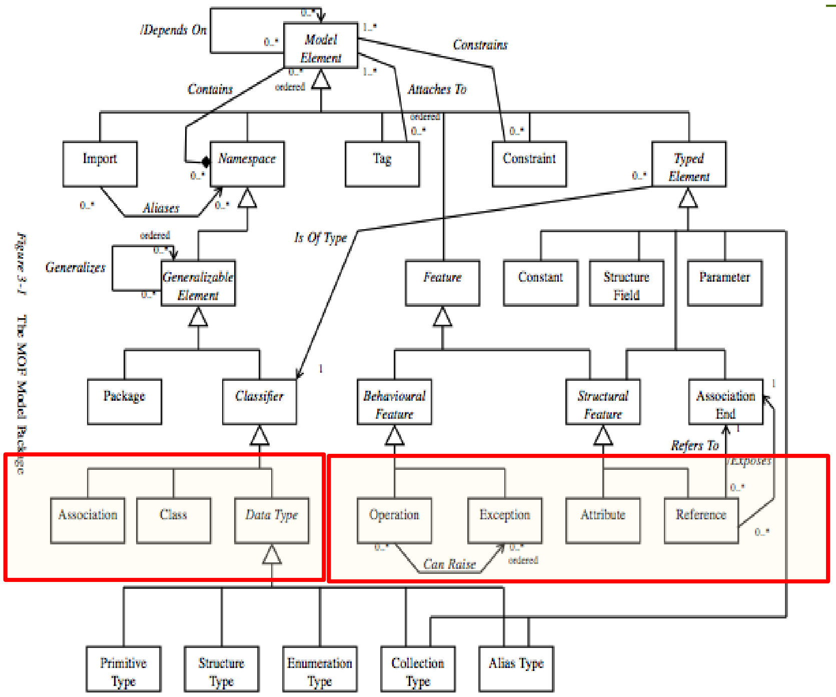
Examples:

- Meta Object Facility – MOF
    - Complete MOF – CMOF
        - **UML core**
    - Essential MOF – EMOF
        - **Ecore** (Eclipse implementation of EMOF)
- GOPRR – Graph Object Property Role Relation (MetaCase.com)
- CROM of ROSI (DFG training group at TU Dresden)
- GXL – Graph eXchange Language

Problem: All tools and materials heavily depend on the MMM of the technical space

10.2.1 Ecore and MOF as Simple Metametamodels

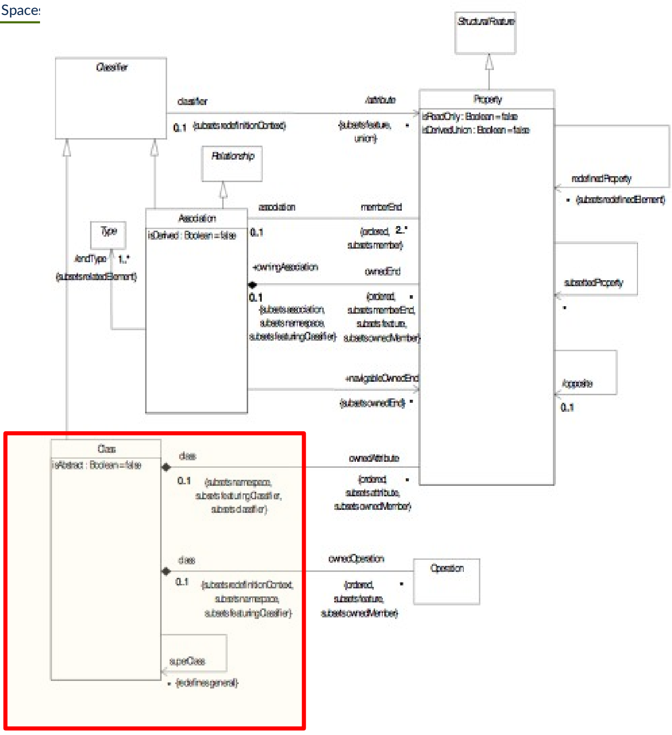
Overview of Metalanguage MOF (CMOF: Complete MOF)



[MOF]

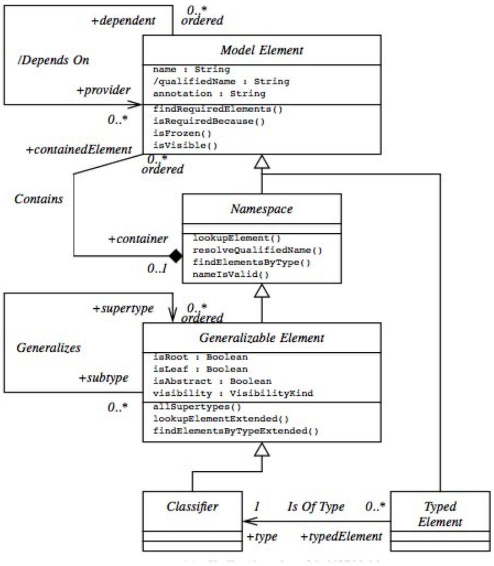
UML Core

- UML core is subset of MOF, and UML-CD
- It is rather minimalistic


StructuralFeature
Classifier
classifier
0..1 {subsets redefinitionContext}
/attribute
{subsets feature, union}
*
Property
isReadOnly : Boolean = false
isDerivedUnion : Boolean = false
Relationship
redefinedProperty
* {subsets redefinedElement}
association
memberEnd
Association
isDerived : Boolean = false
0..1
{ordered, subsets member}
2..*
Type
/endType
1..*
{subsets relatedElement}
+owningAssociation
ownedEnd
0..1
{subsets association, subsets namespace, subsets featuringClassifier}
{ordered, subsets memberEnd, subsets feature, subsets ownedMember}
*
subsettedProperty
*
+navigableOwnedEnd
{subsets ownedEnd}
*
/opposite
0..1
Class
isAbstract : Boolean = false
class
0..1
{subsets namespace, subsets featuringClassifier, subsets classifier}
ownedAttribute
{ordered, subsets attribute, subsets ownedMember}
*
class
0..1
{subsets redefinitionContext, subsets namespace, subsets featuringClassifier}
ownedOperation
{ordered, subsets feature, subsets ownedMember}
*
Operation
superClass
* {redefines general}

[MOF]

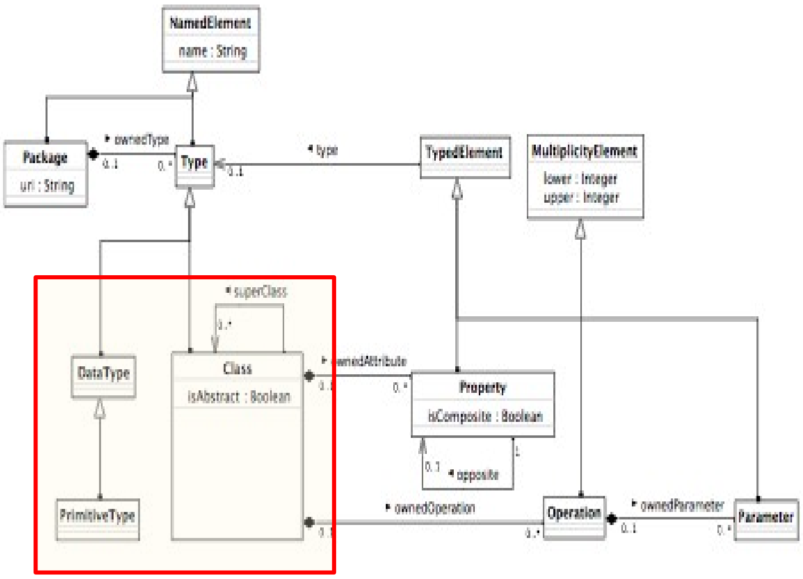
MOF Central Types



- MOF is for modeling of material, tools, automata (not distinguished)

[MOF]

Central MOF Metaclasses with Associations

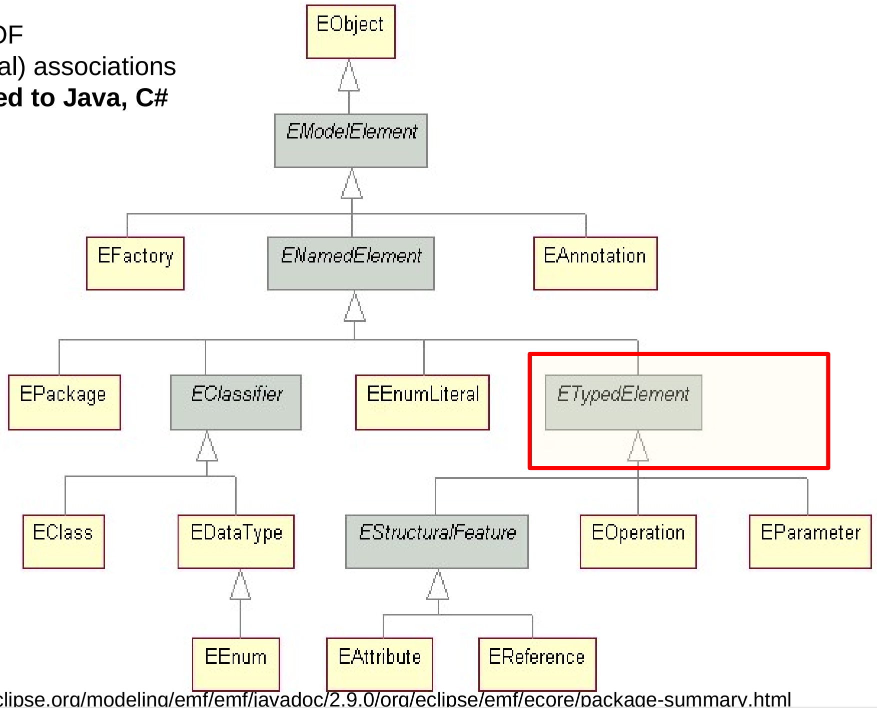


EMOF (Essential MOF)

Subset of CMOF

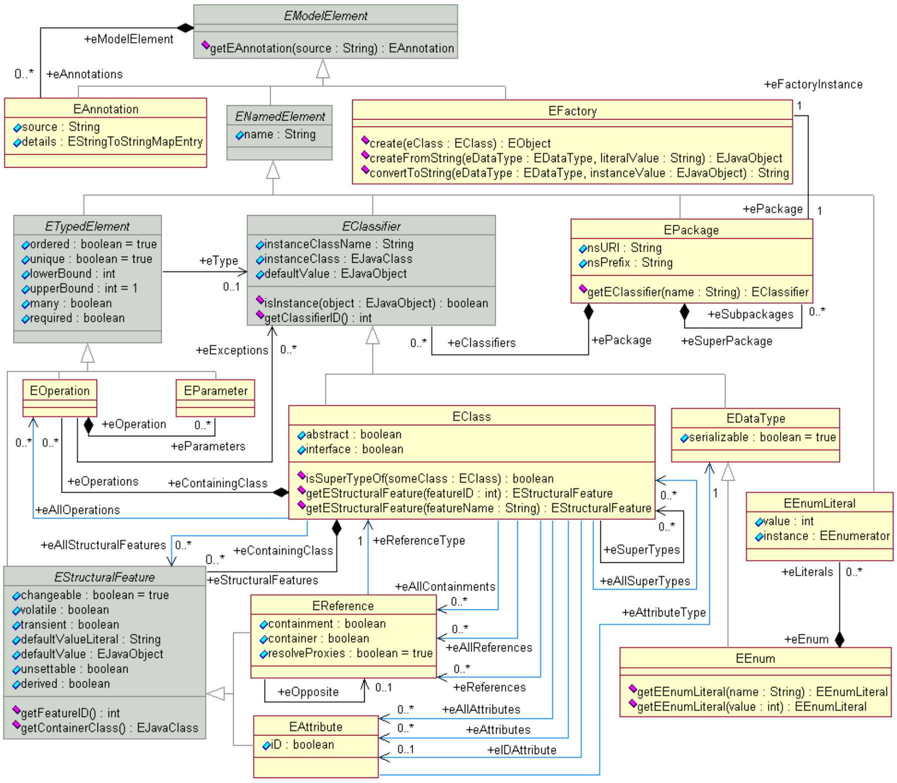
No (bidirectional) associations

Can be mapped to Java, C#



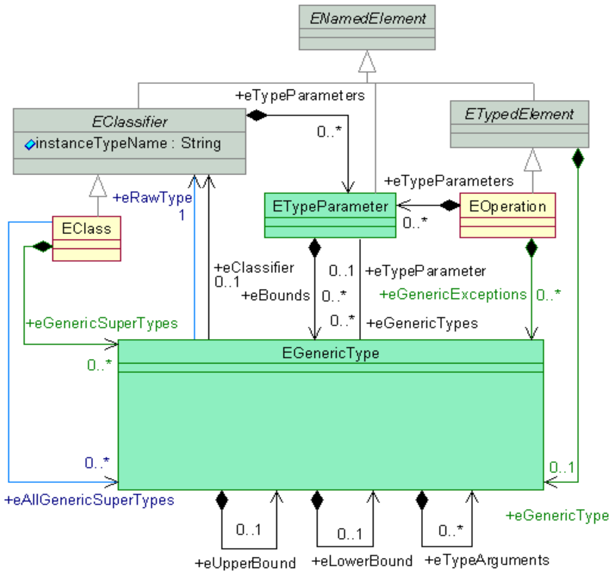
[MOF]

http://download.eclipse.org/modeling/emf/emf/javadoc/2.9.0/org/eclipse/emf/ecore/package-summary.html



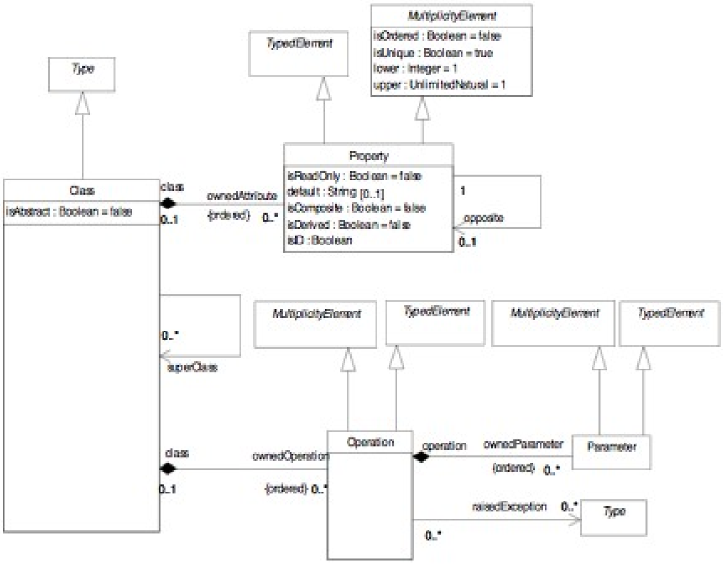
http://download.eclipse.org/modeling/emf/emf/javadoc/2.9.0/org/eclipse/emf/ecore/package-summary.html

Generic Types



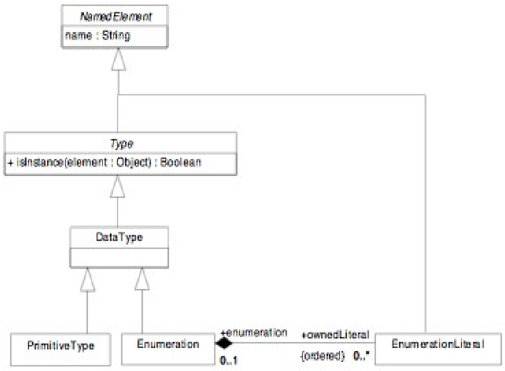
http://download.eclipse.org/modeling/emf/emf/javadoc/2.9.0/org/eclipse/emf/ecore/package-summary.html

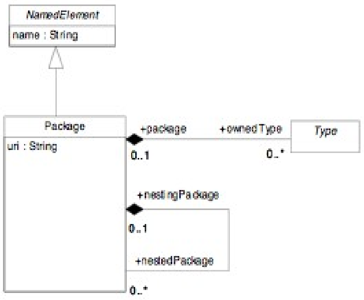
EMOF Classes in Detail



[MOF]

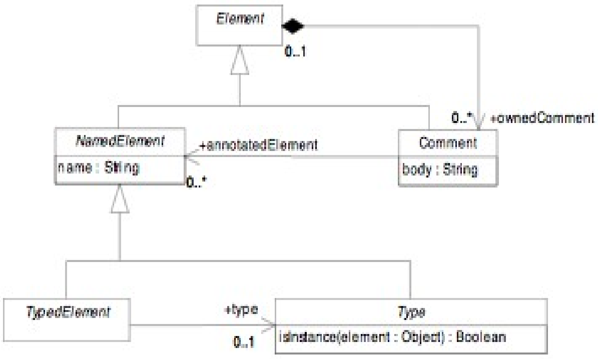
EMOF Data Types and Packages





[MOF]

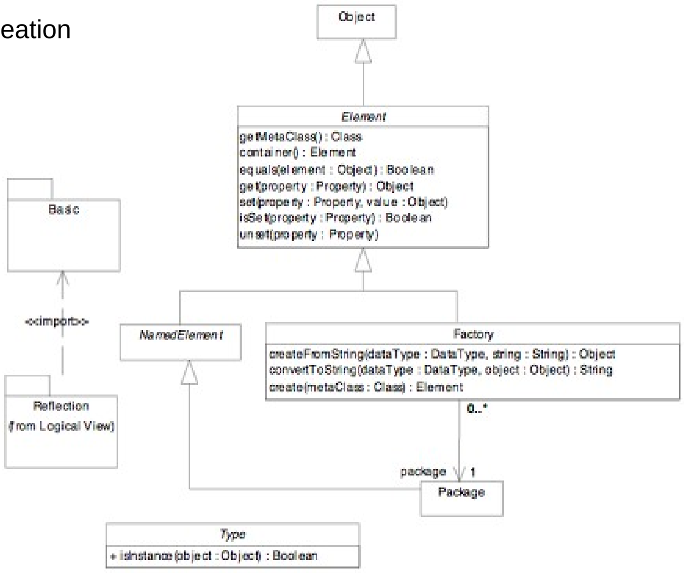
EMOF Types



[MOF]

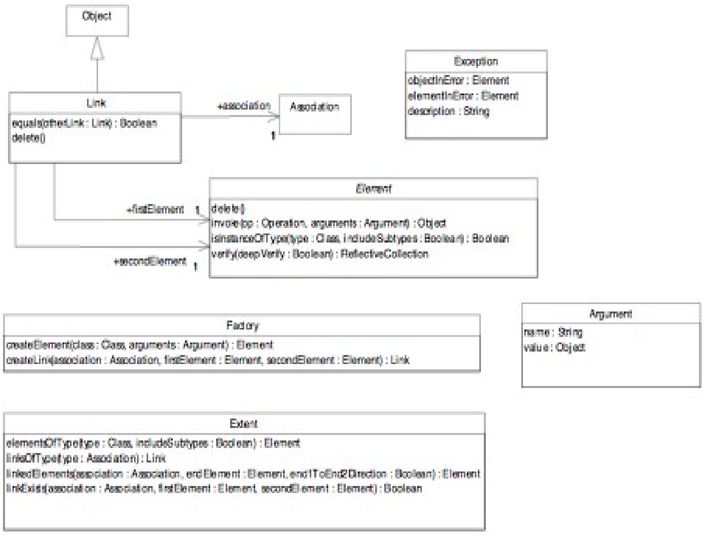
EMOF Reflection

offers access to the metamodel (getMetaClass())
provides a Factory, for creation of a Class from String


Object
Element
getMetaClass() : Class
container() : Element
equals(element : Object) : Boolean
get(property : Property) : Object
set(property : Property, value : Object)
isSet(property : Property) : Boolean
unset(property : Property)
Basic
<<import>>
Reflection
(from Logical View)
NamedElement
Factory
createFromString(dataType : DataType, string : String) : Object
convertToString(dataType : DataType, object : Object) : String
create(metaClass : Class) : Element
0..*
package
1
Package
Type
+ isInstance(object : Object) : Boolean

[MOF]

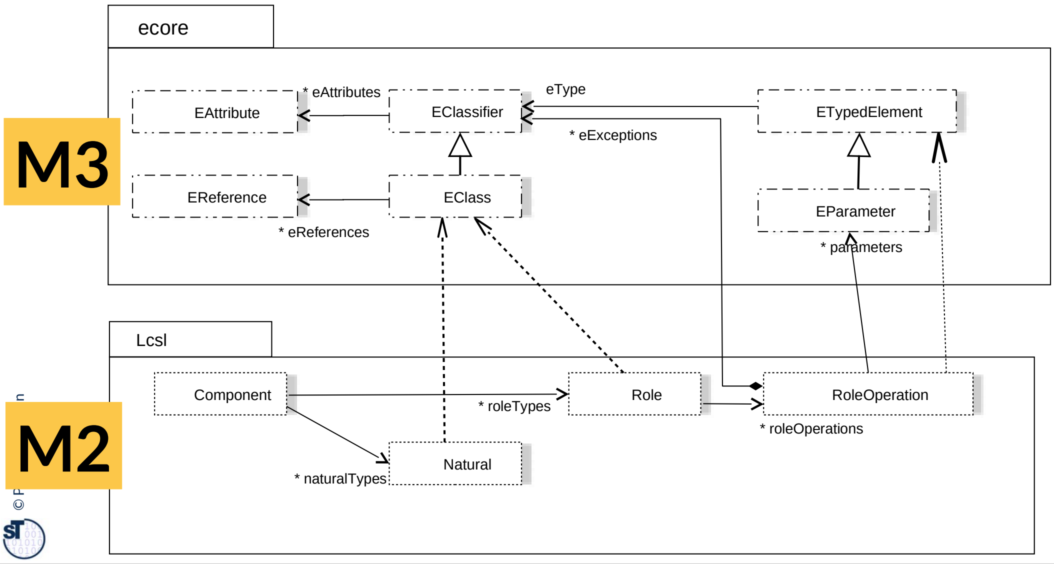
CMOF Reflection


Object
Link
equals(otherLink : Link) : Boolean
delete()
+association
1
Association
Exception
objectInError : Element
elementInError : Element
description : String
Element
+firstElement
1
+secondElement
1
delete()
invoke(op : Operation, arguments : Argument) : Object
isInstanceOfType(type : Class, includeSubtypes : Boolean) : Boolean
verify(deepVerify : Boolean) : ReflectiveCollection
Factory
createElement(class : Class, arguments : Argument) : Element
createLink(association : Association, firstElement : Element, secondElement : Element) : Link
Argument
name : String
value : Object
Extent
elementsOfType(type : Class, includeSubtypes : Boolean) : Element
linksOfType(type : Association) : Link
linkedElements(association : Association, endElement : Element, end1ToEnd2Direction : Boolean) : Element
linkExists(association : Association, firstElement : Element, secondElement : Element) : Boolean

[MOF]

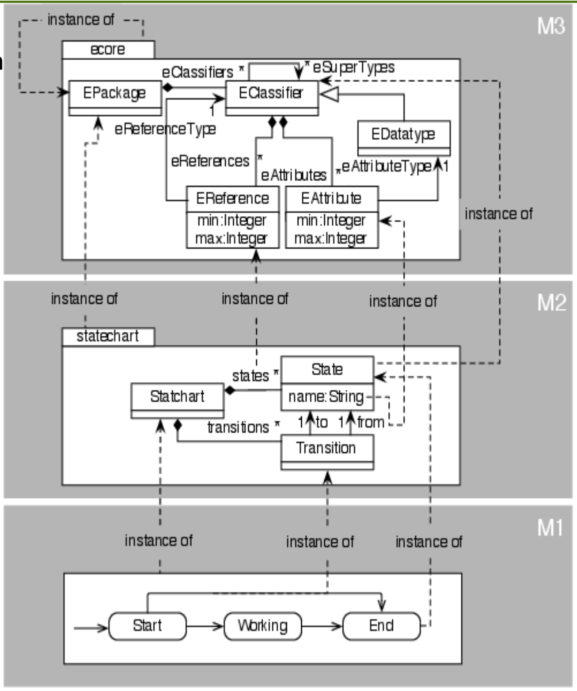
Ex.: Deriving a DSL from EMOF and its Implementation Eclipse ecore

- Ecore is the Eclipse implementation of EMOF
- lcsl is a domain-specific language for component-based modeling [C. Wende]
- Two new Metaclasses Natural and Role derived from EClass



Ex. EMOF/Ecore based Metamodel of Statecharts

- Ecore is the Eclipse implementation of EMOF, provided by the Eclipse Modeling Framework (EMF) on M3
- Here: a metamodel of statecharts (M2), (which is a little DSL)
- a set of states and their transitions (M1)



10.2.2 Lifting of a Metamodel to a Metametamodel

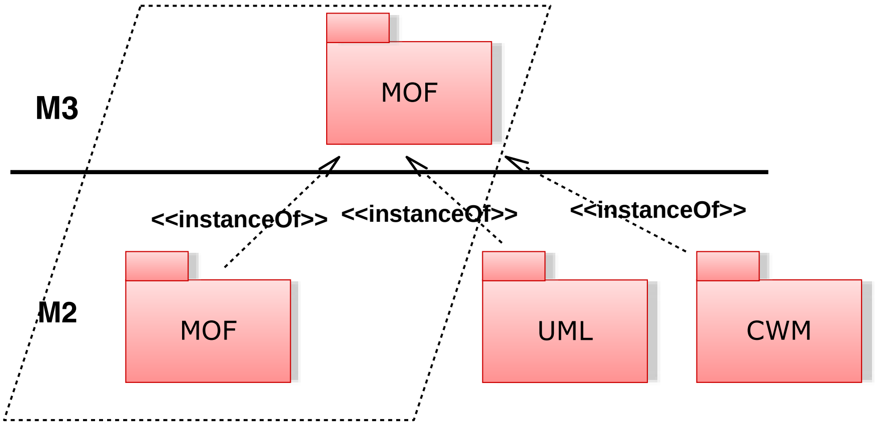
Lifting of Metamodels

A Metamodel of a data definition language in M2 is being ***lifted (promoted)***, if it is used as metametamodel on M3

- Ex. MOF is a simple DDL (Datendefinitionssprache, structural language) for graphs
  - It can be used on M2 to define new languages with package merge (see UML)
  - It can be used on M3 to define metamodels on M2 as instances
  - MOF is self-descriptive

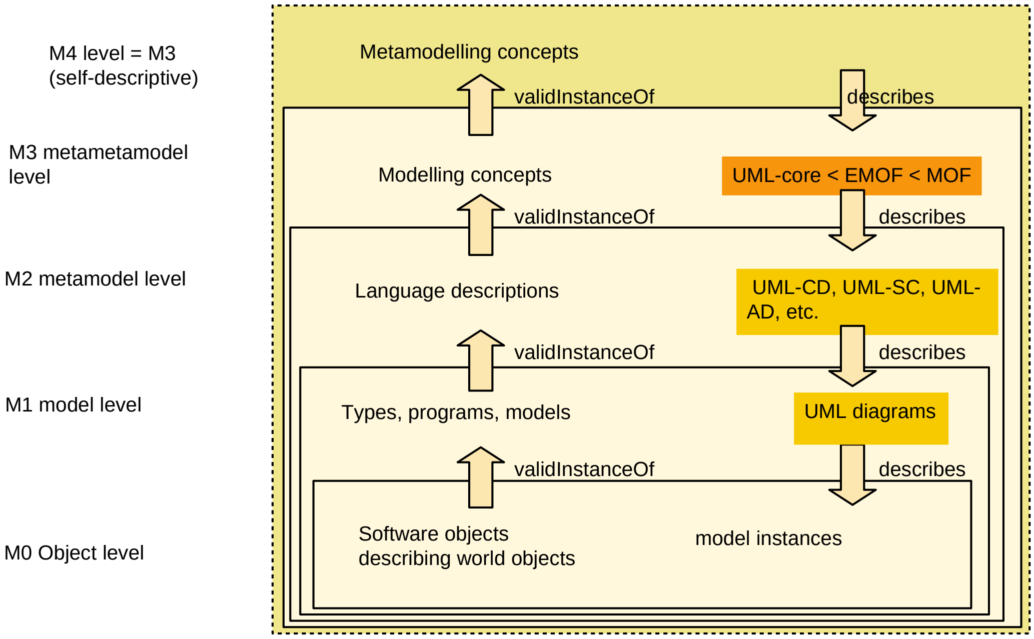
Self-Descriptive MOF

- MOF is ***self-descriptive (selbstbeschreibend)***, because the structure of MOF (M2) is defined in the lifted MOF (M3)
- MOF is *lifted*, because it is used on M2 and M3
- Many other metamodels are also lifted, e.g., EMOF

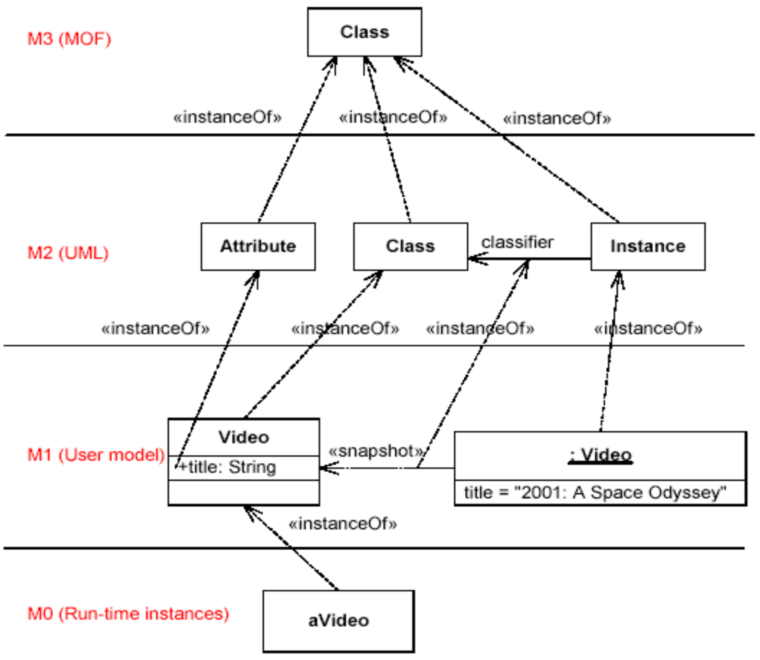


The UML-Core/MOF Metahierarchy

- The UML language manual uses UMLcore, a subset of MOF, as metalanguage

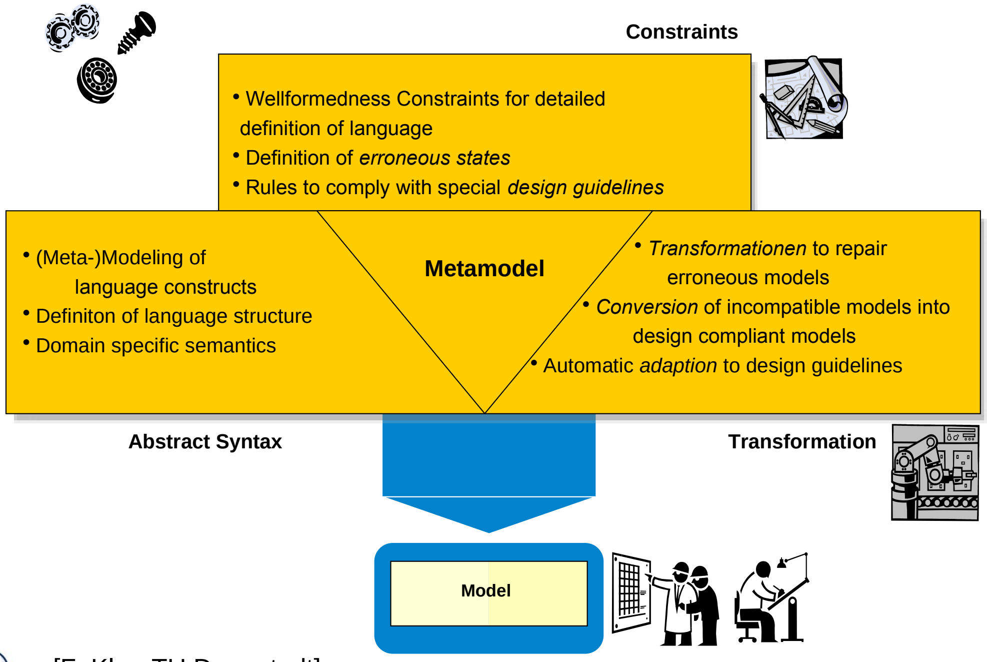


Ex.: MOF-Metahierarchy for UML



From: UML 2.0 Infrastructure Specification; OMG Adopted Specification ptc/03-09-15

Metamodeling – Benefits



Constraints

- Wellformedness Constraints for detailed definition of language
- Definition of *erroneous states*
- Rules to comply with special *design guidelines*

Metamodel

- (Meta-)Modeling of language constructs
- Definiton of language structure
- Domain specific semantics

- *Transformationen* to repair erroneous models
- *Conversion* of incompatible models into design compliant models
- Automatic *adaption* to design guidelines

Abstract Syntax

Transformation

Model

[F. Klar, TU Darmstadt]

Hier hinein muss die Kompositino noch.

10.2.3 Metahierarchies for Metaprogramming

Excursion: Metaprogramming with M2

- **(Dynamic) Metaprograms (reflective programs)** contain code on the basis of the metamodel of their own language (self model)
    - They permanently run in the application and regenerate its parts
    - Hard to statically analyse on termination and other features
    - Reflection is slow
- **Metaprogram-Procedures** (Semantic Macros, Hygenic Macros, Programmable Macros [Weise/Crew], Orchestration Style Sheets) can be typed by a metamodel
    - Parameter types and return types of prodedures are metaclasses
    - → See course CBSE
- **Introspective Programs** inspect the metamodels or metadata of other programs / components and adapt to them (-> CBSE)

Static Metaprograms

- **Codegenerators** are metaprograms producing *new* code or models by introspection
- **Static Metaprograms** run in the compiler and code-generate a program

The End

- Why is lifting an application concept to M2 advantageous?
- Compare MOF and EMOF. Why do many programmers like EMOF more than MOF?
- Explain the advantages that MOF sopports general associations.
- Why is MOF semantically more rich than EMOF and UMLcore?
- What is the purpose of a metametamodel?
- Would it make sense to use Tools-and-Materials Pattern Language (TAM) on the M3 level, i.e., in the metametamodel?
- Explain why TAM stereotypes do not occur on M2.

Different Types of Semantics and their Metalanguages (Description Languages)

- **Structure**
  - Described by a context-free grammar or a metamodel
  - Does not regard context
- **Static Semantics** (context conditions on structure), Wellformedness
  - Described by context-sensitive grammar (attribute grammar, denotational semantics, logic constraints), or a metamodel with context constraints
  - Describes context constraints, context conditions, meaning of names
  - Can describe consistency conditions on the specifications
    - “If I use a variable here, it must be defined elsewhere”
    - “If I use a component here, it must be alive”
- **Dynamic Semantics** (Behavior)
  - Interpreter in an interpreter language (e.g., lambda calculus), or a metaobject protocol
  - A dynamic semantics consists of sets of run-time states or run-time terms
  - In an object-oriented language, the dynamic semantics can be specified in the language itself. Then it is called a meta-object protocol (MOP).