Model Driven Architecture Meta Modeling

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24.05.2006



Metamodeling Intro

- What?
 - meta = above
 - Define an ontology of concepts for a domain.
 - Define the vocabulary and grammatical rules of a modeling language.
 - Define a domain specific language (DSL).
- Why?
 - Concise means of specifying the set models for a domain.
 - Precise definition of modeling language.
- How?
 - Grammars and attributions for textbased languages.
 - Metamodeling generalizes to arbitrary languages (e.g., graphical)



Metamodeling Uses

- Construction of DSLs
- Validation of Models (checking against metamodel)
- Model-to-model transformation (defined in terms of the metamodels)
- Model-to-code transformation
- Tool integration

Terms

Domain restricted area of interest

- technical aspects
- factual aspects

Syntax well-formedness rules

- abstract syntax
 just structure, how are the language concepts
 composed
- concrete syntax defines specific notation
- typical use: parser maps concrete syntax to abstract syntax

abstract syntax

concrete syntax

2 * (x + 3)

$$E ::= c | x | E B E | (E)$$

 $B ::= + | - | * | /$

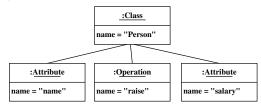
Terms/Abstract Syntax

Example: UML class diagram

concrete syntax

Person
name
salary
raise()

abstract syntax



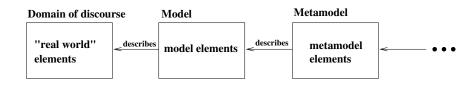
Terms/Static Semantics

- Static semantics defines well-formedness rules beyond the syntax
- Examples
 - "Variables have to be defined before use"
 - Type system of a programming language
 "hello" * 4 is syntactically correct Java, but rejected
- UML: static semantics via OCL expressions
- Use: detection of modeling/transformation errors

Terms/Domain Specific Language (DSL)

- Purpose: formal expression of key aspects of a domain
- Metamodel of DSL defines abstract syntax and static semantics
- Additionally:
 - concrete syntax (close to domain)
 - dynamic semantics
 - for understanding
 - for automatic tools
- Different degrees of complexity possible configuration options with validity check graphical DSL with domain specific editor

Metamodel vs Model



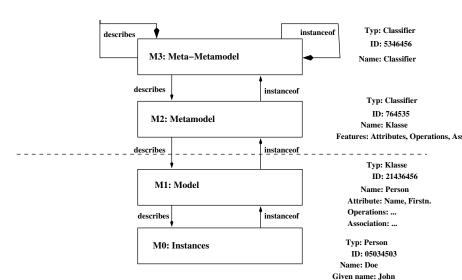
- Insight: Every model is an instance of a metamodel.
- Essential: instance-of relationship
- Model:Metamodel is like Object:Class
- Definition of Metamodel by Meta-metamodel
- ⇒ infinite tower of metamodels
- ⇒ "meta" relation always relative to a model
- Every element must have a classifying metaelement which
 - contains the metadata and
 - is accessible from the element



Metamodeling a la OMG

- OMG defines a standard (MOF) for metamodeling
- MOF (Meta-Object Facility) used for defining UML
- Attention, confusion:
 - MOF and UML share syntax (classifier and instance diagrams)
 - MOF shares names of modeling elements with UML (e.g., Class)
- Approach
 - Restrict infinite number of metalevels to four
 - Last level is deemed "self-describing"

OMG's Four Metalevels



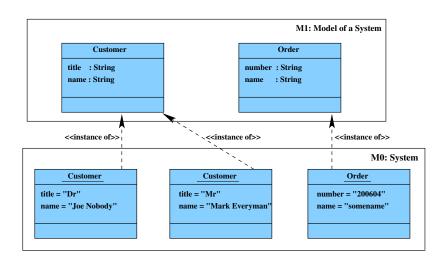
Layer M0: Instances

- Level of the running system
- Contains actual objects, e.g., customers, seminars, bank accounts, with filled slots for attributes etc
- Corresponds to object diagram

Layer M1: Model

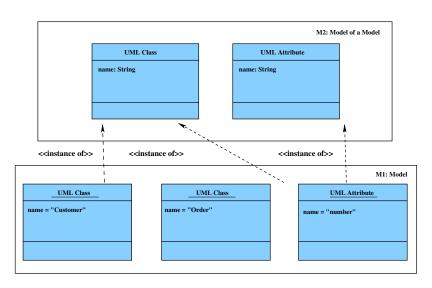
- Level of system models
- Example:
 - UML model of a software system
 - Class diagram contains modeling elements: classes, attributes, operations, associations, generalizations, . . .
- Concepts of M1 categorize (or classify) instances at layer M0
- Each element of M0 is an instance of M1 element
- No other instances are allowed at layer M0

Relation between M0 and M1



- Level of modeling element definition
- Concepts of M2 categorize instances at layer M1
- Elements of M2 model categorize M1 elements: classes, attributes, operations, associations, generalizations, ...
- Examples
 - Each class in M1 is an instance of some class-describing element in layer M2 (in this case, a Metaclass)
 - Each association in M1 is an instance of some association-describing element in layer M2 (a Metaassociation)
 - and so on

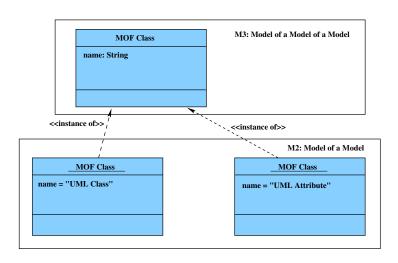
Relation between M1 and M2



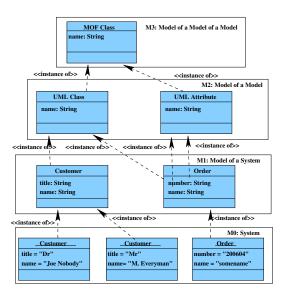
Layer M3: Meta-Metamodel

- Level for defining the definition of modeling elements
- Elements of M3 model categorize M2 elements: Metaclass, Metaassociation, Metaattribute, etc
- Typical element of M3 model: MOF class
- Examples
 - The metaclasses Class, Association, Attribute, etc are all instances of MOF class
- M3 layer is self-describing

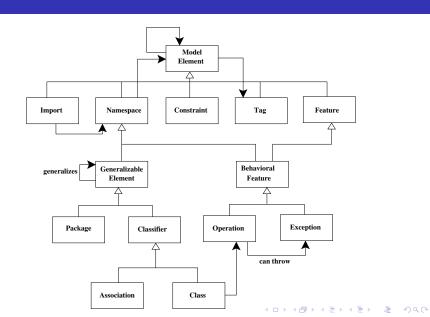
Relation between M2 and M3



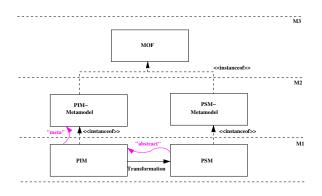
Overview of Layers



Excerpt from MOF/UML



Meta vs Abstract



- Models on the same metalevel may have different degrees of abstraction
- Transformations map between models of different abstraction levels
- Source and target model of a transformation may be defined by different metamodels

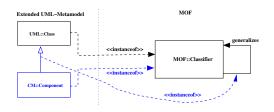
MOF vs UML

- UML (M2) is an instance of MOF (M3)
- UML is older than MOF
- UML had to change to suit MOF
- MOF reuses concrete syntax and some model elements

Designing a DSL

- Definition of a new M2 language too involved
- Typical approach: Extension of UML
- Extension Mechanisms
 - Extension of the UML 2 metamodel applicable to all MOF-defined metamodels
 - Extension using stereotypes (the UML 1.x way)
 - Extension using profiles (the UML 2 way)

Extending the UML Metamodel



- MOF sanctions the derivation of a new metaclass
 CM::Component from UML::Class
- CM::Component is an instance of MOF::Classifier
- the generalization is an instance of MOF's generalizes association

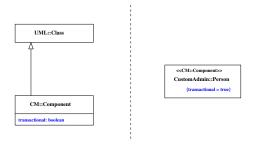


Extending the UML Metamodel/Concrete Syntax



- Explicit instance of metaclass
- 2 Name of metaclass as stereotype
- Convention
- Tagged value with metaclass
- Own graphical representation (if supported)

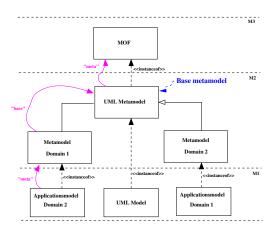
Adding to a Class



- "just" inheriting from UML::Class leads to an identical copy
- Adding an attribute to the CM::Component metaclass leads to
 - an attribute value slot in each instance
 - notation: tagged value (typed in UML 2)



Meta vs Generalization

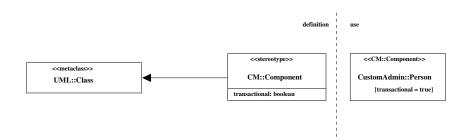


Extension Using Stereotypes (UML 1.x)



- Simple specialization mechanism of UML
- No recourse to MOF required
- Tagged Values untyped
- No new metaassociations possible

Extending Using Profiles (UML 2)



- Extension of the stereotype mechanism
- Requires "Extension arrow" as a new UML language construct (generalization with filled arrowhead)
- Not: generalization, implementation, stereotyped dependency, association, . . .
- Attributes ⇒ typed tagged values
- Multiple stereotypes possible

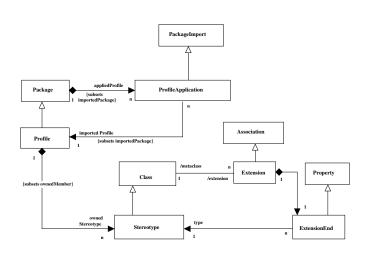


More on Profiles

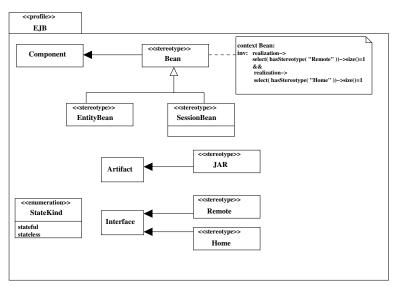
- Profiles make UML into a family of languages
- Each member is defined by application of one or more profiles to the base UML metamodel
- Tools should be able to load profiles and corresponding transformations
- Profiles have three ingredients
 - stereotypes
 - tagges values
 - constraints
- Profiles can only impose further restrictions
- Profiles are formally defined through a metamodel



Profile Metamodel



Example Profile for EJB

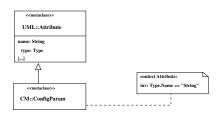


Further Aspects of Profiles

- Stereotypes can inherit from other stereotypes
- Stereotypes may be abstract
- Constraints of a stereotype are enforced for the stereotyped classifier
- Profiles are relative to a reference metamodel e.g., the UML metamodel or an existing profile
- Most tools today do not enforce profile-based modeling restrictions, so why bother with profiles?
 - constraints for documentation
 - specialized UML tools
 - validation by transformer / program generator



Metamodeling and OCL



- OCL constraints are independent of the modeling language and the metalevel
- OCL on layer Mn + 1 restricts instances on layer Mn