Model Transformations

An overview

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Model Transformations @ Google

Outline

- MDE basic principles
- What is a model-transformation?
- Typology of model-transformations
- Examples of transformations

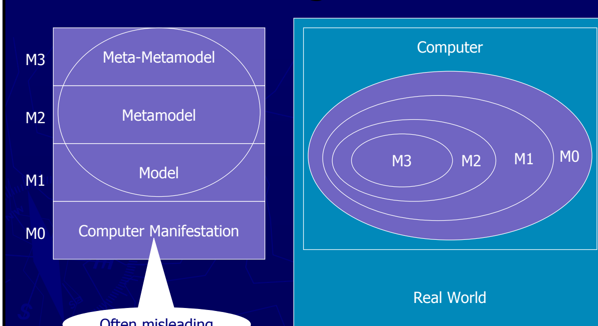
Principles of Model-Driven Engineering

- A kind of (software) development approach
- Models as first class entities
- Everything is a model
- A model conforms to an other model (meta-model)
- A model transformation takes models and produces models
- A model-transformation is a model

MDA = MDE à la OMG

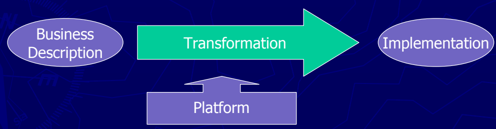
- OMG, Object Management Group
- MDA, Model-Driven Architecture
- PIM, Platform Independent Model
- PSM, Platform Specific Model
- (PDM, Platform Description Model)
- Transformation (PIM, PDM) -> PSM
  - RFP MOF Q/V/T Query, Views, Transformations
  - RFP MOF to Text

Meta-modeling architecture



Motivation

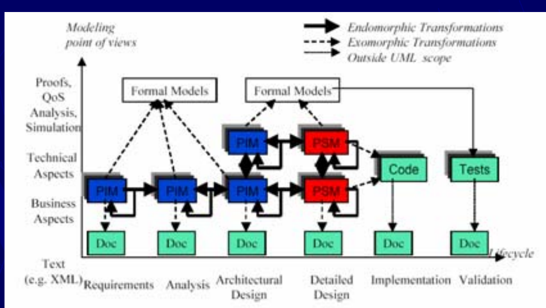
- Model transformation is key to Model-Driven Engineering
  - Automation of the transition from Business models to Implementation models



But also

- Refining models
- Reverse engineering (code to models)
- Generating new views
- Applying design patterns
- Refactoring models

Typical scope for transformations



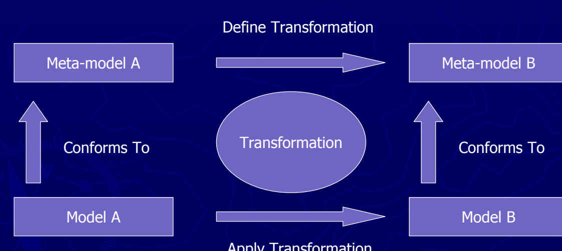
Related fields

- Program transformation and compiler techniques
- Meta-programming techniques
- Graph rewriting techniques

MOF 2.0 Queries/Views/Transformations RFP

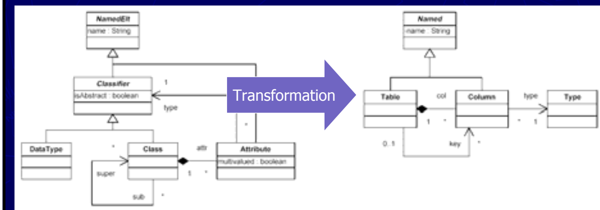
- Define a language for querying MOF models
- Define a language for transformation definitions
- Allow for the creation of views of a model
- Ensure that the transformation language is declarative and expresses complete transformations
- Ensure that incremental changes to source models can be immediately propagated to the target models
- Express all new languages as MOF models

Transformation Architecture



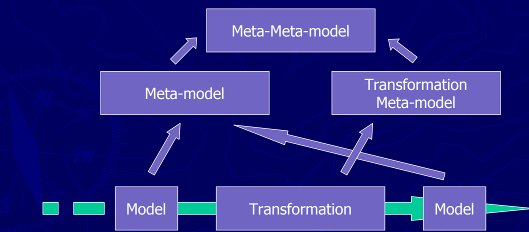
Typical Example

From UML to RDBMS



Transformations as models

- Composition of transformations
- Transformation of transformations



Toward Model-Transformations

- CRUD on model elements
  - Create, Read, Update, Delete
- Transformation rules written in
  - General purpose languages + API
  - Intermediate transformation language
  - Dedicated Model-Transformation languages

General purpose language approach

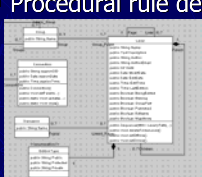
- Java, VB, C++, C#,… Your favorite language!
- Currently available in the tools via APIs
- No overhead to learn a new language
- Tool support to write the transformations

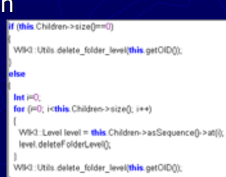
=> Monsieur Jourdain’s approach

- It’s going to be challenging to do better!

Action Language

- Use a general purpose action language
  - Better navigation facility (associations)
  - Get access to the types defined in the models
  - Procedural rule description





Intermediate transformation language

- Typically XML based
  - But XML (XMI) is verbose
- XSLT can be used to transform XML trees into other (XML) (trees)
  - More batch than interactive
  - Parameters are passed by values
  - XSLT transformations are not really easy to maintain
- Better for simple transformations

Example of XSLT transformation

```
<xsl:template match="ECA.BusinessProcessPkg.OutputGroup |
                     ECA.BusinessProcessPkg.ExceptionGroup">
   param name="a"/>
   ariable name="ct" select="concat(@xmi.id,'.condTask')"/>
   l:choose>
    <xsl:when test="self::node()[@isSynchronous = 'true']">
      <xsl:call-template name="condTaskTemplate">
        <xsl:with-param name="ct" select="$ct"/>
        <xsl:with-param name="a" select="$a"/>
      </xsl:call-template>
    </xsl:when>
    <xsl:otherwise>
      <xsl:call-template
          name="asyncCompoundTaskInputGroupOrActivityOutputGroup">
        <xsl:with-param name="a" select="$a"/>
      </xsl:call-template>
    </xsl:otherwise>
  </xsl:choose>
</xsl:template>
```

If isSynchronous

Do this

Else

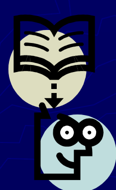
Do that

Dedicated Transformation Language

- Kind of DSL for transformation
- Simplify development and maintenance of model-transformations
- Higher expression power
- Enhanced structuration
  - Composition of rules
  - Interoperability

Dedicated transformation languages

- Terminology
- Features of model transformations



Query

- An expression evaluated over a model
  - Returns one or more instances of types defined either in the source model or by the query language
- OCL is an example of a query language

Examples of OCL queries

OCL Standard Lib Type

Query: *Has Pierre-Alain Muller sent a message about a given subject s?*

s.post->exists (author.name='Muller' and author.firstname='Pierre-Alain')

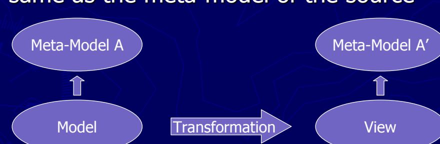
Query: *Knowing that there is only one subject about QVT, I want to retrieve it.*

Subject.allInstances()->any (title = 'QVT')

Model Type

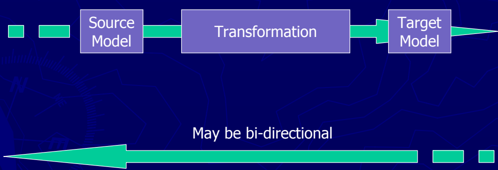
View

- A view is a model that is completely derived from another model
  - The meta-model of the view is typically not the same as the meta-model of the source



Transformation

- A transformation generates a target model from a source model



Q vs V vs T

- A query is a restricted kind of view
- A view is a restricted kind of transformation
  - The target model cannot be modified independently of the source model
- A transformation generates a target model from a source model

Declarative

- Declarative languages describe relationships between variables in terms of functions or inference rules and the language executor (interpreter or compiler) applies some fixed algorithm to these relations to produce a result

Imperative

- Any programming language that specifies explicit manipulation of the state of the computer system, not to be confused with a procedural language

Declarative vs. Imperative Style

- Declarative (what to do)
  - Invariant relations between source and target models
- Imperative (how to do it)
  - How to derive a target from a source
- May be combined via pre- and post-conditions

Execution Strategy

- Invocation of the transformation rules
  - Explicit, via invocation operations (Java like)
  - Implicit, based on context and rules' signature (Prolog like)

Trace

- Trace associates one (or more) target element with the source elements that lead to its creation
  - For Round-trip development
  - Incremental propagation
- Rules may be able to match elements based on the trace without knowing the rules that created the trace

Rule

- Rules are the units in which transformations are defined
  - A rule is responsible for transforming a particular selection of the source model to the corresponding target model elements.

Declaration

- A declaration is a specification of a relation between elements in the LHS and RHS models

Implementation

- An implementation is an imperative specification of how to create target model elements from source model elements
  - An implementation explicitly constructs elements in the target model
  - Implementations are typically directed

Match

- A match occurs during the application of a transformation when elements from the LHS and/or RHS model are identified as meeting the constraints defined by the declaration of a rule
  - A match triggers the creation (or update) of model elements in the target model

Incremental

- A transformation is incremental if individual changes in a source model can lead to execution of only those rules which match the modified elements

Classification of model transformations

Model-to-Text Approaches

- Visitor-Based Approaches
- Template-Based Approaches

Model-to-Model Approaches

- Direct-Manipulation Approaches
- Relational Approaches
- Graph-transformation-based Approaches
- Structure-Driven Approaches
- Hybrid Approaches
- Other

M2T: Visitor-based

- Some visitor mechanisms to traverse the internal representation of a model and write code to a text stream
  - Iterators
  - Write ()

M2T: Template-Based

- A template consists of the target text containing slices of meta-code to access information from the source and to perform text selection and iterative expansion
  - The structure of a template resembles closely the text to be generated
  - Textual templates are independent of the target language and simplify the generation of any textual artefacts

M2T : Template

M2M: Direct Manipulation

- Internal representation plus some API to manipulate it
- Object-oriented framework
- Rules and scheduling implemented from scratch using a programming language
- JMI (MOF-compliant Java Interface)
  - JSR-000040 Java™ Metadata Interface

JMI examples

```
package javax.jmi.model;

import javax.jmi.reflect.*;

public interface Attribute extends StructuralFeature {
    public boolean isDerived();
    public void setDerived(boolean newValue);
}
```

Attributes

```
package javax.jmi.model;

import javax.jmi.reflect.*;

public interface Operation extends BehavioralFeature {
    public boolean isQuery();
    public void setQuery(boolean newValue);
    public java.util.List getExceptions();
}
```

Operations

M2M: Relational Approaches

- Declarative, based on mathematical relations
  - Good balance between flexibility and declarative expression
- Implementable with logic programming
  - Mercury, F-Logic programming languages
  - Predicate to describe the relations
  - Unification based-matching, search and backtracking

Example of logic programming

- Excerpt of Mercury code

```
conditionaltask(Id) :-
        conditionaltask_for_outputgroup_of_activity(Id, _OutputGroup).

conditionaltask_for_outputgroup_of_activity(Id, OG) :-
        outputgroup_of_activity(OG, _Activity),
        mapId(OG^og_id, conditionaltask_for_outputgroup, Id).

outputgroup_of_activity(OutputGroup, Activity) :-
        outputgroup(OutputGroup),
        contains(Activity^a_id, OutputGroup^og_id),
        activity(Activity).
```


M2M : Graph-Transformation-Based

- Declarative, based on the theoretical work on graph transformations
  - Operates on typed, attributed, labeled graphs
  - Rule (LHS, RHS : Graph Pattern)
- Automated source element selection

About Graphs

- G. Rozenberg (ed.); "Handbook of graph grammars and computing by graph transformation: Volume I Foundations". World Scientific Publishing, 1997.
- Web site of Reiko Heckel ☺

M2M : Graph-Transformation-Based

- Powerfull, but complex because of the non-determinism in scheduling and application strategy
  - Require careful consideration of termination of the transformation process and the rule application ordering
- It is unclear how practitioners will receive these complex approaches

M2M : Structure-Driven Approaches

- 1st Phase
  - Creation of hierarchical structure of target model
- 2nd Phase
  - Set the attributes and references in the target
- Users provide the transformation rules
- Framework determines the scheduling

M2M : Structure-Driven Approaches

- Pragmatic approaches developed in the context of EJB and Databases schema generation from UML models
- Strong support for 1-to-1 and 1-to-n correspondence between source and target
- Unclear how well these approaches can support other kinds of applications

M2M : Hybrid Approaches - others

- Any combination of different techniques
- <u>Practical approaches are very likely to have the hybrid character</u>

Practically speaking

- How many developers are familiar with the prolog-like style of rules writing?
- Where is the advantage of a dedicated explicit language vs. a general purpose language?
- Hybrid Languages or transformation libraries for general purpose languages…

Tools

- Generic transformation tools
- CASE tools scripting languages
- Dedicated model transformation tools
- Meta-modeling tools

Generic transformation tools

- XSLT
- Graph Transformation tools
  - Ask Reiko ☺

CASE tools scripting languages

- **Arcstyler** from Interactive Objects
  - MDA-Cartridge, JPython (Python & Java)
- **Objecteering** from Objecteering Software
  - J language
- **OptimalJ** from Compuware
  - TPL language
- **Fujaba** (From UML to Java and Back Again)
  - Open Source

Dedicated model transformation tools

- **Mia-Transformation** from Mia-Software
  - Inference rules + Java
- **PathMATE** from Pathfinder Solutions
  - Esay to integrate with modeling tools
- **Open-Source**
  - **ATL, MTL, AndroMDA, BOTL, Coral Mod-Transf, QVTEclipse** or **UMT-QVT**

Meta-modeling tools

- **MetaEdit+** from MetaCase
- **XMF-Mosaic** from Xactium
- **Open-Source**
  - KerMeta from INRIA
  - www.kermeta.org

Coming soon

- **Model Transformations in Practice Workshop**
  - **October 3rd 2005**
  - **Part of the MoDELS 2005 Conference**
- **Comparing and contrasting various approaches**

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Questions?