On some Complementary Trends in Model Transformation Generation
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On some complementary trends in Model transformation generation

Marianne Huchard

Joint work with Xavier Dolques, Jean-Rémy Falleri and Clémentine Nebut

LIRMM - University Montpellier 2, CNRS

FTMDD, June 2010
1. MDE/MT/MTG

2. Metamodel alignment based MTG

3. Example based MTG

4. Towards a global MTG architecture
Outline

1. MDE/MT/MTG
2. Metamodel alignment based MTG
3. Example based MTG
4. Towards a global MTG architecture
Model Driven Engineering

Development paradigm
- model-centered

Advantages
- capitalizing on modelling
- interoperability
- coding technology independent
Consequences

- dependent from modelling technology
- a lot of models, meta-models
- a lot of transformations
The nature of transformations

A few examples

- CIM-PIM-PSM and variants
- software migration
- metamodel version changes
- model building, merging, refactoring

Classifications


Programming a model transformation

Actors
- domain expert
- transformation developer

Languages
- generalist programming languages + model manipulation frameworks (e.g. Java + EMF)
- dedicated programming languages (e.g. QVT, ATL, Kermeta, VIATRA, etc.)

Required knowledge
- transformation language
- source and target meta-model
- meta-meta-model
- complete specification of the transformation
The need for generating model transformations

Context

- Many tools that manipulate models and need to exchange them (code generators, model transformation editors, graphical editors)
- Many evolution of software with technology change
- Many close models (e.g. class models UML, MOF, EMOF, KMT3)
- Many versions of the same metamodel (e.g. UML)

Support for transformation developers

Automatically generate part of the transformation program
Opportunities for generating model transformations

What makes it possible
- Simplicity of many transformations
- Declarative paradigm (rules : model pattern → model pattern)

Close problematics with experience
- Web semantic, ontology alignment, schema matching techniques
- Database, interoperability (ETL tools)

Currently two main tracks
- Metamodel alignment based MTG
- Example (Model) based MTG
Metamodel alignment based MTG

UML metamodel to Entity-Relationship metamodel
Model alignment based MTG

UML metamodel to Entity-Relationship metamodel
What we know to do?

Starting from metamodels
- Metamodel alignment
- Derive rules from alignment

Starting from models (transformation examples)
- Model alignment
- Derive rules from alignment
Outline

1. MDE/MT/MTG
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4. Towards a global MTG architecture
Metamodel alignment (A task in MTG)

Principle

Establishing a match between the two metamodels
# Metamodel alignment (A task in MTG)

**Context**
- metamodels: describing same sort of things
  (class metamodels, traceability metamodels, etc.)

**Interest**
- not necessary to have examples (except for testing)
- abstract language manipulation
- prior specification of the transformation is not required
What we did

Similarity Flooding (Melnik et al.) for matching

- Similarity flooding works on labeled directed graphs
- Similarity flooding is easily tunable

Using matching

- Testing several configurations for Similarity Flooding use
- Definition of a metamodel alignment
- Automatic construction of alignment models
The three steps

- From metamodels to graphs
- Application of Similarity Flooding
- Construction of an alignment metamodel using the result of Similarity Flooding
1. From metamodems to graphs
# Transform a metamodell into a labelled directed graph

<table>
<thead>
<tr>
<th><strong>Input</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A metamodell</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Output</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A directed labelled graph representing the model</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Objective</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Study the impact on Similarity Flooding of the configuration choice</td>
</tr>
<tr>
<td>- Six tested configurations</td>
</tr>
<tr>
<td>- Comparison of the results</td>
</tr>
</tbody>
</table>
Configuration Minimal

- Metamodel elements are converted into labelled nodes
- Relations are converted into labelled edges
- Derived attributes, references, operations and parameters are ignored
Next configurations

- Basic : separate elements and their names
- Standard : adding metaclasses, cardinality and containment
- Full : adding derived attributes and references
- Saturated : close supertype, apply inheritance
- Flattened : abstract class nodes and supertype edges are removed
2. Similarity Flooding
First step: The compatibility graph
First step: The compatibility graph

exCG

(Operation, JTypedElement) ▸ ref ▹ (operations, type)

(Class, JTypedElement) ▸ type ▹ (Operations, type)

(type, type) ▸ type ▹ (Class, JClass)

(Operation, JClass) ▸ supertype ▹ (NamedElement, JMethod)

(operations, methods) ▸ ref ▹ (NamedElement, JTypedElement)

(EString, String) ▸ datatype ▹ (name, name)

(name, name) ▸ type ▹ (Operation, JMethod)

(Operation, JMethod) ▸ type ▹ (Class, JMethod)
Second step: propagation graph
Third step: assigning initial similarity values

- 0 if \(x\) or \(y\) is an identifier (not a model element name)
- \(1 - \text{levenshtein}(x, y)/\max(\text{length}(x), \text{length}(y))\) otherwise

<table>
<thead>
<tr>
<th>Compatibility node</th>
<th>Initial similarity value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NamedElement, JElement)</td>
<td>0.5833334</td>
</tr>
<tr>
<td>(name, name)</td>
<td>1.0</td>
</tr>
<tr>
<td>(EString, String)</td>
<td>0.85714287</td>
</tr>
<tr>
<td>(NamedElement, JTypedElement)</td>
<td>0.6923077</td>
</tr>
<tr>
<td>(Operation, JTypedElement)</td>
<td>0.23076922</td>
</tr>
</tbody>
</table>
Fourth step: propagation and fix point calculus

**Principe**

- Propagation of similarity values in the propagation graph, until finding a fix point.
- Propagation formulae: at step $i$,
  
  $$s_{n}^{i+1} = s_{n}^{i} + s_{n}^{0} + \sum_{m \in I_n} w(m, n) \times (s_{m}^{0} + s_{m}^{i})$$

- Fixpoint: when similarity values differences is less than $\epsilon$ during two successive steps.
Fifth step : filtering

Principe

- To keep best matches.
- A node of $G_{source}$ can match with several nodes of $G_{target}$.
- A relative similarity value is computed for each node looking at the leaving edge similarities.
- Pairs with a similarity under a threshold are eliminated.
## Case study

### Objectif

Testing the six configurations

### Data

- `exMMSource → exMMTarget`
- `Ecore → Minjava`
- `Ecore → Kermeta`
- `Ecore → UML`
Metrics

\[
\text{precision, recall et } f\_\text{score :}
\]
\[
\text{precision} = \frac{\text{Number of Correct Found Mappings}}{\text{Number of Total Found Mappings}}
\]
\[
\text{recall} = \frac{\text{Number of Correct Found Mappings}}{\text{Number of Total Existing Mappings}}
\]
\[
\text{f\_score} = \frac{2 \times \text{recall} \times \text{precision}}{\text{recall} + \text{precision}}
\]
Results

exMMSource → exMMTarget

- Not so bad results, good precision
- Better results for similar metamodel size
- Configurations Saturated and Basic give good results
Not so bad results, good precision
Better results for similar metamodel size
Configurations Saturated and Basic give good results
Conclusion on metamodel alignment

- A tool that automatically aligns two metamodels
- Assessment of different configurations
- Alignments can be used for the transformation generation e.g. with the approach of [Lopes et al.]
Outline

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Example based MTG (MTBE)

**Principle**

Inducing transformation rules from transformed models examples.

**Context**

- metamodels: similar to very different;
- a set of examples

**Interest**

- use of existing data
- concrete language manipulation
- prior specification of the transformation is not required
Input data
Output data

Transformation rules

<table>
<thead>
<tr>
<th>UML</th>
<th>Entity–Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Entity</td>
</tr>
<tr>
<td>Property +association(Association)</td>
<td>Role</td>
</tr>
<tr>
<td>Property –association(Association)</td>
<td>Attribute</td>
</tr>
</tbody>
</table>
Two-step process
## Anchor discovery

### Anchor pair
An element in a source model which is surely connected to an element of the target model.

### Hypothesis
When the model is transformed, names remain quite the same.

### String matching operations
- equality
- substring
- levenshtein (editing) distance
### Principle

- Inspired by anchorPROMPT approach (noy et al.)
- Align a path in the source model and a path in the target model
- Admit a little size difference between the two paths
- Give weights to matchings, then filter
Anchor-based matching process

Original anchorPROMPT propagation
Anchor-based matching process

Extension to paths with different size
e.g. generalization in UML versus is-a relation in ER
Precision on case study

number of relevant retrieved matches / number of retrieved matches

![Graph showing precision in various case studies](image)
Recall on case study

number of relevant retrieved matches / number of relevant matches

![Chart showing recall on case study](chart.png)

- Red: recall substring
- Green: recall anchorPrompt
Fscore on case study

\[
Fscore = 2 \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}} \quad \text{(best is 1)}
\]

![Graph showing Fscore values for different classes and associations]
Rule discovery

Examples

Rules discovery

Relational Concept Analysis

Rules

- UML
  - Class
  - Property +association(Association)
  - Property -association(Association)

- Entity–Relation
  - Entity
  - Role
  - Attribute
## Rules discovery

### Discovery process’ properties
- classification of models elements
- classification of mapping links
- derive rules

### Relational Concept Analysis [Huchard et al. 2007]
- extension of Formal Concept Analysis [Wille1982]
- considers relationships in the classification process
Example data

UML model example (seen as instance of the metamodel)

Simplified UML meta-model
Classification of model elements

<table>
<thead>
<tr>
<th><strong>meta-class</strong></th>
<th><strong>Class</strong></th>
<th><strong>Property</strong></th>
<th><strong>Association</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Account</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>owner</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>owned</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>owns</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>numero</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>name</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model element classification using their meta Classes
Classification of model elements

<table>
<thead>
<tr>
<th>meta-class</th>
<th>Class</th>
<th>Property</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Account</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>owner</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>owned</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>owns</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>numero</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>name</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

model element classification using their meta-Classes

concepts
Classification of model elements

<table>
<thead>
<tr>
<th>owningClass</th>
<th>Account</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>name</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>owner</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Model elements classification using their target by the relation `owningClass`. 
Model elements classification

Lattice of the UML model’s elements
Classification interpretation

Concept 3 description.

Concept 6 description.
## Classification properties

### Classification properties of a model element

- its type
- relations of which it is one end
- types of the elements of which it is associated

### Contexts to create

- **Formal contexts:**
  - model elements context
  - meta-model elements context
- **Relational contexts:**
  - instance relation between model and meta-model
  - relations between elements in the model
Classification of mapping links

<table>
<thead>
<tr>
<th>linkA</th>
<th>Account</th>
<th>Client</th>
<th>number</th>
<th>name</th>
<th>owns</th>
<th>owner</th>
<th>owned</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L4</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>L9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

**Table:** Relation of mapping links with model source elements

<table>
<thead>
<tr>
<th>linkB</th>
<th>Account</th>
<th>Client</th>
<th>number</th>
<th>name</th>
<th>owns</th>
<th>owner</th>
<th>owned</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L4</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>L9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

**Table:** Relation of mapping links with model target elements.
Mappings lattice

mapping links lattice
Rules extraction

Concept 8 description

Concept 10 description
Implementation

Tools

- Eclipse Modeling Framework (EMF)
- lattice generation plugin : eRCA
- template generation tool : Acceleo
- declarative model transformation language : ATL

Correlation between Source and Target MMs using Mapping MM.

Generated code

Modeling framework:

- Source MM
- Target MM
- Mapping MM
- eRCA MM
- RCA
- Lattices
- Rules
- Generated code
The rule lattice
The rule Property Attribute
The rule Property Role

![Diagram showing the relationship between Property, Association, and Role]

- **Property**
  - association 1-1 to **Association**
  - role 1-1 to **Role**

- **Association**
  - owningClass 1-1
  - ownedEnd 1-1
  - owningAssociation 1-1
  - association 1-1
  - memberEnd 1-1
  - association 1-1
  - Relationship 1-1
  - role 1-1
  - refersTo 1-1
  - role 1-1
**Validation (in progress)**

**Table:** Data obtained from the case study (ATL zoo)

<table>
<thead>
<tr>
<th></th>
<th>F2P ¹</th>
<th>B2D ²</th>
<th>C2R ³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source MetaModel size</td>
<td>4</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Target MetaModel size</td>
<td>5</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Source Model size</td>
<td>23</td>
<td>48</td>
<td>9</td>
</tr>
<tr>
<td>Target Model size</td>
<td>19</td>
<td>59</td>
<td>15</td>
</tr>
<tr>
<td>Mapping size</td>
<td>28</td>
<td>115</td>
<td>18</td>
</tr>
<tr>
<td>ATL transfo. Number of rules</td>
<td>2</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>ATL transfo. Number of helpers</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Generated transfo. Number of rules</td>
<td>6</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Generated target model size</td>
<td>21</td>
<td>54</td>
<td>16</td>
</tr>
<tr>
<td>Bad generated elements</td>
<td>2</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Missing elements in generation</td>
<td>0</td>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>

¹ : Family2Person — ² : BibTex2DocBook — ³ : Class2Relation
Outline

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## Related work

### MM-based MTG
Adapted to similar metamodels
- Ontology-based, pivot ontology (Roser at al., Kappel et al.)
- Propagation and complete process (Lopes et al.)

### M-based MTG (MTBE)
Adapted when examples are known
- Guiding the way from concrete to abstract syntax with OCL rules (Wimmer et al.))
- Inductive logics based (Varró et al.)
- Optimization approach (Kessentini et al.)
## A road map

### The solution / a mix of
- Alignment
- Learning
- Domain knowledge, semantics

### Open questions
- Improve alignment techniques for metamodels and models
- Propose alternative learning schemes
- Classifying MT - characterizing suitable MTG methods
- Measuring rule interestingness (e.g. support and lift)
- Propose an integrated approach
- Collaboratively build a benchmark
Links

- Gum (similarity flooding alignment) - http://code.google.com/p/gumm-project
- eRCA - http://code.google.com/p/erca

References