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
**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
<table>
<thead>
<tr>
<th>Opportunities for generating model transformations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What makes it possible</strong></td>
</tr>
<tr>
<td>- Simplicity of many transformations</td>
</tr>
<tr>
<td>- Declarative paradigm (rules : model pattern → model pattern)</td>
</tr>
<tr>
<td><strong>Close problems with experience</strong></td>
</tr>
<tr>
<td>- Web semantic, ontology alignment, schema matching techniques</td>
</tr>
<tr>
<td>- Database, interoperability (ETL tools)</td>
</tr>
<tr>
<td><strong>Currently two main tracks</strong></td>
</tr>
<tr>
<td>- Metamodel alignment based MTG</td>
</tr>
<tr>
<td>- Example (Model) based MTG</td>
</tr>
</tbody>
</table>
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

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Metamodel alignment (A task in MTG)

Principle

Establishing a match between the two metamodels

Diagram showing the alignment between two metamodels, with classes and operations mapped to each other.
## 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 metamodels to graphs
Transform a metamodel into a labelled directed graph

Input

A metamodel

Output

A directed labelled graph representing the model

Objective

- Study the impact on Similarity Flooding of the configuration choice
- Six tested configurations
- Comparison of the results
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
- **(Class, JTypedElement)**
  - type
  - supertype
- **(operations, type)**
  - ref
- **(Class, JTypedElement)**
  - type
  - supertype
  - ref
- **(type, methods)**
- **(NamedElement, JElement)**
  - own
  - supertype
- **(NamedElement, JTypedElement)**
  - supertype
- **(EString, String)**
  - datatype
  - name
  - name
- **(name, name)**
  - type
- **(Operation, JMethod)**
  - type
- **(Class, JMethod)**
  - type
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.

![Diagram illustrating the matching process with similarity values](image)
### Objectif

**Testing the six configurations**

### Data

- `exMMSource → exMMTarget`
- `Ecore → Minjava`
- `Ecore → Kermeta`
- `Ecore → UML`
precision, recall et f_score :

- precision = \frac{\text{Number of Correct Found Mappings}}{\text{Number of Total Found Mappings}}

- recall = \frac{\text{Number of Correct Found Mappings}}{\text{Number of Total Existing Mappings}}

- f_score = \frac{2 \times \text{recall} \times \text{precision}}{\text{recall} + \text{precision}}
Results

exMMSource $\rightarrow$ exMMTarget

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

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

Examples

Alignement

Matching ex.

Matching ex.

Rules discovery

Relational Concept Analysis

Rules
Anchor discovery

<table>
<thead>
<tr>
<th>Anchor pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>An element in a source model which is surely connected to an element of the target model</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the model is transformed, names remain quite the same</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>String matching operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>- equality</td>
</tr>
<tr>
<td>- substring</td>
</tr>
<tr>
<td>- levenshtein (editing) distance</td>
</tr>
</tbody>
</table>
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 for different terms]
Recall on case study

number of relevant retrieved matches / number of relevant matches
\[ F_{score} = 2 \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}} \] (best is 1)
Rule discovery

Examples

Rules discovery

Relational Concept Analysis

Rules

- UML
- Entity-Relation

- Class
- Entity

- Property
- Role

- Property
- Attribute

Examples

Class

Property

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>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>X</td>
<td></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>X</td>
<td></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 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></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>L6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</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></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>L6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</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
The rule lattice
The rule Property Attribute
The rule Property Role

```
xnetwork
[Property] - association 1-1 - [Association]

[Association] - owningClass 1-1
[Association] - ownedEnd 1-1
[Association] - owningAssociation 1-
[Association] - association 1-1
[Association] - memberEnd 1-1
[Association] - association 1-1

[Role] - Relationship 1-1
[Role] - role 1-1
[Role] - refersTo 1-1
[Role] - role 1-1
```

 tackled. Based on a Simple Example Based
### Table: Data obtained from the case study (ATL zoo)

<table>
<thead>
<tr>
<th>Source MetaModel size</th>
<th>F2P</th>
<th>B2D</th>
<th>C2R</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>21</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Target MetaModel size</td>
<td>5</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>23</td>
<td>48</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Source Model size</td>
<td>19</td>
<td>59</td>
<td>15</td>
</tr>
<tr>
<td>Target Model size</td>
<td>28</td>
<td>115</td>
<td>18</td>
</tr>
<tr>
<td>Mapping size</td>
<td>2</td>
<td>9</td>
<td>6</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

<table>
<thead>
<tr>
<th>The solution / a mix of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment</td>
</tr>
<tr>
<td>Learning</td>
</tr>
<tr>
<td>Domain knowledge, semantics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve alignment techniques for metamodels and models</td>
</tr>
<tr>
<td>Propose alternative learning schemes</td>
</tr>
<tr>
<td>Classifying MT - characterizing suitable MTG methods</td>
</tr>
<tr>
<td>Measuring rule interestingness (e.g. support and lift)</td>
</tr>
<tr>
<td>Propose an integrated approach</td>
</tr>
<tr>
<td>Collaboratively build a benchmark</td>
</tr>
</tbody>
</table>
Links

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

References