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

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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
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## 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

Models (examples)

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
1 MDE/MT/MTG
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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](image-url)
# 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

<table>
<thead>
<tr>
<th>Similarity Flooding (Melnik et al.) for matching</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Similarity flooding works on labeled directed graphs</td>
</tr>
<tr>
<td>- Similarity flooding is easily tunable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Using matching</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Testing several configurations for Similarity Flooding use</td>
</tr>
<tr>
<td>- Definition of a metamodel alignment</td>
</tr>
<tr>
<td>- Automatic construction of alignment models</td>
</tr>
</tbody>
</table>
Three steps

The three steps

1. From metamodels to graphs
2. Application of Similarity Flooding
3. 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
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

Diagram showing the relationships between various elements such as `Operation`, `JTypedElement`, `Class`, `JClass`, `NamedElement`, and `JMethod`, with arrows indicating relationships like `ref`, `type`, `supertype`, `own`, and `datatype`.
Second step: propagation graph
Third step: assigning initial similarity values

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

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

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

**Principle**
- 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.

```
operations \(\times\) type
\(0.11 \times 0.64\)
\(0.52 \times\) methods

operations \(\times\) type
\(0.21 \times 0.21\)
\(1.0 \times\) methods
```
## Case study

### Objectif

Testing the six configurations

### Data

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

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

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

\[ \text{f-score} = \frac{2 \times \text{recall} \times \text{precision}}{\text{recall} + \text{precision}} \]
Results

exMMS Source → exMM Target

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

Ecore → Minj ava

- Minimal
- Basic
- Standard
- Full
- Flattened
- Saturated
Results

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

Entity

Role

Attribute

Association

Class

Type

Role

RelationShip

Cardinality

min:int

max:int

Property

upper:int

lower:int

ownedEnd

memberEnd

ownedClass

owningClass

ownedAttribute

Association

owning Association

0..1

0..1

1

Account

number

owns

owner

1

Client

name

1

1

1

1

1

min:int

max:int

0..1

0..1

memberEnd

ownedEnd

owner

owned

entity

attribute

refersTo

relationShip
Output data

Transformation rules

UML

Entity–Relation

Class

Entity

Property +association(Association)

Role

Property −association(Association)

Attribute
Two-step process

Examples → Alignement → Matching ex.

Alignement anchor PROMPT → Rules discovery

Matching ex. → Relational Concept Analysis → Rules

Rules

- URL
- Entity-Relation
  - Class → Entity
  - Property
    - "association/absent" → Role
    - "property/absent" → Attribute
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
Anchor propagation

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

![Bar chart]
Recall on case study

number of relevant retrieved matches / number of relevant matches

![Bar chart showing recall rates for various case studies](chart.png)
\[ F_{score} = 2 \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}} \text{ (best is 1)} \]
Rule discovery

Examples

Rules discovery

Relational Concept Analysis

Rules

- Class
  - Entity
- Property +association(Association)
  - Role
- Property −association(Association)
  - 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></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

### Simple concepts

Model element classification using their meta-Classes
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>x</td>
<td></td>
</tr>
</tbody>
</table>

Model elements classification using their target by the relation `owningClass`. 
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 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>
</tr>
<tr>
<td>L2</td>
<td></td>
<td>x</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>
</tr>
<tr>
<td>L4</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>x</td>
</tr>
<tr>
<td>L6</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>
</tr>
</tbody>
</table>

Table: Relation of mapping links with model source elements

<table>
<thead>
<tr>
<th>linkB</th>
<th>Account</th>
<th>Client 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>
</tr>
<tr>
<td>L2</td>
<td></td>
<td>x</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>
</tr>
<tr>
<td>L4</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>x</td>
</tr>
<tr>
<td>L6</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>
</tr>
</tbody>
</table>

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

Concept 8 description

Concept 10 description
Tools

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

Implementation
The rule lattice
The rule Property Attribute
The rule Property Role
### Validation (in progress)

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

<table>
<thead>
<tr>
<th>Source MetaModel size</th>
<th>F2P $^1$</th>
<th>B2D $^2$</th>
<th>C2R $^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target MetaModel size</td>
<td>4</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Source Model size</td>
<td>5</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Target Model size</td>
<td>23</td>
<td>48</td>
<td>9</td>
</tr>
<tr>
<td>Mapping size</td>
<td>19</td>
<td>59</td>
<td>15</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
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## Related work

### MM-based MTG
Adapted to similar metamodels
- Ontology-based, pivot ontology (Roser et 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