Ontology-based Verification of Core Model Conformity in Cadastral Modeling

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Agenda

1. Information Technology and Standardization
2. Conformity Verification for the Cadastral Domain
3. A Worked Example
4. Conclusions
Information Technology

- **Standard software for cadastral systems?**
  - Currently, cadastral systems are custom-made technology
  - Standard software is state-of-the-art in other application domains:
    - Enterprise Resource Planning (ERP) systems
  - ERP run worldwide despite differences in IT infrastructure, data and process models, national legislation

- **Conformity verification**
  - Technology that supports data and process modeling
  - Basis for cadastral systems as customizable standard software
Cadastral Standardization

- A common misunderstanding
  - Standardization does NOT aim at having a single cadastral system running in all countries.
  - The purpose of standardization consists in identifying common structures in cadastral data and process models.
  - and to exploit them for building software components for customizable standard software.

- Data and process modeling
  - Development of a core cadastral data and process model
  - National models as extensions of the core cadastral model
To ensure interoperability, every cadastral system should implement concept X.

I found concept X in all cadastral systems I looked at so far.

Core Cadastral Domain Model

Core Modeler (TU Delft, ITC)
I modeled concept Y to match concept X of the core cadastral model.

I understood concept X in the following way.

Domain Modeler
(Greek Cadastre)
Conformity Verification

Core Model

Conceptual Conformity Checker

CCC

Domain Model

Conformity Intentions

Modeling Intentions

Hess, Schlieder: Ontology-based Conformity Verification
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Iterative Modeling Process

Core Model: Formalization of Conformity Intentions

Domain Model: Formalization of Modeling Intentions

Reasoning support by CCC:
- Necessary Modifications
- Inconsistencies
- Satisfaction of Constraints

Conformity
Data Modeling Technologies

- Technology generations
  - Entity-Relationship Models
  - Object-oriented Modeling (UML and literate UML)
  - Ontological Modeling

- Ontological modeling?
  - Enhanced expressiveness
  - Reasoning support

International Committee for Documentation of the International Council of Museums (ICOM-CIDOC)

1994  Entity relationship model
2002  Object-oriented model
2004  Formal ontological model
Ontological Modeling

XMI + text

```xml
<UML:Class xmi.id = 'a15' name = 'Person'
    visibility = 'public' isSpecification = 'false'
    isRoot = 'false' isLeaf = 'false' isAbstract = 'false' isActive = 'false'>
    ...
    <UML:Attribute xmi.id = 'a373' name = 'tmin' visibility = 'private' isSpecification = 'false'
        ownerScope = 'instance'>
        ...
    </UML:Attribute>
    ...
</UML:Class>
```

OIL

```xml
<daml:Class rdf:about="#Person" rdfs:label="Person"> ...
    <daml:Restriction>
        <daml:onProperty>
            <daml:DatatypeProperty rdf:about="#Person_tmin"/>
        </daml:onProperty>
        <daml:hasClass rdf:resource="http://www.w3.org/2000/10/XMLSchema #date"/>
        <daml:disjointUnionOf rdf:parseType="daml:collection">
            <daml:Class rdf:about="#NaturalPerson"/>
            <daml:Class rdf:about="#NonNaturalPerson"/>
        </daml:disjointUnionOf>
    </daml:Restriction>
    ...
</daml:Class>
```

"Each Person is either a NaturalPerson or a NonNaturalPerson. No Person can be a NaturalPerson and a NonNaturalPerson."
Generic Mapping Relations

- **Modeling workflow**
  - Correspondences are identified by domain experts
  - Small set of generic mapping relations

- **Correspondences**
  - Classes
  - Attributes
  - Classes and attributes

- **Heterogeneity problems**
  - Structural heterogeneity: Semantically equivalent information is stored in different data structures
  - Semantic heterogeneity: Different interpretation of syntactically the same information
Correspondence in OIL

- Correspondence between attributes: `daml:samePropertyAs`

```xml
<daml:ObjectProperty
    rdf:about="core_cad.daml#Person_SubjID"
    rdfs:label="Person_SubjID">
    <daml:domain rdf:resource="core_cad.daml#Person"/>
    <daml:range rdf:resource="core_cad.daml#oid"/>
    <daml:samePropertyAs rdf:resource="#Greek_cad.daml#BENEFICIARY_BEN_ID"/>
</daml:ObjectProperty>
```
Types of Correspondence

- **Reasoner**
  - determines type of the identified correspondence by ontological reasoning

- **Types**
  - Equivalence
  - Subsumption
  - Overlapping

- **Special Cases**
  - Restriction of the range of an attribute
  - Co-extensional concepts without corresponding attributes
  - Corresponding packages
Query and Interpretation

<table>
<thead>
<tr>
<th>Type</th>
<th>Query to RACER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalence</td>
<td>concept-equivalent?</td>
</tr>
<tr>
<td>Subsumption</td>
<td>concept-subsumes?</td>
</tr>
<tr>
<td>Overlapping</td>
<td>Create new class + concept-satisfiable?</td>
</tr>
</tbody>
</table>

Example:
(concept-equivalent?
|core_cad.daml#Person||Greek_cad.daml#BENEFICIARY|);

... 

Result: True or false

Interpretation: The classes Person and BENEFICIARY are, according to the identified correspondences, overlapping.

Is this type of correspondence sufficient?
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1st Iteration: “Person”-Classes

Corresponding Person-Classes must be in every cadastral model.

Core Modeler

Core Model

Greek Model
1st Iteration: Results of the Reasoner

- Correspondences only of the overlapping type:
  - Person – BENEFICIARY
  - NaturalPerson – BENEFICIARY
  - NonNaturalPerson – BENEFICIARY

- No relation between the specialization classes

- No corresponding attribute for
  - t_min and t_max (class Person)
  - BEN_TYPE (class BENEFICIARY)
2\textsuperscript{nd} Iteration: Proposed Modifications
2nd Iteration: Results of the Reasoner

- Person and BENEFICIARY are equivalent
  - Temporal aspects must be either added to the class BENEFICIARY or omitted in the class Person!
- Equivalence between the specialization classes:
  - NaturalPerson equivalent with NATURAL,
  - NonNaturalPerson equivalent with LEGAL.
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First results

Evaluation of the example
- Poor results of the first iteration due to the limited number of formalized correspondences
- First iteration provides advice for the subsequent iteration
- Results of the 2nd iteration must be evaluated by domain experts

Next steps
- Refinement of the correspondences between core and Greek cadastral model
- 2nd iteration with all refined correspondences
- Elaboration of the attribute-level of core and domain models
Conclusions

- Improved conformity between the models
  - Resoner results provide useful advice for subsequent iterations
  - Iterative refinement of the correspondences

- Difficulties in the models are revealed
  - Need for discussing core and domain models
  - Core and domain models at the same level of abstraction

- Conforming models as basis for new applications
  - Exchange of cadastral data
  - Development of customizable standard software

- Future research
  - Conformity verification is not restricted to the cadastral domain
  - Extension of the conformity verification to process models