Scientific Report

Ontology Engineering for the Core Cadastral Domain Model

Short Term Scientific Mission at Delft University of Technology

COST-STSM-G9-00459

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Table of Contents

1 Introduction

The Short-Term Scientific Mission (STSM) “Ontology Engineering for the Core Cadastral Domain Model” aimed at supporting the modeling process of the core cadastral model with Semantic Web technologies. The structure of the modeling process and the conformity between core and national models were focus of attention. Discussions with domain experts and practical work on the basis of the approach to conformity verification developed at Bamberg University were planned. This approach defines “conformity” between core and derived models with the help of ontologies. An evaluation of its contributions to the further development of the core cadastral domain model and the national cadastral model was intended.

The STSM was held at Delft University of Technology, 09/08/04 – 13/08/04. The scientific work carried out during the visit and its results are described in section 2. Common research interests for future cooperation will be described in section 3.

2 Research Topics

2.1 Discussion on the Ontology Engineering Process for the Core Cadastral Model

From the point of view of the information sciences, it is interesting to look at the development process of the core cadastral model which takes place in an international context requiring the coordination of the sometimes contrary interests of most European countries.
Peter van Oosterom and Christiaan Lemmen took in 2003 the initiative for a core cadastral domain model. At the FIG working week in Paris 2003, they proposed the standardization of a cadastral model and presented a first version of the core cadastral domain model. This first version was centering more on implementation issues of cadastral systems whereas in the following versions, the focus changed to communication issues. The current version of the core cadastral model is therefore not only a database model, but a model supporting the exchange of cadastral information between different organizations and nations. It acts as an ontology formalizing concepts and their shared understanding.
Subsequent versions of the core cadastral domain model were developed on the basis of feedback given by domain experts from different countries on the relations between their national model and the current version of the core cadastral model. The refinement of the core cadastral domain model is iterative, but up until now, there is no formal conformity test between each new version of the core cadastral domain model and national models.

In the context of the standardization effort for a core cadastral domain model, Claudia Hess was interested in the question whether or not there might be more than one core model for the cadastral domain. This might be the case if conceptual models of an application domain show so many differences that it becomes impossible to develop one single core model. Instead of one model cluster of models with central and peripheral models can be identified.
Peter van Oosterom argued that this does not hold in the cadastral domain. Each national cadastral model should be in some way similar to the core cadastral domain model. Otherwise it

would not represent a conceptual model for the cadastral domain because its boundaries to adjacent domains would be so different from the core cadastral domain model that its content would not be any more the content of a cadastral system.

2.2 Presentation on the Conformity Verification and Demonstration of the Prototype

After a presentation of the current version of the core cadastral domain model by Wilko Quak (Delft University of Technology) and a discussion about several modeling decisions, Claudia Hess presented the ontology-based verification of core model conformity developed at Bamberg University. A demonstration of the prototype followed the presentation. The presentation can be found in the appendix.

The presentation aimed at giving an overview of the work carried out in Bamberg and its advantages for the standardization effort in the cadastral domain. We had an extended discussion on the value of the approach and the different expectations on the possible contributions of Semantic Web technologies to the development of a core cadastral domain model. Furthermore, we discussed whether or not it would be reasonable to define conformity constraints for the core cadastral domain model.

2.2.1 Value of the Conformity Verification for Cadastral Modeling

Conformity verification offers several features being able to increase the quality of the core cadastral domain model and the national cadastral models. It supports users in verifying their intentions in a formal way. For example, the class *BENEFICIARY* (Greek cadastral model) should correspond to the class *Person* (core cadastral model). A representation of the core cadastral domain model and the Greek model in an ontology modeling language permits to check the type of the identified correspondences by a reasoner. Remark that the type of a correspondence is not necessarily the intended type because classes are embedded in a hierarchical structure. Implicit knowledge can be made explicit, i.e. knowledge encoded in the models which might be missed by human readers is determined by the reasoner. In addition, a reasoner detects inconsistencies in and across core and national cadastral models. The results obtained by the inference services are interpreted by the prototype developed in the scope of the work in Bamberg.

Since the modeling work is not yet completed for both the core cadastral model and the Greek model and only few correspondences were identified between the core and the Greek model, we cannot expect the reasoner to come up with a result of the type “domain model conforms to the core model”. However, an analysis of the reasoner’s results can give indications on the modeling steps to take in the next iteration of the modeling process. For instance, a large number of overlapping concepts show that conformity constraints and intended correspondences need to be strengthened. Possible modifications in core or Greek cadastral models serving as input for subsequent iterations were discussed in the following days. For this discussion, see 2.3.

An important question is as to whether or not the results of the conformity verification justify the manual identification of correspondences. But taking into account the effort investigated in the modeling of core and national cadastral models and their high quality, it is justified to use a manual identification guaranteeing to preserve the this high quality. An automated approach could not guarantee that. State-of-the-art approaches to automated matching, like lexical analysis of concept names, are not applicable to the cadastral models as they are not necessarily provided in the same language and use very different concept names due to historical development of the national cadastral systems.

2.2.2 Definition of Conformity Constraints

Conformity constraints permit to describe a core model as a normative standard for conceptual models of the same domain. These domain models are not forced to implement the core model as it is, but could extend it to their own requirements. Conformity constraints therefore formalize, according to the conformity verification developed at Bamberg University, a set of classes in the core cadastral model for which a corresponding class must be present in the national cadastral model. The type of the correspondence must be the type required by the conformity constraint. For instance, we might allow for a concept in the national model to be equivalent to a concept to the core model or to be a specialization, i.e. to extend it to the national legislation or local particularities. Thus, conformity constraints define a base model as part of the core cadastral domain model, which must be present in every national cadastral model declared as an extension of the core cadastral model. Conformity constraints would guarantee a minimum of exchangeable information between all European cadastral systems.

It could be argued that such conformity constraints decrease the acceptance of the core cadastral domain model. National cadastral modeler could have the impression that they should be forced to implement the core model and give up their own model. But this would lead to the discussion whether or not a core cadastral model will be accepted by national cadastral experts as a normative model for cadastral systems. From the point of view of the information sciences, the conformity constraints are sensible as they define the parts of the conceptual realm which can be translated into another conceptual realm. The decision whether or not this is sensible for the cadastral domain is reserved to the cadastral experts.

2.3 Modeling Issues of the Greek Cadastral Model

Peter van Oosterom, Jaap Zevenbergen and Claudia Hess studied the Greek cadastral model with regard to its correspondences and differences to the core cadastral domain model. We discussed several decisions made during the modeling of both models. We concentrated on the legal and administrative aspects of both model. It would be interesting to continue this discussion during the next working group meeting WG2 in Székesfehérvár, Hungary in September 04 with cadastral experts from Greece.

The following modeling issues concerning different formalizations and modeling primitives used in both the core and the Greek cadastral model were discussed:

- In the core cadastral model, the class *RigthOrRestriction* is represented as association class to the association between the classes *Person* and *RealEstateObject*. The structure between the corresponding classes *BENEFICIARY*, *RIGHT* and *REAL_PROPERTY* in the Greek model and the above mentioned classes of the core model is different. We discussed whether or not both structures are conceptually equivalent. From the point of view of ontological modeling, it can be stated that an association class must be converted to the same structure as provided by the Greek model.
- Testing the conformity between the Greek cadastral model and the core cadastral domain model, it is problematic that the Greek model does not keep track of history like the core cadastral domain model.
- In general, it can be stated that the Greek model is – in contrast to the core cadastral model being a conceptual model - rather an implementation model. An example is the attribute *Ben_Type* in the class *BENEFICIARY*.

2.4 Refinement of the Correspondences between Core and Greek Model

We reflected on the correspondences between the person-classes of both models proposed by Greek domain experts and used for the first iteration of conformity verification between the core and the Greek cadastral models. The results of the first iteration, that is only relations of the overlapping type for the person-classes, were analyzed and correspondences were strengthened in order to obtain relations of the type specialization or even equivalence.
The discussion resulted in some proposed modifications in the Greek model and above all, modifications in the correspondences identified between Greek and core cadastral model. Note that the following points are only propositions. The decision whether or not they should these proposed modifications should be realized must be made by the Greek domain experts themselves.

- The attribute *Type* in the class *RightOrRestriction* in the core cadastral model specifies a look-up table for different rights. In contrast, the Greek model defines a set of subclasses for the different types of laws. Thus, a correspondence between this set of subclasses and the attribute *Type* is required as input for the tool verifying conformity. As this is a discrepancy on the meta-level, it cannot be resolved by the merging functionality of the tool.
- It seems that the attribute *Ben_Type* is added to the class *BENEFICIARY* in the Greek model only due to implementation issues. If both concepts are intended to be equivalent, this attribute should be removed.
- In the class *NaturalPerson* of the core model, the attribute *PersonExtID* specifies information related to the Person-Registry of a country. In contrast, the class *NATURAL* of the Greek model lists attributes which might be imported from the Person-Registry. Therefore, the attributes *Name*, *Surname*, *F_Name*, *F_Surname*, *M_Name*, *M_Surname* should be merged to an attribute "*AdditionalID*" corresponding to the attribute *PersonExtID*.
- The same applies for the class *LEGAL*.

The following figure illustrates the proposed modifications. Additionally, we will remove for this second iteration the attributes *t_min* and *t_max*. We do not suggest this in general, but only for this example.

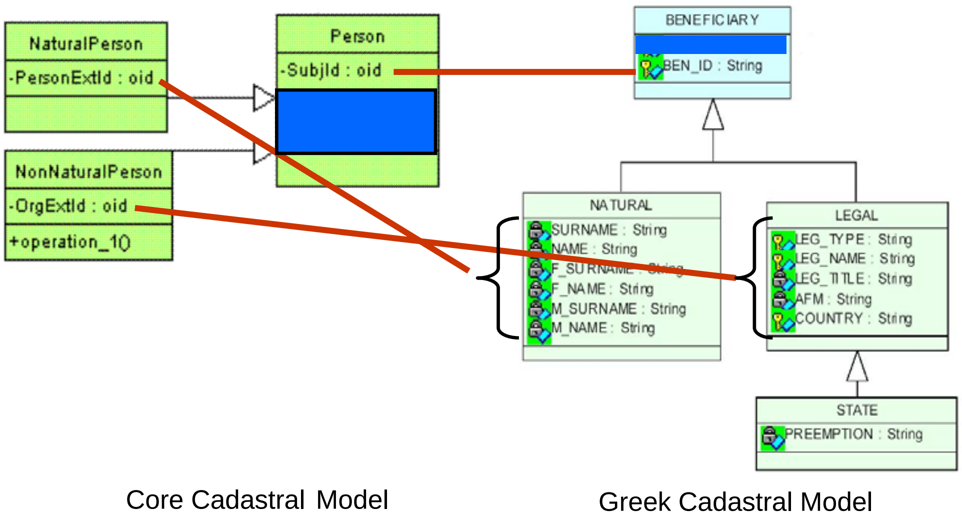


Figure 1 – Proposed Modifications

If these proposed modifications are used for a second iteration of the conformity verification, we obtain the following results:

- The classes *Person* and *BENEFICIARY* are identified as equivalent by the reasoner.
- The classes *NaturalPerson* and *NATURAL* are identified as equivalent.
- The classes *NonNaturalPerson* and *LEGAL* are identified as equivalent.

The results of this second iteration in the verification of conformity between the core and the Greek cadastral model must be reviewed by the Greek domain experts. They can decide whether this formalization reflects their modeling intentions in a better way than the correspondences identified for the first iteration resulting in relations of the overlapping type.

2.5 Ontologies and Conformity Verification in the Context of different Projects

Marian de Vries (Delft University of Technology), Rob Lemmens (International Institute for Geo-Information Science and Earth Observation) and Claudia Hess discussed the use of Semantic Web technologies in several projects:

- We compared knowledge engineering tools for different tasks, e.g. choice of an ontology editor, of a reasoner etc. Different tools currently available such as Protégé and OilEd were discussed in regard to their suitability in current research projects of Delft University of Technology and Bamberg University.

- Difficulties with these tools were discussed. For instance, the exchange of ontology models between different tools is often problematic due to different serializations of the ontology language by different tools.
- First experiences with the ontology language OWL, a recommendation of the World Wide Web Consortium since February 2004, were exchanged.
- Assertional and terminological knowledge was differentiated. This differentiation is rather clear for most ontologies, but when describing WebServices with the help of an ontology modeling language, it might not be obvious.

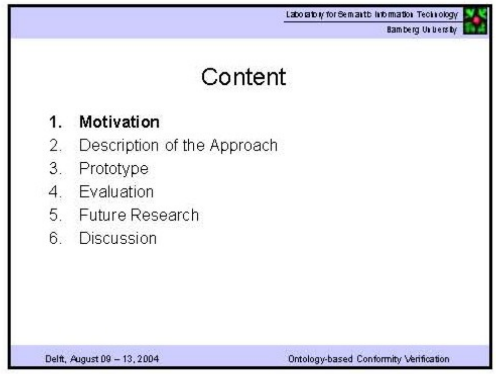
2.6 Review of the Modeling Approach to the Cadastral Models of Bhutan and Nepal

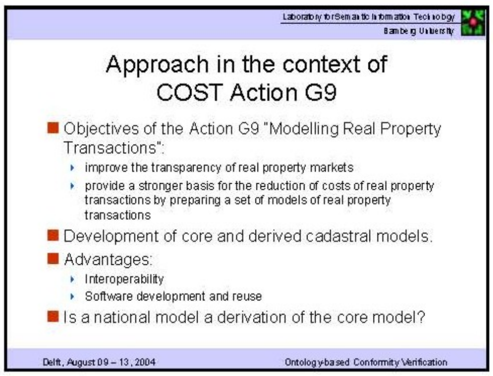
Peter van Oosterom proposed to review the modeling approach to the cadastral models of Bhutan and Nepal which are developed by Arbind Man Tuladhar in his PhD thesis “Parcel based Geo-information System: Concepts and Guidelines”. These cadastral models are intended to be extensions of the core cadastral domain model including particularities of Nepal and Bhutan. We planned to verify the conformity of the cadastral models proposed for Bhutan and Nepal with the core cadastral domain model by applying the conformity verification developed at Bamberg University. But due to the short remaining time until the defense of his PhD thesis, Arbind Man Tuladhar was not available for discussions on correspondences between these models. Thus, we decided only to provide a description of the conformity verification for A. Tuladhar and a version of the prototype implementing the conformity verification.

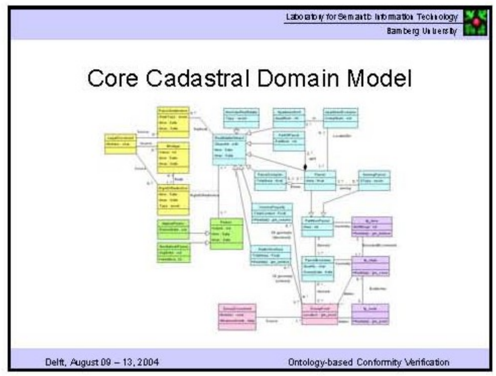
3 Future Cooperation

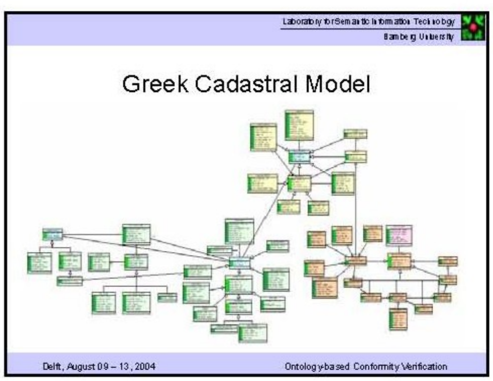
On the basis of the lively discussions and the obtained results, a common conference paper is planed by Marian de Vries and Claudia Hess for the Workshop “Standardization in the Cadastral Domain”, Bamberg Germany, Dec 04.
In the article, we will present the exchange of cadastral data between different countries. This exchange is only possible if these national cadastral models are extensions of the core cadastral domain model. The work for the conference paper is planned on the basis of research carried out at Delft University of Technology and Bamberg University.

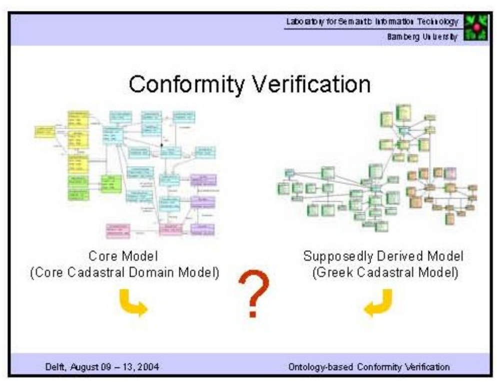
Appendix





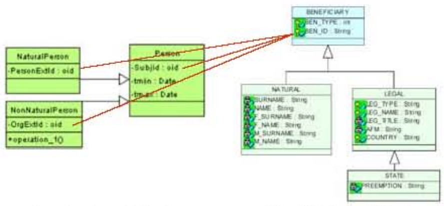






C. Heß, Bamberg University

Example: "Person"-Classes



Core Cadastral Model Greek Cadastral Model

Conformity?

- Complex UML models
- Core cadastral domain model as normative model
- Is the Greek cadastral model a derivation of the core cadastral model?
- Decision is not trivial!
- Up until now: No formal approach!

Content

1. Motivation
2. **Description of the Approach**
3. Prototype
4. Evaluation
5. Future Research
6. Discussion

"Ontology-based Verification of **Core Model Conformity** in Conceptual Modeling"

- What does *conformity* mean?
  - Intuitively: "Derived models extend the core model according to particular / local requirements"
  - Definition of formal criteria
- Different approaches:
  - Top-down: Derived models as specializations of a normative core model
  - Bottom-up: Inductive modeling of a core model on the basis of already existing models
  - Action G9: mixed scenario!
- Conformity verification is not restricted to the cadastral domain!

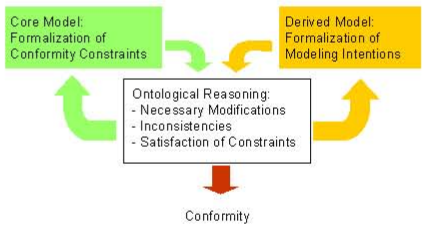
"**Ontology-based Verification** of Core Model Conformity in Conceptual Modeling"

- Ontologies: „explicit account of a shared understanding" (Uschold & Grüniger 1996)
- Represent UML class diagrams and textual constraints of Literate UML
- Reasoning about ontologies:
  - Computes the type of a relation between concepts
    - Indicator for the "strength" of the relation
    - Formal verification of the domain experts intentions
  - Detects inconsistencies in and across core and derived models

"Ontology-based Verification of Core Model Conformity in **Conceptual Modeling**"

- Cadastral models available as Literate UML models
- Prerequisite for the ontology-based conformity verification: cadastral models as ontology models
- Ontologies as a new approach to conceptual modeling
- Transformation from UML into an ontology language
  - Modeling primitives can be translated (e.g. UML class → daml.class)
  - Automated transformation

Iterative Modeling Process



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Formalization of Conformity Constraints

- Conformity Constraints: Set of classes and attributes of the core model which must have a corresponding element in the derived model
- Define the minimum of required "similarity" between core and derived models
- Attention with changes in the conformity constraints!

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Generic Mapping Relations

- Correspondences are identified by domain experts
- Small set of generic mapping relations
- Correspondences are identified between
  - 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

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Workflow for the Identification of Mapping Relations

- Intentions of domain experts:
  Classes with semantically equivalent information
- Structural heterogeneity on the concept level
  - Bilateral relation between corresponding classes?
  - Multilateral relation between corresponding classes?
  - Relation between class and property (discrepancy at the meta-level)?
- Structural heterogeneity on the attribute level
  - Bilateral relation between attributes?
  - Multilateral relation between attributes?

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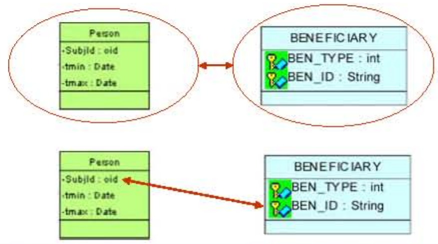
Example: *Person - Beneficiary*



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Types of Correspondence

- Reasoner determines type of the identified correspondence by ontological reasoning
- Types:
  - Equivalence
  - Subsumption
  - Overlapping
  - Approximate Mapping
- Special Cases
  - Restriction of the range of an attribute
  - Co-extensional concepts without corresponding attributes
  - Corresponding packages

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Interpretation of the Results

- Are changes in the derived model necessary in order to obtain a derivation of the core model?
- Inconsistencies in and across core and derived models
  - Patterns which might lead to inconsistencies
  - Example: Jointly exhaustive and pairwise disjoint classes
  - In the core cadastral model: class Person and its subclasses
- Taxonomy
  - Based on the identified correspondences
  - Inferred knowledge
- Interpretation of the conformity constraints

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Prototype (1/2)

- Demonstrates the feasibility of applying the theoretical approach
- Most important features of the theoretical approach are realized
- Tested with core cadastral domain model and Greek cadastral model

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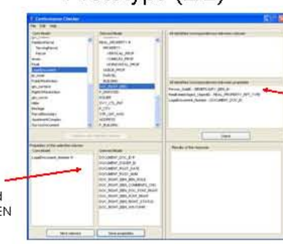
Prototype (2/2)



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Example of Use (1/2)

- Verification of conformity between
  - Core cadastral domain model and
  - Greek cadastral model
- Difficulties during the adaptation of the input models:
  - Constraints such as "disjointUnionOf"
- Identified relations:
  - Necessity to modify the models
  - Only few correspondences between core and Greek model

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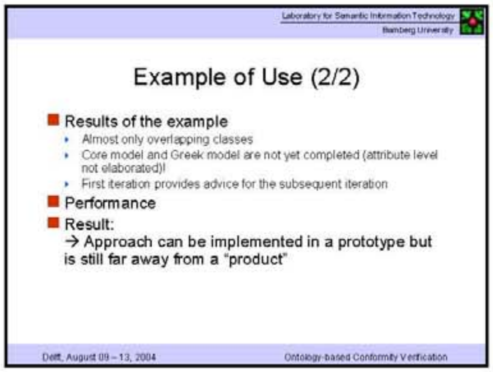

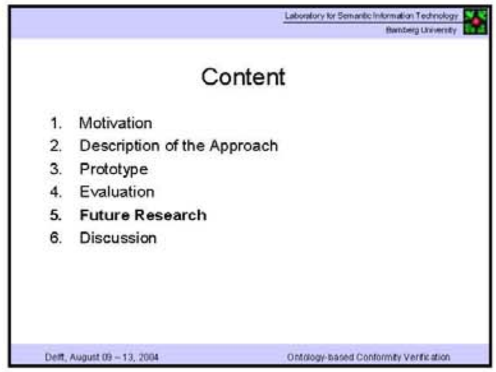

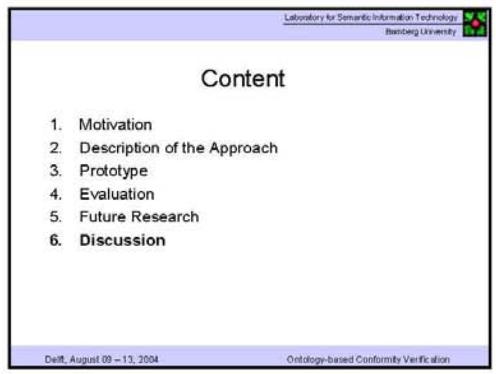

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