Available online at www.sciencedirect.com
ScienceDirect
Computers, Environment and Urban Systems
30 (2006) 529–542
Computers, Environment and Urban Systems
www.elsevier.com/locate/compenvurbsys

From models to data: A prototype Query Translator for the cadastral domain

Claudia Hess [a,*], Marian de Vries [b]

[a] *Laboratory for Semantic Information Processing, Bamberg University, Feldkirchenstr. 21, 96045 Bamberg, Germany*
[b] *GIS Technology—Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, Jaffalaan 9, 2628 BX Delft, The Netherlands*

Received 12 November 2004; received in revised form 9 August 2005; accepted 9 August 2005

Abstract

The missing possibility of exchanging cadastral information between different countries in an efficient way leads to rather complicated procedures of collecting and analyzing cadastral data in land transactions with multinational parties. Cross-border exchange of cadastral information is not only interesting in the real property financial market, but also for authorities, for example in land management and infrastructure development, and for international companies, e.g., in their property management. In this paper, we propose an approach to query translation based on the core cadastral model [Lemmen, C., van der Molen, P., van Oosterom, P., Ploeger, H., Quak, W., Stoter, J., et al. (2003). A modular standard for the cadastral domain. In *Proceedings of Digital Earth 2003*, September 21–25, 2003 (pp. 108–117). Brno, Czech Republic] which serves as connecting piece between various national cadastral systems. We will show by demonstrating a query translation from one national cadastral model into another that interoperability between cadastral systems conforming to a core model can be achieved. A prototype Query Translator demonstrates the practical use of our approach. The approach is evaluated with queries between the core cadastral model and two national cadastral models: the current Dutch model and a prototype Greek model. On the basis of the experiences obtained, recommendations are given for further improvement of the query translation. We also make suggestions to make the core model better suitable for a role as an intermediary model for query translation. Choices must be made here: about system boundaries of the model and about desired level of abstraction.

* Corresponding author. Tel.: +49 951 863 2844; fax: +49 951 863 5841.
E-mail addresses: claudia.hess@wiai.uni-bamberg.de (C. Hess), m.d.vries@otb.tudelft.nl (M. de Vries).

0198-9715/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compenvurbsys.2005.08.008

Keywords: Query translation; Conformity verification; Interoperability

1. Introduction

To facilitate cross-border exchange of cadastral information, a number of initiatives have been taken. As it is not feasible to install one single cadastral system in all European countries, other approaches are required. Lemmen et al. (2003) proposed a core model for the cadastral domain representing basic concepts of most cadastral systems. National domain models adapted to the particular requirements in the respective countries can be modeled as extensions of this core model. In this work, we show by demonstrating a query translation from one national cadastral model into another via the core cadastral model that interoperability between cadastral systems conforming to a core model can be achieved.

Until now, the exchange of cadastral data between different countries—even in the European Union—is not possible in a completely automated way. For example, it is not easily feasible for a bank to verify the cadastral information indicated by a customer asking for a loan when the property is situated in another country. Cadastral information must be collected with the help of local experts or a local branch in this country (Ollén, 2002). Our approach to query translation between national cadastral systems would be helpful in this context. In the above example, it would be possible for the bank to check the cadastral information of the customer by sending the corresponding queries directly to the supplier of cadastral data in the foreign country in consideration. Our approach is characterized by the fact that the employee of the bank does not need to know the concepts and the processes of each foreign country in detail but only those of its own country. The query translation permits to formulate the query with the concepts of the cadastral system of the home country, familiar to the bank employee, and to present the results again in the terms of the cadastral system of the home country. This facilitates the cross-border exchange of cadastral information because it is not required that users are familiar in detail with all connected cadastral systems. It is guaranteed by the transformation via the core model that semantically equivalent concepts are retrieved.

In a European (or even global) context cadastral information exchange between countries should be enhanced. This can be accomplished using Web services that provide access to national cadastral data. With a query translation approach national cadastres can make their administrative information and geo-information available to authorized users in other countries without having to completely rebuild their current cadastral information systems. Agreement on a core information model and the use of query translation software would then be sufficient. The prototype presented in this article is meant as a proof of concept for the idea of query translation based on semantic relations between information models. With the prototype we can test with real cadastral data the feasibility of this approach.

The paper is structured in the following way: In Section 2, we discuss different approaches to query translation and compare them with our approach. Section 3 describes how the mapping works in our query translation. The next section presents use cases characteristic for the queries that can be handled by our prototype Query Translator. The use cases are based on actual cadastral models and test databases. Section 5 evaluates the results of our tests. Recommendations on the basis of our experiences are discussed in Section 6. The last part, Section 7, summarizes our work and discusses restrictions of our current implementation which could be addressed in future work.

2. Related work

In the following, we set our approach to query translation in the context of research in data integration. Then, we will discuss how the exchange of cadastral data is realized in other projects from the cadastral domain.

2.1. Approaches to data integration

Integration of information from different heterogeneous data sources is an 'old' subject in computer science and database research. Before the advent of Internet, integration of heterogeneous data sources was already an issue in situations where data from several databases had to be combined to get the requested information. Halevy (2003) gives a useful overview of the research questions in data integration that are still not solved. With the Internet, there is now an extra dimension: the technology to access, retrieve and query information on remote servers exists. But because of the loose coupling of all this information, the fact that the user group is not known and the unpredictable nature of the queries that will be posed, the information integration issue has only become more imminent.

Many research disciplines are involved in data integration: from computer science and database research to artificial intelligence, the Semantic Web and Description Logics (see, e.g., Borgida, Lenzerini, & Rosati, 2003; Stuckenschmidt, 2003; Wache, 2003).

Our Query Translator approach uses concepts and techniques from the Semantic Web, in the form of using an ontology language to specify the correspondences and relations between the data models of the cadastral systems of different countries and the core model. However, we do not use a semantic reasoner that computes semantic relations 'on-the-fly'. In the Query Translator prototype the semantic relations between the models are established beforehand during the conformity verification process (Hess, 2004). These semantic relations are explicit ontological mappings between the elements of both core and national model reflecting that an element, i.e., the classes and attributes of these classes, of the national model corresponds—or can be mapped—to an element of the core model.

From the database research there is an interesting distinction between the global as view (GAV), local as view (LAV) and GLAV (sometimes called BAV, i.e., both as view) approaches to data integration (Halevy, 2003). If we position the Query Translator in this spectrum, it will be close to the GLAV/BAV approach: a 'global' query model is used to pose the selection queries to several heterogeneous data sources with the structure and terminology of that query model. Via the ontological mapping the query is then reformulated into the right classes and attributes of the 'local' data sources. Attributes of the local data sources that are not in the global model are still presented to the user, because these should also be available for narrowing down the search conditions in the query. So the approach is a mix of GAV and LAV.

Finally, there is no direct mapping between the national models in the Query Translator: the core model always acts as 'intermediary' or central model. This is also how, e.g., Feature Manipulation Engine (FME) works, a software product for conversion between various technical file or data formats. The advantage that is mentioned by the designers of FME is, that changes in a file or data format only lead to a change in the mapping between that format and the internal intermediary model that FME uses. With pair-wise conversion all mappings between the changed file format and all other formats would have to be changed (Murray & Chu Chow, 2002). For the same reason we also chose a two-step translation for the Query Translator. In Section 5 we will see, that this choice also has some disadvantages.

In contrast to this approach to integration via an intermediary model or format, there is currently also much research into another strategy for data integration, such as peer-to-peer data integration (see Halevy, 2003).

2.2. Exchange of cadastral information

Cross-border exchange of cadastral information is also part of the project European Land Information Service (EULIS).[1] The goal is to provide a single entrance to land and property registers across several countries. Just like our approach to query translation is embedded in the overall context of the COST Action G9 'Modeling Real Property Transactions', the query translation in EULIS is only one part of the project. With our query translation we also aim at improving the exchange of cadastral information between national cadastral systems, but there are many differences from the technical point of view.

In contrast to EULIS, in which national cadastral information can be accessed via one portal but with separate connections to every national cadastral system, our approach to query translation provides one single query interface for all national cadastral systems. Furthermore, our query interface permits to formulate queries in the terms of the user's cadastral system, i.e., in a language familiar to the user. Thus, it is not necessary to provide an explanation of the retrieved concepts as in EULIS. An important difference is also that the translation is realized in our approach on the basis of a common core model connecting the national cadastral systems. This is not the case in the EULIS project. This different approach in the EULIS project results in the fact that there is no mapping required between the different national cadastral systems as each of them is queried individually. But the mapping between the national cadastral models and the core cadastral model is central to our approach.

3. Query translator

We present an approach for a prototype Query Translator that uses the formalized relations between two models as input for a 'mediator' component to query and retrieve information from actual, 'real life' cadastral data sets. Goal of the Query Translator prototype is to function as a proof of concept:

- Demonstrate the possibilities to exchange cadastral data arising from core and conforming national models.
- Investigate the possibilities and limitations of a 'semantic mediator' based on the Web ontology language OWL for data integration in the cadastral domain (W3C, 2004).

[1] http://www.eulis.org

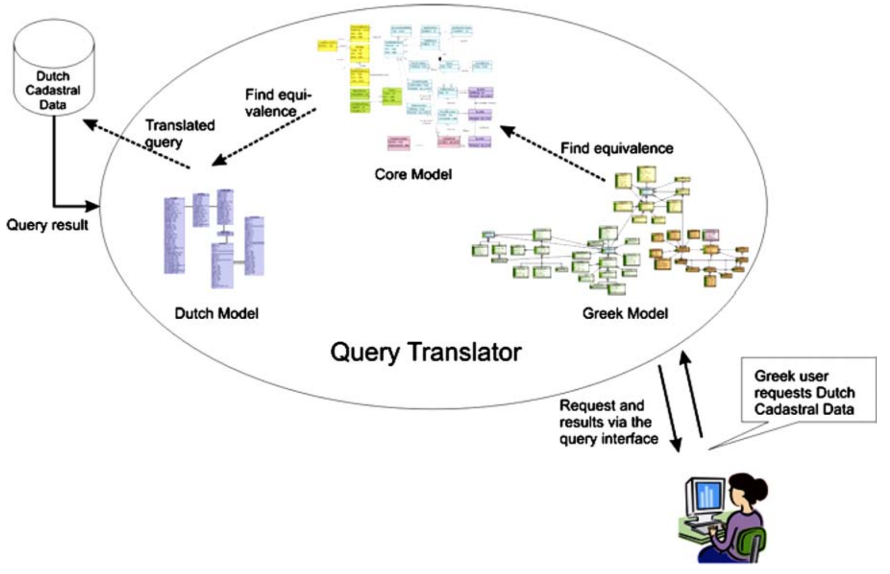

Fig. 1. Translation of queries with the Query Translator.

Fig. 1 gives an impression of the Query Translator architecture. Depicted is a user in Greece who wants to retrieve information from the Dutch cadastral database. The user can pose the select query in terms of the Greek cadastral model she/he is familiar with; the Query Translation software takes care of translating the query into a query that is in accordance with data structure and concepts of the Dutch cadastral model. Shown in Fig. 1 is a two-step translation: from Greek information model to core model and from core model to the Dutch data model. Not depicted is another possibility of the Query Translator: to choose the core model as query model. In that case there is only a one-step translation: from core model to Dutch model. In the remainder of this section we will explain the working of the Query Translator in more detail.

3.1. The core cadastral model

The core cadastral model plays a central role in the architecture of our query translation. The core cadastral model was proposed by Lemmen et al. (2003). This core model reflects features found in most or even every cadastral systems and models them according to international standards from ISO and OGC (OpenGIS). The main advantages of the core model are in two different areas. One the one hand, it represents the core software component of cadastral systems. On the other hand, it facilitates the exchange of cadastral data between the cadastral systems of different countries (Lemmen et al., 2003).

In the following, we concentrate on the second point and show how the core model can be used as basis for data exchange. The core cadastral model serves as connecting piece between the national cadastral systems. Mappings need not be formalized between every pair of national models but only between each national model and the core cadastral model. The query translation is established on the basis of the mappings that can be defined for each of the national models and the core cadastral model.

3.2. The mapping ontologies

In this paper, we built on the results of the conformity verification research. Conformity verification analyzes—in the case of the cadastral models—the relationship between a national cadastral model and the core cadastral model. An approach to ontology-based conformity verification between core and national models was proposed by Hess (2004) and Hess and Schlieder (in press). This approach and the software implementing it—the conceptual conformity checker (CCC)—captures domain experts' modeling intentions, i.e., the relations they intend to hold between national models and the core model. Inference services compute the type of these identified relations that is equivalence, subsumption or overlapping. Furthermore, conformity constraints are defined. They formalize a set of concepts in the core cadastral model for which a corresponding concept must be available in the national cadastral model. The type of the correspondence has to be the type required by the conformity constraint.

Thus, conformity means in this approach that all conformity constraints are satisfied by the identified correspondences. Conforming national cadastral models are therefore extensions of the core cadastral model. The conformity verification guarantees a minimum of exchangeable information between all European cadastral systems because the core model is reflected in every conforming national model.

The mediator component uses the formalized correspondences that have been discovered in the conformity verification process and their computed types as translation rules between data sources. This is possible because the relations are described in an ontology language, in this case OWL (Web Ontology Language), which was standardized by the World Wide Web Consortium in 2004 (W3C, 2004). It is therefore one of the core technologies in the context of the Semantic Web. OWL does not only offer a high expressiveness but also provides reasoning capabilities on the ontological models. Specialized software, called reasoner, can discover and check the correspondences between the concepts of core and national models. With the help of a reasoner, relationship types of correspondences are computed: equivalence, subsumption and overlapping (Hess, 2004; Hess & Schlieder, in press).

In order to use the output of the conformity verification as input for the query translation, the verification results must be changed into the form required by the Query Translator prototype. The cadastral models used in the conformity verification are represented as one ontology model that contains the core and the national cadastral model as well as the relations identified between both. This model does not include the results of the computations made by the reasoner. This was not necessary for the conformity verification as the results can be reproduced by sending the ontology model again to a reasoner. Results were analyzed and their interpretation given to the user. In the query translation, we maintain core and national models in separate files because cadastral systems are stored in a distributed way. The architecture for the exchange of cadastral data is based on the fact that the cadastral systems with their databases are maintained in each country individually. Furthermore, suppliers of cadastral data offer an ontology model of their national cadastral system including the mapping relations between their national model and the core cadastral model. Thus, we have one ontology model of the core cadastral model and one ontology model for each national cadastral system with all its mapping relations to the core cadastral model.

Fig. 2 shows a part of the merged ontology of the three cadastral models used in the prototype tests, with some of the mappings between the Greek cadastral model (with prefix

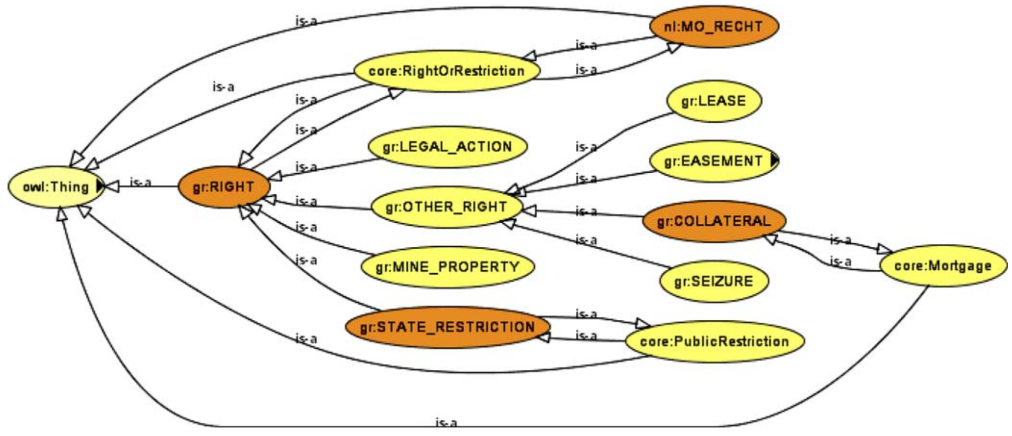

Fig. 2. Part of the merged ontology.

```
- <owl:Class rdf:about="greek_cad.owl#STATE_RESTRICTION">
    <owl:equivalentClass rdf:resource="core_cad.owl#PublicRestriction" />
  </owl:Class>
- <owl:DatatypeProperty rdf:about="greek_cad.owl#BENEFICIARY_BEN_ID">
    <owl:equivalentProperty rdf:resource="core_cad.owl#Person_SubjID" />
  </owl:DatatypeProperty>
```

Fig. 3. Example of OWL encoding.

'gr'), the Dutch model ('nl') and the core cadastral model ('core'). Fig. 3 gives an example of the way these mappings are encoded in the OWL ontology language.

In this architecture, modifications in a national cadastral system will not influence any other national cadastral system. Having modified a national cadastral model, the experts that are responsible for this model renew the conformity verification and use its output directly for the query translation. It will be helpful if future versions of the conformity verification are able to generate the results in the format required by the Query Translator.

Our approach to query translation permits a formulation of queries and the presentation of their results in the terms of the query model, i.e., the terms used in the cadastral system of the user's own country. The conformity verification ensures that the results of the query translation from the data source, i.e., the model from which the user wants to select cadastral information, correspond semantically to the concepts of the query model which were used for the query formulation. This semantic equivalence is guaranteed as the mapping models are based on the correspondences identified by the domain experts during the conformity verification. The user of the query translation system therefore does not need to know the terms of the data source model but only those of the 'own' national cadastral system.

3.3. The Query Translator

The Query Translator prototype is set up as a Web application that accesses an Oracle Spatial database. The user selects a 'data source' and a 'query model'. This 'query model' can be the model of the data source itself, but can also be another model (the core model or

Fig. 4. Selection form for specifying the query.

another national model). For our tests at this moment we have the choice of three query models: the core, the Greek (Tzani, 2003) and the Dutch model (Van Oosterom & Lemmen, 2001). For the data sources, two test data sets are available: a data set with Greek cadastral data and a data set with Dutch cadastral data.

The 'Advanced' button gives access to a Selection form that helps the user to specify the query. The Selection form is a dynamic HTML page that is generated 'on-the-fly' using the OWL ontology for the model as input. Fig. 4 shows a selection form generated for the Greek cadastral model as query model. That means that the user formulated the queries in the terms of the Greek model. Presented to the user are the classes and subclasses of the query model that was chosen, with their attributes.

The user enters selection criteria and submits. The Query Translator software searches in the ontology document(s) and retrieves the translation rules that map concepts from one model to concepts in the other model. The Query Translator then rewrites the query into the terms and structure of the model of the data source. The query results are either presented in terms of the data source, or in terms of the chosen query model.

The prototype is based on very standard Web technology: (dynamic) HTML, JavaScript, and XML and XSLT. With eXtensible Stylesheet Language for Transformations (XSLT) it is possible to read an XML document, retrieve its content and transform it into other XML or HTML. Because the OWL ontologies are coded in XML, XSLT is a practical solution for handling the mediation and query translation in the prototype.

The Dutch and Greek test data sets are stored in an Oracle Spatial database. We can access the data itself via a Web service, but to make ‘offline’ tests possible we stored the output of the Web service (in GML, or Geography Markup Language) in local GML files, so we were more flexible.

The prototype is at present built solely for testing, thus the user interface itself is very straightforward. With it, however, we can test several scenarios (selection queries) and evaluate the success and also the limitations of our query translation approach.

Queries can be formulated on two different levels of complexity. In the lower complexity level, *equivalence* is defined in a weaker way. Equivalence means only that there is an extensionally equivalent concept in the query model and the data source. It can be used for rather general queries, e.g., `select * from core:Person` with the Greek model as data source. This query would retrieve all beneficiaries form the Greek cadastral system. The results describe the same extensions, i.e., the owners of a piece of land. For more specific queries—which will be the normal case in the query translation, equivalence is defined in a stronger way, i.e., by requiring structural equivalence. For example, the query `select from core:NaturalPerson where name = '...'` with the Greek model as data source assumes that the data entries in the Greek database implementing the concept *NATURAL* have an attribute that corresponds to the attribute *name* of the concept *NaturalPerson* in the core cadastral model. The name of the attribute may be different but there must be a mapping between the attributes encoded in the mapping model. This correspondence was established during the conformity verification and can be used later on in the query translation.

Test queries will be formulated both against the administrative part of the cadastral data source, and against the spatial part, i.e., the actual parcels with parcel-boundaries, survey points, etc.

4. Use cases

We describe a number of test cases, from simple queries to more complicated ones.

An example of a ‘simple’ scenario is the following case: a class in the data source has another name and maybe other names for attributes as a class in the core model, but is intended as the same concept: core:NaturalPerson versus greek:NATURAL.

Core model

`select * from naturalperson where name[2] = '...'`

Greek model

`select * from natural where name = '...'`

An example of a more complicated scenario is a query that involves an association between two or more classes. This would mean—in relational database terms—a join between two tables:

[2] We obtained the attribute *name* by splitting the attribute *PersonExtID* of the class *NaturalPerson* which refers to the external Person-Registry into the attributes *name*, *lastname*, etc. as being available in the Person-Registry.

Core model

```
select name, address, type_of_right from naturalperson, right
where person.id = right.person_id
and municipality ='...'
```

Here, the complicating factor is not the different names for classes and/or attributes, but different (names for) associations between classes plus knowledge about the join attributes (foreign keys) that must be used.

In this second case it might not be trivial to rewrite the query based on the semantic relations formalized in the merged ontology models. One of the research questions is therefore whether not only the basic query statements but also the more complicated ones like joins between tables can be correctly generated from the formal definitions in the ontology documents.

5. Evaluation

The first tests with the Query Translator prototype led to the following observations and preliminary conclusions.

5.1. System boundaries of the models

The system boundaries of the core model are stricter than those of the national cadastral models. Classes from 'outside' the cadastral domain, e.g., (Postal) Address, are not incorporated in the core model. On the other hand, such classes and attributes exist in the national models and are very important for selection purposes.

5.2. Conceptual versus technical models

Both the Greek model and the Dutch model that we used for testing our Prototype Query Translator are close to the data as stored in the database. They are based on the implemented (technical) data models. The core model, however, is a mix of conceptual and technical data modeling. It reflects the conceptual level of a cadastral system and is therefore abstracter than a national cadastral model that is based on the concrete implementation of the cadastral system. As we work in the query translation on the databases of the respective cadastral systems, we need models that reflect directly the structure of the database. A match between concepts in the models as they are is often not found and structural equivalence cannot be established while on an intentional level (see Section 3.3), a correspondence does exist.

Examples are:

(a) In conceptual models, many-to-many (*n*:*m*) associations between classes are frequently used. This can be expressed with the help of one association class as it is modeled in the core model. In the national models this is not the case. Because the national domain models we tested are closer to the database, a many-to-many association will be modeled as two 1:*n* associations.

(b) The core model has a Person class with two subclasses *NaturalPerson* and *NonNaturalPerson*. In the Dutch test data source, there is only one table, hence class in the model, called '*Subject*' that contains both natural and non-natural persons, but there is an attribute called '*subjectType*' that holds a value to distinguish between the two categories. So there is (conceptually) a correspondence here, but it will not be found (in the present prototype).

5.3. Translation via the core model

One of the basic principles of the Query Translator prototype design is to use the core model as intermediary between national models instead of a direct mapping between all national models. As the core model is less detailed than the two national domain models, a number of possible matches between the two national models are 'lost', especially between properties. Therefore, in order to increase the possibility of successful translation from one national model into another, we had to modify in some parts the core model.

6. Recommendations

Based on our experiences with the query translation by our prototype Query Translator we make some recommendations for future modifications in core and national cadastral models.

6.1. Extent of the core cadastral model

For harmonized access to the different national cadastral data sources, it is necessary to recognize and define the most important search criteria. The core cadastral model should contain all classes and attributes that are known to be used by end-users in selection queries. These classes and attributes could be selected on the basis of a use case analysis of actual search queries in the national context, or in the context of EULIS. Attributes that will most likely be used for selection purposes are, for example,

- address,
- name (of a person or an organization),
- cadastral parcel number,
- type of right.

It is very probable that in many queries the geometry and topology aspects will be 'shielded' from the end-user. He or she will, e.g., zoom in or zoom out on a map, or click on an object, but will not directly specify coordinates. It is rather the 'administrative' selection criteria (address, name, parcel number) that will be used. The core model should therefore contain these concepts as abstract classes that function as 'placeholders' for the localized classes, for example *dutch:PostalAddress*, *greek:PostalAddress*.

This does not mean that it is recommended to model all the components of for example *Address* ('street', 'house-number', 'town', 'district'), but just the (abstract) class '*Address*', maybe with two subtypes '*PostalAddress*' and '*LocationAddress*'. A Greek address is, also in the real world, different from a Dutch address, so the core model can never offer the right 'structure' for both situations. Thus, the core model should offer more classes that act as placeholders for the concrete realization in the different countries. Introducing these classes, the core model would become more suitable as an intermediary model in the case of a cross-border information system for the cadastral domain. However, the placeholder classes are strictly conceptual and do not have a 'structure' in the sense of a list of attributes. This guarantees that the placeholder classes are modeled in a general way and that they are not specific for some country. Only in the national cadastral models these classes will get a data structure by extending the core model classes.

It is important to find the appropriate level of detail. The core model should contain all essential selection properties, but also less technical detail such as the attributes *tmin* and *tmax* for the temporal aspects, but an abstract class, e.g., '*VersionInfo*' or '*Temporal*'.

6.2. Modeling issues in core and national cadastral models

The following recommendations are only small changes in the modeling of core and national cadastral models but would make the translation between models much more successful. The chance to find matches between the national models, especially in a two-step process with the core model as intermediary, will increase.

First of all, we recommend providing more classes for groups of attributes in core and national cadastral models. These complex data types group as 'attribute classes' the attributes that belong together. Candidates are for example: Address, PersonName, OrganizationName, PostalAddress, LocationAddress, ParcelNumber, etc.

Secondly, a harmonization of attribute values would improve the query translation. For selection queries with conditional statements, it can be necessary to have knowledge of the list of attribute values that can occur. For instance, there would be the problem that the user does not know what to fill in as selection criteria for '*typeOfRight*' if it is not clear what can be chosen. These can be implemented as 'drop down' lists in the user interface supposed that the list of permitted values is finite. Precondition for such harmonization is that the permitted values are defined in the conceptual models of core and national cadastral models.

6.3. Architecture of the Query Translator

Another approach to solve the problem that the national models are closer to implementation then the core model would be to make the national domain models used in the Query Translator more conceptual and therefore to have, e.g., one *n*:*m* association, instead of two 1:*n* associations. This means that the Query Translator has to map from one conceptual model to the other (if the user wants this) and from the conceptual model to its technical data model. This can be handled by the Query Translator but could also be part of the Web service application software that accesses the cadastral data source. This last architecture set-up would move the responsibility for correct mapping/translating between the conceptual and the technical model to the Web service provider, and leave it out of the 'middle layer' to which the Query Translator belongs in the overall architecture. This is of course a more fundamental change in the Query Translator design.

7. Conclusions and future research

In the paper, we presented the translation of queries between two national cadastral systems via a common core model, the core cadastral model. By reformulating queries from the Dutch into the Greek cadastral system via the core cadastral model, we demonstrated that data can be exchanged between different information systems which have no direct links and no common historical background but which are only extensions of a common core model. Both systems were not adapted to each other but modeled to reflect the basic concepts of European cadastral systems as defined by the core cadastral model as well as the particularities, e.g., in legislation or administration, of their countries. Concepts in the core model which are present as equivalent or specialized concepts in every national cadastral system can therefore be exchanged between these cadastral systems. The relations between national models and the core cadastral model were identified by domain experts during the conformity verification which is used as basis for the query translation. The benefit of a query translation via the core cadastral model is that even without complete correspondences between all national cadastral systems, meaningful data exchange can take place. The use of mapping documents that are based on the conformity verification ensures that only semantically corresponding information is retrieved. Also a partly conforming model can be included in this way into a cadastral information exchange infrastructure.

In the current version of the Query Translator, we translated queries on the basis of matching concepts in the Dutch and Greek cadastral models. We tested translation based on equivalency between classes in two models, between attributes and between (simple) associations. Our results with the first version of the prototype Query Translator are encouraging. Difficulties primarily arose because of the fact that the models themselves were not (yet) comparable enough.

Firstly, national models can extend the core model in very different ways. Thus, it might be the case that data is not available on the same level of detail in both cadastral systems. This means that there are differences in the generalization–specialization hierarchies of both models. Approximate queries based on the hierarchical structure defined in core and national models and supported by ontological reasoning on this hierarchy would offer a solution to this problem.

Secondly, the differences in the abstraction level, i.e., the core model is more conceptual and the national domain models are closer to the technical implementation, lead to problems during the identification of mapping relations and the rewriting of queries. Recommendations were discussed in previous sections.

Thirdly, the Query Translator offers no translation for those parts of the national model which have no corresponding part identified in the core cadastral model. It is clear that there are aspects, e.g., in the legal context, which are very difficult to represent in the core model in such way that correspondences can be identified between all—or at least most—national cadastral systems and the core model. In the query translation, we could therefore benefit from improved relations between the core cadastral model and the national models.

Future work on the query translation should be closely related to the further development of core and national models and address the above mentioned problems. Experiences obtained can be used as feedback for further development of core and national cadastral models.

In general, the benefits of using OWL ontology files in the Query Translator were clear. OWL can easily be used in Internet applications due to the fact that OWL is serialized in XML. In addition, its constructs ‘equivalentClass’, ‘equivalentProperty’ and ‘sameAs’ provide a good basis for the definition of mapping relations.

In the present Query Translator prototype, the query is only sent to one single data source. It presupposes that the end-user knows in which country's cadastral database to look. The current design of the user-interface reflects this: now, if the data source has more attributes than the query model, or attributes that cannot be translated to the query model, these will be presented to the user as extra selection criteria and in the query results. If, however, we want to answer a query like 'Select all real estate property of this firm in Southern-Europe', the query must be sent to a number of national data sources at the same time. In a distributed setting, such service would be based on a number of separate national Web services, similar to EULIS, but which can be reached by one single query formulated in the terms of the chosen query model. Such a cross-border selection query needs a different user-interface, one that is truly 'pan-European'. The role of the core model will become even more important in such a completely connected system. If the core model is extended with classes that are relevant for selection queries and if also lists or taxonomies of possible selection values are incorporated, this will greatly improve its potential to act as mediator model between European cadastral systems.

References

Borgida, A., Lenzerini, M., & Rosati, R. (2003). Description logics for databases. In F. Baader, D. Calvanese, D. L. McGuinness, D. Nardi, & P. F. Patel-Schneider (Eds.), *The description logic handbook: Theory, implementation, and applications* (pp. 462–484). Cambridge: Cambridge University Press.

Halevy, A. (2003). Data integration: A status report. In *Proceedings of the German database conference*, *BTW 2003* (pp. 24–29).

Hess, C. (2004). Ontology-based verification of core model conformance in conceptual modeling. Master's thesis, Bamberg University.

Hess, C., & Schlieder, C. (in press). Ontology-based verification of core model conformity in conceptual modeling. *Computers, Environment and Urban Systems*, doi:10.1016/j.compenvurbsys.2005.08.009.

Lemmen, C., van der Molen, P., van Oosterom, P., Ploeger, H., Quak, W., Stoter, J., et al. (2003). A modular standard for the cadastral domain. In *Proceedings of Digital Earth 2003*, September 21–25, 2003 (pp. 108–117). Brno, Czech Republic.

Murray, D., & Chu Chow, J. (2002). An XML-driven data translation engine for XML. In *GIS 2002, GEO Tec Event*, April 8–11, Toronto, Canada.

Ollén, J. (2002). ArcCadastre and EULIS—New tools for higher value and increased efficiency in the property market. In *FIG XXII International Congress*, April 19–26, 2002, Washington, DC, USA.

Stuckenschmidt, H. (2003). Query processing on the semantic web. *Künstliche Intelligenz, 3*, 22–26.

Tzani, A. (2003). Object-oriented modelling of the Greek cadastre. Master's thesis, School of Rural and Surveying Engineering of Aristotle University of Thessaloniki.

VanOosterom, P., & Lemmen, C. (2001). Spatial data management on a very large cadastral database. *Computers, Environment and Urban Systems, 25*(4–5), 509–528.

Wache, H. (2003). Semantische mediation für heterogene informationsquellen. Ph.D. thesis, Technologie-Zentrum Informatik, Universitat Bremen, Akademische Verlagsgesellschaft Aka GmbH, Dissertationen zur Kunstlichen Intelligenz, Berlin.

W3C (2004). OWL Web Ontology Language, Overview. W3C Recommendation, February 10, 2004. Available from http://www.w3.org/TR/2004/REC-owl-features-20040210/.