The Model Driven Architecture Approach Applied to the Land Administration Domain Model Version 1.1 - with Focus on Constraints Specified in the Object Constraint Language

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ABSTRACT

An overview is given on current research efforts with the aim of supporting the implementation of the Land Administration Domain Model, following its most recent developments and related standardization proposals concerning ISO and INSPIRE. From its initial Cadastral Core, the development history and details on the most recent version 1.1 are summarized. A brief report on the actual derivation of a country profile from the given domain model, the Land Administration Domain Model for Portugal (LADM-PT), based on real cadastral data from a pilot project in a Portuguese municipality is included. Research is being performed at the Delft University of Technology in the Netherlands to experiment with the Model Driven Architecture (MDA) approach. A Computer Aided Software Engineering (CASE) tool is being developed, based at the open source Eclipse development platform, aiming at a country specific implementation of the LADM-PT. Simultaneously, a prototype in the commercially available tool Enterprise Architect is being developed, aiming at experimenting with automatic conversions of classes, attributes and relationships from Platform Independent to Platform Specific Models, based on determined MDA transformation/implementation rules. Both approaches have a focus on spatial attributes and constraints in the Object Constraint Language (OCL). Constraints are used more and more in modelling, including, the LADM in order to express additional semantics indicating valid data content. A few initial MDA/OCL related experiments will be discussed, varying in flexibility, and approach, as well as the paths for further research.

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1. INTRODUCTION

Cadastre 2014 (Kaufmann, Steudler, 1998) concerned a view on the future developments of Cadastres. This view was widely recognised and used in cadastral 'renovations'. Now, in 2008, the Cadastre 2014 can also be seen a first (user driven) step into the standardisation of Cadastre. It is based on the 'Object' (land) – 'Right' (people – land relation) – 'Subject' (persons) approach; also supported by (Henssen, 1995). One key issue in the Cadastre 2014 view is the application of object orientated systems.

The Land Administration Domain Model (LADM) – earlier named the 'Core Cadastral Domain Model' (van Oosterom et al., 2006) aims to support "an extensible basis for efficient and effective cadastral system development based on a model driven architecture (MDA)" and to "enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model".

The 'drivers' in such architecture are models which are developed in itself in a standardised approach: the Unified Modelling Language. The diagrams as a result of a modelling exercise can be used for software generation. This paper overviews the status of supporting tools in this type of software generation in relation to the LADM – which includes both the legal administrative and the spatial component of a land administration.

As it can be observed in the development of Relational Database Management Systems (RDBMS) that the supporting functionality for spatial data, spatial operators and spatial indexing did not have the first priority; it took some time before this type of functionality was available – after substantial efforts made by organisations such as the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO). Something similar can be observed now in relation to Model Driven Architectures: the supporting tools are available, but the support in generating software with spatial functionality is not yet optimal. Especially the synchronizing/upgrading of generated software after changing UML (Unified Modelling Language) diagrams (initiated by changing user requirements) disserves further attention within existing MDA tools. This paper tries to support in this – driven by the awareness of the urgent needs of easy manageable land administration applications worldwide.

Section 2 gives an overview of the status of LADM development – the LADM has been submitted as a New Working Item Proposal (NWIP) to the ISO by the FIG. Section 3 introduces an integrated country profile based on a case from Portugal. In section 4 the MDA approach in relation to the LADM is introduced, and experienced are reported. Given the growing importance of using constraints in modelling, including the LADM (e.g. the sum of all shares of members in a group must total to 1), section 5 discusses the use of the Object Constraint Language (OCL) in addition to using UML in the context of the MDA approach. Finally, the paper ends with conclusions and recommendations in section 6.

2. THE LAND ADMINISTRATION DOMAIN MODEL VERSION 1.1

The versions of the Land Administration Domain Model (LADM) are described in a series of publications of which the last one was presented at the FIG congress in Munich, Germany, October 2006 (Lemmen and van Oosterom, 2006). This was called version 1.0 of the FIG Core Cadastral Domain Model (CCDM), also called the Munich-version. Due to several developments the model has been further refined and developed into the version 1.1, presented in this section. One remarkable difference is the change of name from CCDM to LADM. The reason for this is the fact that the term 'cadastral' was not perceived by everyone to cover both the legal/administrative side and the geometric side of such a registration. This became clear in some of the comments received on the ISO New Work Item Proposal (NWIP 1859, CCDM), as well as in discussions with experts from UN-Habitat. The term 'Cadastre' is associated with formal systems – it is most relevant that non-cadastral approaches are included. As the term 'land administration' better covers the full scope of the model, it was therefore decided to change the name, despite all the drawbacks of dropping the reasonably well know term CCDM after more than five years.

The LADM has been used as an example in the INSPIRE document D2.6: Methodology for the development of data specifications (Annex C), in which also several elements of the INSPIRE Generic Conceptual Model (document D2.5) were included, such as the VersionedObject class. Every object class that needs versioning, inherits from this class (as other 'themes' within INSPIRE would also do). In this way, it is not needed anymore to explicit add the tmin and tmax attributes to the core classes RegisterObject, RRR and Person. An extension of the new model is the inclusion of a new class: LegalNetwork as specialization of OtherRegisterObject. This class has an external reference to a physical network description in the information source at the organization responsible for the network. Other relevant attributes of the LegalNetwork class are belowSurface and dangerous (both Boolean), networkType (gas, water, telecom, etc.) and networkStatus (planned, inUse, outOfUse). Note that only the legal space related to the network is registered within the LADM and not the network itself. As the LegalNetwork is a subclass of RegisterObject, it is related to a Person via RRR (see Fig. 1 below).

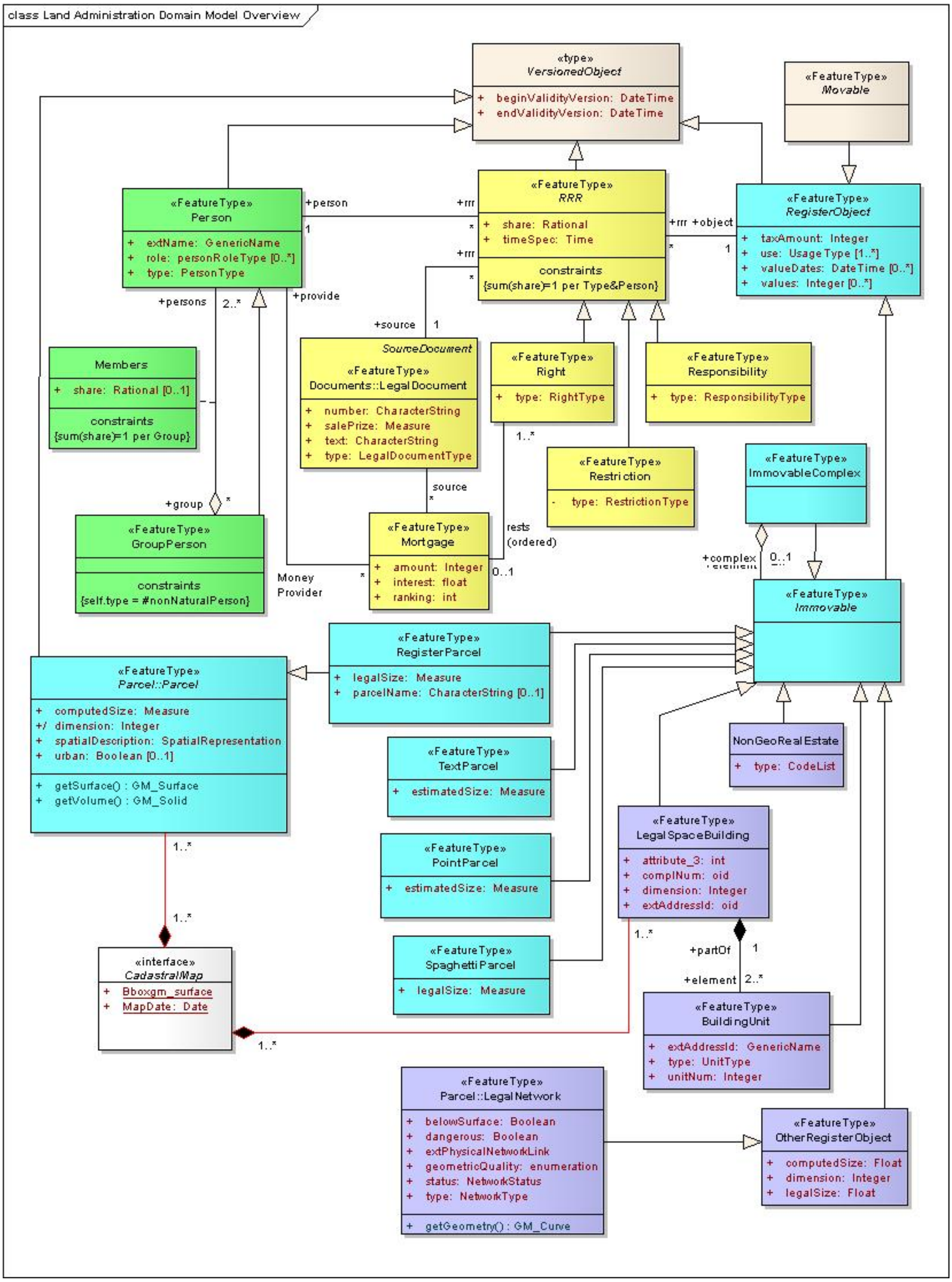

Figure 1 - Overview of the Land Administration Domain Model Version 1.1 (not showing the survey and the geometry/topology packages)

In order to keep the model as simple as possible, a number of subclasses have been removed in case no specific attributes, associations or operations for these subclasses could be defined. As the person registration itself is outside the scope of the LADM, both for natural and non-natural person, the only attribute is a reference to an external object and this is equal in both subclasses. Therefore, these subclasses have been removed. The class Person has now an additional attribute type (PersonType indicating a natural or non-natural Person) and the class has been made instanciable (as it was an abstract class before). Something similar happened to BuildingUnit and its two (old) specializations SharedUnit and IndividualUnit. Also here no difference in attributes and associations of the subclasses, so these were removed and their parent class has been extended with an attribute type (i.e. UnitType indicating a shared or individual unit).

Perhaps the most remarkable change in the LADM version 1.1 is the fact that the model is now fully compliant with ISO 19107 Spatial Schema, and in the past the CCDM used a more free interpretation of geometry and topology classes (same intention, but slightly different model). Direct from ISO 19107 are now the classes TP_Solid, TP_Face, TP_Edge, TP_node, and their 4 directed counterparts. A Parcel has a spatialDescription attribute of type SpatialRepresentation, which is a union of TP_Face (in 2D) and TP_Solid (in 3D). Constraints are used to indicate valid representations in the 2D and 3D case. Finally, the SurveyPoint information is attached to the topological primitives (ISO/TC211, 2003) providing the basis for the geometric realization. Of course it remains possible to include in a country profile 'boundary' related attributes as field survey observations, name of the responsible surveyor, date of survey, etc.

3. INTEGRATED COUNTRY PROFILE FOR PORTUGAL: LADM-PT

This section describes an example of how the LADM (understanding/communication and efficiency/development) goals are being fulfilled through a case study on the current cadastral situation and development efforts concerning the Portuguese Cadastre, integrated in a PhD research at Delft University of Technology in the Netherlands.

Current research efforts also include an implementation proposal, which is on the MDA approach, aiming at a higher degree of automation or at least computer support regarding the generation of database schema and other database artefacts from the original specification of a UML Model. Other MDA results could include: generation of GML compliant schemas for data exchange and the generation of parts of the user interface. This will be described in more detail in section 4.

The LADM should provide a first, generic view of the main objects and their association into dedicated packages, which should be considered on the design (or reform/renovation) of a Land Administration Information System. At this level, the LADM corresponds to a Platform Independent Model (PIM) according MDA terminology (Gaševic 2006; chapter 4), once it conveys the basic ontology of the domain irrespective of any considerations regarding

implementation, like computer data representations and platforms, specific database schemas and other implementation details.
Considered as a PIM, the Land Administration Domain Model it is absolutely not meant to define a worldwide applicable standard for a Land Administration Information System. Instead, it should be considered as supplying a generic blueprint that must be adapted to each country situation, while carefully considering a number of requirements, summarized below, constituting the so called Country Profile:

- Existing technologies and extent of cadastral coverage in the country, mainly dealing with surveying and mapping regulations;
- Institutional settings contributing to the definition of the set of Register Objects;
- Legal and regulatory framework governing Rights, Restrictions and Responsibilities in Land, including both the fields of private (usually through a Land Registry) and public law;

Within the MDA approach, this can also be classified as a Model Transformation (PIM -> PIM), generating a Country specific LADM which is still a Platform Independent Model. This Country specific Domain Model was not developed in a single iteration, but (until now) two successive iterations. First, the RegisterObject/Immovable/RegisterParcel (and other Parcel descriptions) and OtherRegisterObject from the former CCDM were considered in order to derive a Country Profile centred on the Cadastral functions (Hespanha et al, 2006). Although other packages were also considered at that time, the need to further refine the Legal and Administrative packages lead to a second proposal, encompassing both the Parcel related objects resulting from Private Law and the OtherRegisterObject resulting from Public Law and Regulations (Hespanha et al, 2007). All the above referred object classes are depicted on the class diagram in Fig. 1, the class names being still the same as in CCDM.

Conceptually, this integration mainly refers to the Legal Domain, reflecting also the evolution from the CCDM to the LADM, and offering a contribution to tackle the problem identified in the Bathurst Declaration (1999): "…most land administration systems today are not adequate to cope with increasingly complex range of rights, restrictions and responsibilities in relation to land."
In order to derive a PIM which can be further implemented on a computer based system supporting standardized spatial objects, it was decided to define a new UML Profile (a standard UML extension mechanism) which builds on the Simple Features Access for Structured Query Language (SQL) standard (OGC, 2006).

The current version of LADM-PT (PT = Portugal) was manually derived from previous versions of LADM and considers a number of technical, administrative and legal regulations which constitute the existent Portuguese Cadastral framework. This being the main source of requirements regarding adaptation of Parcel related packages, described in sub-section 3.1, while the Portuguese Civil Code and a number of other Law Decrees together form the requirements for the Legal and Administrative packages are described in sub-section 3.2.

3.1 Cadastral Objects and Geometry Packages

The objects directly related to the spatial representation of the RegisterParcel on the Portuguese Cadastre are grouped around the Parcel_G Class, which plays a fundamental role in the Cadastral component. Parcel_G objects store the geometry of each Immovable Property (thus, under Private Law) surveyed by the Cadastre and have a Land Registry counterpart, the RegisterParcel_PT. Both Parcel_G and RegisterParcel_PT classes are specializations of LADM RegisterParcel, imposed by specific organizational and institutional arrangements within the country (separate Cadastral Surveying and Land Registry organizations). The SheetSocialArea class from LADM-PT is a specialization from the LADM ServingParcel, where the joint owner is in fact the State, whereas in LADM the 'owners' would be the surrounding parcels using the ServingParcel. The Unit class in LADM-PT exactly corresponds to the BuildingUnit definition of LADM, while the Building class in LADM-PT corresponds just to its physical limits, and so is a derivation from the LADM LegalSpaceBuilding (see lower right corner of Fig. 1).

The examples introduced above show the main range of choices when deriving a specific country profile from the LADM. Modifications should be imposed by previously identified requirements and should follow regular UML constructs, further refined by the use of constraints, which should use OCL wherever possible as a standard approach in constraint setting; see section 5.

The classes belonging to the Portuguese Cadastral component were implemented into a prototype Cadastral Data Base belonging to the Ílhavo Municipality, following a protocol with University of Aveiro. An attempt was made in order to derive it from the UML Model through the use of a CASE tool, but software version incompatibilities dictated a manual implementation into an ArcGIS Geodatabase.

3.2 Legal and Administrative Packages

As referred previously, the Legal and Administrative Country Profile for the LADM-PT was obtained as result of a second modelling iteration. The higher-level conceptual model for the Legal Domain was based on another PhD research effort (Paasch, 2005) which perfectly fits into the current Legal component of the LADM.

The core abstract legal class in LADM-PT is no longer the LADM's RRR (Rights, Restrictions and Responsibilities), but Forms of Property. The name represents a high-level concept regarding the different forms of property recognized in the Portuguese Constitution. Previous results concerning the application of this classification schema to the Portuguese legislative framework were reported on (Hespanha et al, 2007; waits publication).

For practical purposes, the implication is that the LADM (or at least the LADM-PT) extends its modelling domain to all the different types of Land Parcels, defined by related Forms of Property, being privately owned, public domain or held in common (this last one called

"Baldios" in Portugal). Another important implication is that LADM-PT is not any longer restricted to those Land Parcels which can be registered in the Land Register. This fact has also major impact at the organizational level, once the number of actors to consider in a full implementation substantially increases, especially at governmental level.

3.2.1 Modelling the Legal Domain

The high-level classification schema for the Legal Domain considers based on (Paasch, 2005) a bi-axial system defining four quadrants, each typifying a specific legal space:

- I Quadrant: Rights regulated from Public Law, considered from the Positive Side. Abstract class is called "Public Advantage";
- II Quadrant: Restrictions regulated from Public Law, considered from the Negative Side. Abstract class is called "Public Regulation";
- III Quadrant: Restrictions regulated from Private Law, considered from the Negative Side. Abstract class is called "Encumbrance";
- IV Quadrant: Rights regulated from Private Law, considered from the Positive Side. Abstract class is called "Appurtenance".

In this schema, the Positive Side refers to the powers granted by each Right, while the Negative Side refers to the restrictions and responsibilities imposed by each Right. Considering a future implementation, only the positive side needs to be stored and then the negative side is implied. In a traditional Cadastral System, only Real Rights and related restrictions shall be considered, once they are subject to registration in most jurisdictions (both originating from Common Law or the Civil Code legal traditions). However, Real Rights just concern privately owned land parcels, leaving out all the terrain under Public Domain. The schema above allows for the consideration of Rights (and related restrictions) arising from Public Law, extending the legal space to the broader domain of Land Administration.

The current version of the LADM-PT, reflecting previous work by Paasch, still gives a larger focus to Real Rights defined in Portuguese legislation, thus the IV Quadrant is defined in greater detail.

The current version does not define yet how specific Public Regulation classes (II Quadrant) shall be represented spatially, once they can overlap a number of Land Parcels under private ownership (where IV and III Quadrant Rights and Restrictions apply). Research being done in the context of PhD and MSc studies will address issues related to the conceptual mapping of the legal space quadrants to the physical space of Land Parcels.

3.2.2 An Integrated Legal Model

The class diagram in Fig. 2 depicts the core relationship of people with land through rights, using the basic LADM colour schema (shown in the legend), for the specific case of a

Horizontal Property Right. Two different types of legal rights exist in this situation: Horizontal Property (as a Right of Joy) and Common Parts (as a Common Right). Both Right of Joy and Common Right are abstract classes representing specializations of Ownership, according Paasch's detailed level classification (see identification of super-class on the upper right corner of each class on Fig. 2).

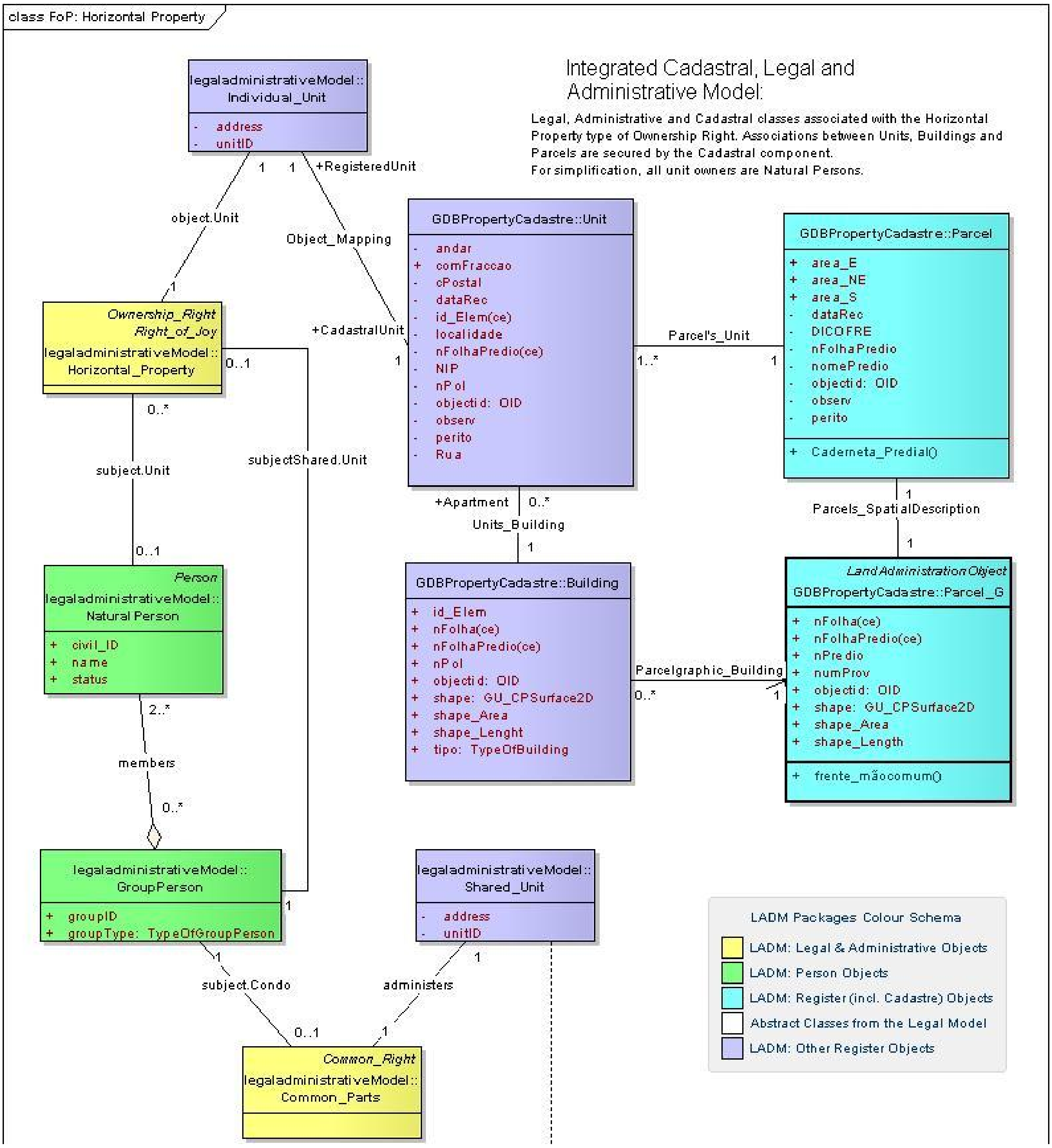

Figure 2 - LADM-PT Integrated Country Profile: Horizontal Property

The Horizontal Property Right is held by a single Natural Person (in this diagram) which is the subject of the Right, the object being an IndividualUnit (a special type of BuildingUnit in the LADM), typically an apartment in a residential building. On the cadastral component side, depicted on Fig. 2 through identification of the related package (GDBPropertyCadastre), each Unit should be related both to a Parcel (including the entire land surface held in common) and a Building (where the Unit should be spatially included). The Building should be also spatially bounded by the spatial representation of the Parcel (object Parcel_G).

The Common Parts Right respects all the Unit's individual owners (or owners assembly), in this way the subject is of the Group Person type. Corresponding object is the SharedUnit (another special type of BuildingUnit in LADM), which comprehends all the parts held in common within the Building and its surroundings, like access corridors, elevators, car parking space, the roof of the building and other premises. Currently, this is just a Land Registry object and does not have a spatial representation in the Cadastre.

The final version of the Integrated Country Profile (LADM-PT) shall have a specific diagram for each of the identified types of Rights, including those on the I^{st} and II^{nd} Quadrants, while currently only IV^{th} Quadrant Real Rights were modelled.

4. APPLYING THE MDA APPROACH

Current research efforts at Delft University of Technology aim to develop a Computer Aided Software Engineering (CASE) tool including a number of features from the MDA approach, which can support a development team implementing a specific LADM Country Profile.

This tool should perform a Model Transformation referred as Model-to-Text (Eclipse Project page), where the initial UML Model expressed as an XML Metadata Interchange (XMI) file shall be translated to a SQL text file with a set of Data Definition Language (DDL) commands. In order to achieve a successful transformation, the original LADM-PT should be previously transformed into a Platform Specific Model (PSM). This implies that decisions must be taken regarding the hardware and software platform on which the model will be implemented.

The first beta version will parse XMI files produced by Enterprise Architect software, which is being used in INSPIRE and ISO initiatives. The tool will use a Spatial UML Profile complying with the Simple Features for SQL standard (OGC, 2006) in order to generate a SQL script compatible with the open source PostgreSQL database (with PostGIS spatial extensions).

Our Model Transformation will operate in two main steps:

- The UML Model, this input encoded in an XMI file, will be parsed into an internal Object Oriented representation. This will include a number of components, namely the database schema generation, the OCL constraints processor and (possibly) an OCL queries generator;

- The internal Object Oriented representation, also called the Abstraction Layer (Bauer, 2007) in Object/Relational Mapping literature, will be used as the source for the generation of the database schema, through support of a properly set up Hibernate Spatial project.

The Integrated Development Environment of choice is the open source Eclipse platform, offering powerful tools which can assist in the coding phase, like JAXP for XMI parsing (JAXP, 2007) or the Hibernate Tools (Hibernate, 2007). At the present stage, existing solutions are being tested against a test data set representing a small part of the previously described Cadastral Component (sub-section 3.1).

Parallel to the experiments with model transformation in the Eclipse environment, a master thesis project is currently being executed with regard to the transformation possibilities that are offered by the aforementioned Enterprise Architect (EA) software. These possibilities are investigated in a prototype, which is aiming at implementing the Survey Package of the LADM in a PostgreSQL/PostGIS environment. Enterprise Architect offers a significant amount of functionality with regard to UML modelling.

The model transformation adjustment possibilities in EA are also considerable, although many specifications for these transformations are left to the EA user (programmer), only basic transformations are standard provided. Transformations from the platform independent (source, object oriented) to the platform specific viewpoint (target, relational database) are conducted in EA with *transformation definitions*, for a specific type of conversion, for example from UML to a "PostgreSQL" environment. Transformation definitions consist of a number of specific *conversion templates* for UML elements, for example some of the elements that are relevant to database platform specific implementation: Class (to Table), Attribute (to Column), and Connector (to relationship or intersection tables). In addition, EA offers a *Software Developers Kit*, which allows for using program units in the transformation, to fine-tune the transformation in subsequent cycles. With the transformation definitions and the EA software development kit, a prototype has been build that can automatically perform the transformation from an object oriented PIM to a PSM, targeting a relational PostgreSQL database (see Figure 3, respectively left and right side). This transformation is based on a number of *MDA transformation rules*, or implementation decisions. Take for example the MDA transformation rule with regard to the stereotype classes <<enumeration>> and <<CodeList>>, both used in the LADM for indicating a list of allowed values. Two implementation alternatives are possible: 1. define a second (look-up) table with the allowed values and define foreign key constraint from the original table to the look-up table, and 2. add a check constraint on the attribute and hard code in the check the allowed values. What to choose? As enumeration types are considered to be part of the model (application schema) and code lists are considered to be part of the application (registration) they might be treated differently by the MDA transformation rule.

We therefore propose to have the following MDA transformation rules: for <<enumeration>> we use method 2 (check constraint with hard code values, as the values are fixed) and for <<CodeList>> we use method 1 (look-up table with initial values as indicated in the LADM, but with the final application administrator responsibility for maintaining the allowed values in a registry). Figure 3 shows that <<enumeration>> class "Quality", with attributes "local" and "gnss" from the UML model (left side) has been converted into a check constraint "check_quality" in a database table model (right side). Note: the check constraint is defined as "quality IN ('local', 'gnss')". The <<CodeList>> SurveyDocumentType has been converted into a lookup table "codelist_surveydocumenttype", and a DDL script to insert the initial values into the lookup table has been created.

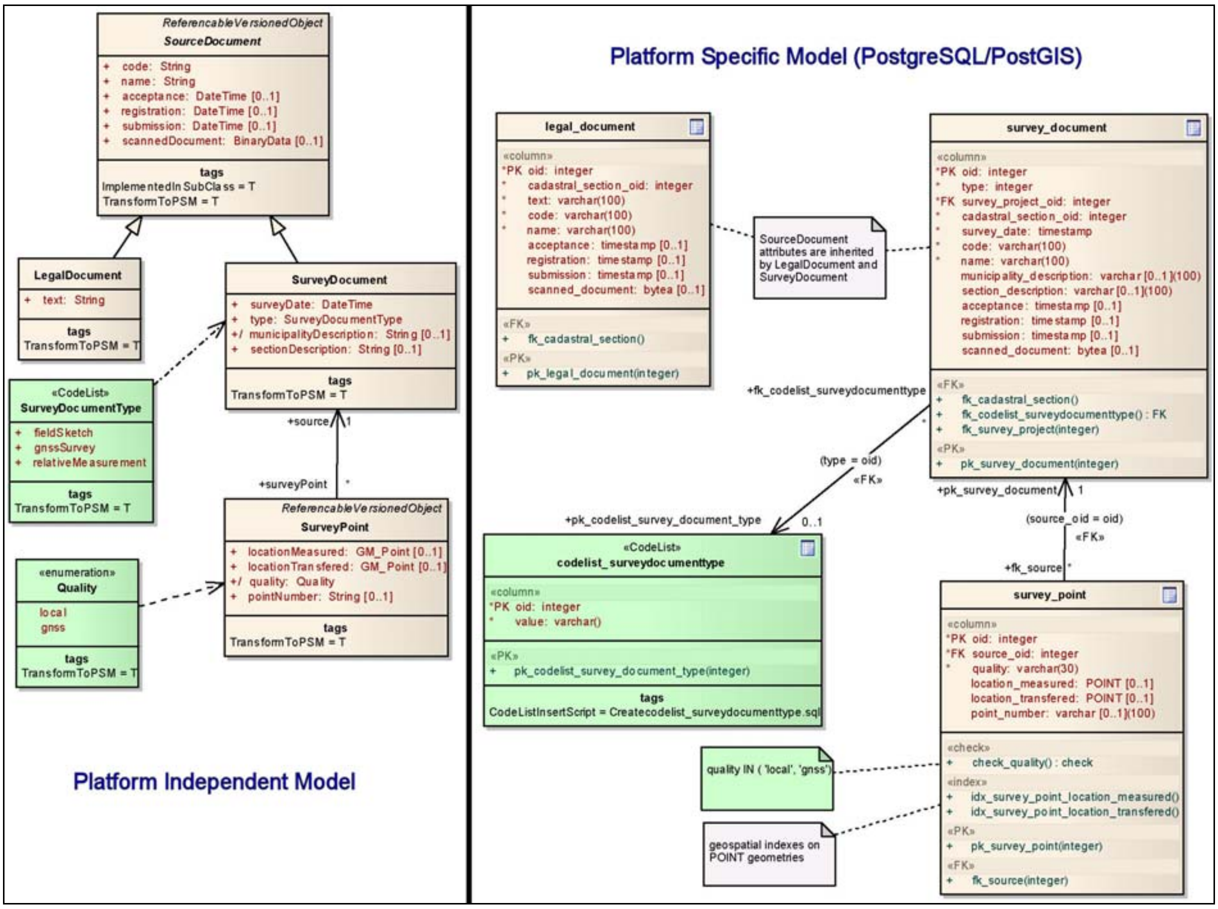

Figure 3 - EA Model Transformation: from PIM (left) to PSM (right)

The offered flexibility also enables the generation of spatial attributes in PostGIS based on attributes defined by datatypes according to the OGC SFS/ISO 19107 standard (ISO/TC211, 2003), for example the SurveyPoint attributes locationMeasured and locationTransfered of the standard datatype "GM_Point" are converted to PostGIS datatype POINT, including spatial indexes and constraints. Another example is the conversion of one super class (SourceDocument) and two sub classes (LegalDocument and SurveyDocument) into two implemented tables (legal_document and survey_document), where all attributes (code, name, acceptance, registration, submission, scannedDocument) and outbound foreign keys (fk_cadastral_section) are inherited.

5. OCL SUPPORT UNDER THE MDA APPROACH

Constraints in information systems can be defined and implemented in many different ways, where constraints are not always an integral part of the system. This will allow the constraint validation to be avoided and bypassed, which negatively affects data integrity. Often the constraints are defined at the implementation phase, making communication about constraints quite complex and cumbersome, as well as the maintenance of constraints in these situations. When constraints are described in a natural language, although highly understandable for layman, the disadvantage is that these constraints very easily lead to ambiguities in semantics, and in implementation. A formal description of constraints is required at the beginning of the development lifecycle.

UML, an Object Management Group (OMG) standard for modelling information systems (OMG. 2007a, 2007b), although powerful in describing and visualizing systems from a Platform Independent and Platform Specific Viewpoint, is not capable of modelling every kind of constraint. The Object Constraint Language (OCL, OMG. 2006b) is a formal language, which has been defined as an extension to UML. OCL enables the specification of those constraints, which cannot easily be recorded in UML, in an unambiguous manner. In the definition of OCL, one of the goals was to keep OCL easy to read and write, resembling the English natural language. OCL is a descriptive language which does not change anything to the model, nor does it specify the action to be taken when the constraint is violated.

The formal nature of the OCL, enables the automatic processing and implementation of OCL constraints, and can be used as a query language and it can be used to specify constraints, referring to classes, attributes, associations, and methods. An example of an OCL constraint in the context of Figure 3 is provided here; The constraint CheckQuality involves (instances of) the object *SurveyPoint*, represented by variable p, and its attribute *quality*, stating that a *SurveyPoint* must either be described in *quality* 'local' or 'gnss'.

```
context p.SurveyPoint inv CheckQuality:
p.quality = 'local' or p. quality = 'gnss'
```

In the field of information system development an increasing interest can be witnessed for documenting constraints in a formal manner, a few examples of these developments and research will be described in the following paragraphs.

As part of Oracle's Custom Development Method (CDM, Gylseth et al., 2000), business rule (constraint) modelling is described, called CDM Ruleframe, in the context of the CASE tool Oracle Designer. CDM Ruleframe categorized the business rules into the classes related to their implementation in an Oracle database, based on a structure of tables, views, stored packages, procedures, functions and triggers. A transaction management mechanism deals with enforcing rules at the moment of committing the changes of one transaction to the Oracle database, while message handling takes care of communicating information about rule violation. The classification of business rules from a platform specific viewpoint, as well as the mentioned transaction management mechanism, are assumed to be a possible basis for conversion and implementation of OCL constraints, subject to further research.

The Dresden OCL2 toolkit, maintained by the Software Technology Group at the Technical University of Dresden, contains the OCL2^{2}SQL tool (Dresden OCL, 2008) for converting UML models and OCL constraints to SQL statements for the Oracle and PostGIS database. The OCL2^{2}SQl tool is currently still based on the metamodels of (older) MOF version 1.4 and UML version 1.5. The OCL invariants, described a separate file, are translated to SQL views, which are based on the SQL views for superclasses and their specialised sub-classes. The OCL views can be used in different manners, depending on the constraint evaluation strategy. The Dresden OCL2 toolkit is currently under research; a new infrastructure has been developed on a so-called pivot model, serving as an exchange format for UML/OCL models (Bräuer, M. 2007).

When reviewing the data types and operations that can be used in OCL, one can see that OCL does not directly support the creation of spatial constraints, nor to the spatial datatypes and operations. An extension of OCL (OCL Spatial) was proposed by Pinet (Pinet, et al, 2007). Pinet proposes the integration of the eight Egenhofer binary relationships into OCL (i.e. disjoint, contains, inside, equal, meet, covers, coveredBy, overlap). Part of this proposal was also the definition of a new OCL BasicType, called BasicGeoType. This BasicGeoType is a generalisation of the types Point, Polyline and Polygon, which are used in UML to specify the geometry attributes of classes. For code generation based on these OCL and UML definitions, the abovementioned Dresden OCL2^{2}SQL tool was proposed to be extended. The syntax of a OCL function would be "A.Egenhofer_topological_relation(B)" and an OCL invariant could look like this (A being a class with an association B) :

```
context A inv:
not ( self.geometry. Egenhofer_topological_relation (self.B.geometry))
```

Enterprise Architect supports the recording of OCL, OCL constraints can be stored and validated in the platform independent model at the level of class, attribute and relationship (e.g. generalization, association). When a MDA transformation is performed, based on the standard available DDL transformation template, the OCL constraints are not propagated nor converted to the platform specific model, requiring the EA user to manually copy these constraints, as well as defining the code (DDL) to implement these in the RDBMS. The EA transformations can be adjusted and extended, partly based on EA Software Development Kit, which is now subject for further research. The conversion/implementation of PIM objects to elements play a role in the transformation rules for OCL constraints. For example class "SurveyPoint" has been converted to table "survey_point", which has an impact on the OCL syntax.

6. CONCLUSIONS AND RECOMMENDATIONS

The LADM has been extended with a new type of RegisterObject, namely LegalNetwork (representing the legal space around utility networks). In order to keep the model as simple as possible, a number of subclasses have been removed in case no specific attributes, associations or operations for these subclasses could be defined (in the cases of Person and BuildingUnit). An important change in the LADM version 1.1 is the fact that the model is now fully compliant with the INSPIRE Generic Conceptual Model (based on ISO 19107 Spatial Schema and the use of the VersionObject class). It has further been illustrated how a Country Profile for Portugal has been developed: the LADM-PT.

Some useful advice concerning the derivation of a Country Profile from LADM, following research results so far, is summarized bellow:

- Gather all existing, country specific, information concerning each of the LADM package-related domains; together defining the main technical, administrative and legal requirements;
- If a computer based (legacy) data model already exists, it will be most useful to depict it using UML Class Diagrams. Current MDA software can offer reverse engineering capabilities which can support this task;
- Core object classes should be assessed first, looking for direct matches from the LADM to the Country Profile. A complete match includes not only Class descriptions but also its associations in the UML Diagram;
- A Country Profile will use a subset of LADM Classes (although certain Classes should be considered mandatory) and can define a number of new Classes, using all the available specialization mechanisms in UML;
- A small number of iterations are expected in order to achieve a stable version of a Country Profile. Intermediary versions should be discussed among LADM and Country experts, which should constitute multidisciplinary teams (lawyers, surveyors and computer experts were among those involved on the Dutch-Portuguese team defining LADM-PT).

Regarding the CASE Tool being developed and tested on the LADM-PT Country Profile, one of its main advantages is to generate and make accessible an Abstraction Layer which can be extended in order to implement additional functionalities, namely a query and analysis user interface. Care should be taken, however, regarding performance issues, once a number of functionalities can be directly implemented to the database (the schema, stored procedures and triggers, etc.) which will run faster using standard database facilities.

The preliminary conclusions of the EA prototype are that the transformation definitions and the EA software development kit facilitate a fully automatic conversion of object oriented models (UML) to a relational (spatial) database model (PostGIS), for the MDA transformation rules that have been investigated (with regard to classes, attributes, datatypes and relationships). However, the fine-tuning of these transformations in the commercially available tool EA requires a lot of (programming) input. Specific EA related characteristics require a peculiar approach to generation of, for example, views (a stereotype of class) and stored procedures (a class method), which are envisioned to play a role in the OCL approach.

No MDA tools can be found that are fully capable of generating platform specific code for OCL constraints (e.g. for an Oracle or PostgreSQL/PostGIS database). Further research is being performing in applying and extending possibilities with regard to OCL, with regard to the classification of OCL constraints from a platform specific/implementation viewpoint, and the definition of some (semi-) automatic MDA transformation rules.

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