Integration of Land Administration Domain Model with CityGML for 3D Cadastre

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SUMMARY

As our urban environments are densifying, it is essential to extend traditional cadastral systems that are based on two dimensional representation of ownership to support 3D. With the need to define property ownership in vertical as well as horizontal dimensions becoming pertinent around the world, a practical solution to represent 3D cadastral data is needed. The Land Administration Domain Model (LADM, ISO 19152) already covers such situations since the spatial unit defined in the Spatial Unit package in LADM can refer to a single volume of space (or multiple volumes of space) besides 2D representations. LADM is a conceptual model that allows land administration objects and relationships to be described. The power of the model is the ability to describe different cadastral systems in different countries or regions in a consistent way.

CityGML is an information model and data exchange standard for 3D city model data. It does not contain specifics about land administration. The paper examines how the LADM conceptual model, the representation of legal spaces in particular, can be mapped to and encoded as a CityGML Application Domain Extension (ADE). The CityGML ADE implements a data exchange format but the underlying model could also be used as a starting point to create a database schema for data storage. The paper addresses the modelling issue of integrating different information models that define or refer to the same or overlapping concepts. The possibility to achieve greater integration between ISO19152 and CityGML by including each others concepts in future versions is also discussed. Relating legal features to physical features, a common occurance in practice, is addressed from a data modelling perspective.

The paper is intended to stimulate discussion about the topic as well as further development. It suggests a modelling solution to integration some parts of LADM and CityGML.

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1. INFORMATION MODELS

This paper examines how the Land Administration Domain Model (LADM) conceptual model, the representation of legal spaces in particular, can be mapped to and encoded as a CityGML Application Domain Extension (ADE) (section 2). Section 3 presents an alternative for the integration of CityGML and LADM, i.e. the establishment of an explicit overlap between the two standards and the embedding of LADM concepts in CityGML and vice versa. The paper ends with conclusions. First the two models are introduced in this section.

1.1 Land Administration Domain Model (LADM, ISO19152)

The ISO 19152 - Land Administration Domain Model (LADM) defines an conceptual model for land administration. It defines key information model components that are relevant for the creation and operation of cadastral systems in general. The core entities in LADM are

- Basic administrative units, subject to registration (by law), consisting of
- Spatial units against which (one or more) unique and homogeneous
- Rights (e.g. ownership right or land use right),
- Responsibilities or
- Restrictions are associated and linked to relevant parties.

LADM can also be seen as a meta model for land administration and has important connections with other standards because the administrative units in LADM are legal spaces that can have a relationship with physical features maintained in other domain models, for example in the case of pipelines or apartment units. The integration of data on legal spaces and on physical features is important because the boundaries of legal spaces often refer to physical features. Integration enables to reuse geometrical data in different domains in general and to define legal spaces based on physical constructions in specific. In addition, integration assures consistency between legal and physical registrations. To accommodate this integration, LADM refers for orientation purposes to physical features that are maintained in other data sets using the stereotype <<blueprint>>. This stereotype defines classes at an abstract level, which are further defined in other models. For example the LA_LegalSpaceBuildingUnit refers to an ExtPhysicalBuildingUnit and the LA_LegalSpaceUtilityNetwork refers to the external class ExtPhysicalUtilityNetwork. Referring to physical features is especially relevant in case of large scale 3D topography, which is the domain of CityGML.

It is envisaged that the practical application of ISO19152 will require the creation of application schemas, for example national or regional profiles in which LADM is utilised to describe the existing or planned implementation of land administration in the context of relevant law and practice.

We are looking only at a small part of LADM which is the geospatial definition of the extent of ownership right. These are mainly expressed in the Spatial Unit package regarding the spatial representation and the Administrative package for semantics. The party package is not considered in this paper. The following feature classes are particularly relevant:

LA_SpatialUnit: base class for spatial representations. LADM explicitly allows volumetric spatial representations in 3D.

LA_LegalSpaceBuildingUnit: A specialisation of LA_SpatialUnit to link legal spaces to physical ones. This is useful to describe legal spaces within a building which coincide with the physical space of the building or parts of it.

LA_SpatialUnitGroup: grouping of SpatialUnit instances allowing hierarchies (for example parcels into registration areas into parishes into districts into counties).

LA_BAUnit: An administrative unit that can be represented by spatial units.

LA_RRR is used to describe Right, Restriction, Responsibility to give meaning to a BAUnit which is represented by a spatial unit.

The following feature classes could also be relevant but are not considered by this paper:

LA_RequiredRelationshipSpatialUnit: explicit spatial relationships, when the geometry of the spatial units is not accurate enough to give reliable results

LA_BoundaryFace and LA_BoundaryFaceString: representation of a boundary parts

LA_Level: can be used to structure topologies between SpatialUnits

1.2 CityGML

CityGML is an information model and data exchange standard issued by the Open Geospatial Consortium. It is supported by a large number of software products and data providers around the world and defines a semantically rich 3D representation of geospatial features in urban areas. CityGML's level of detail concept allows for multiple representations of a single feature such as a building and allows the representation of the building interior. Today CityGML is mainly utilised to structure and represent observed physical phenomena such as walls, roofs, curbs or vegetation objects. The representation of legal extents is not explicitly covered in the standard, but can be implemented using CityGML's extension mechanism called Application Domain Extension (ADE). This approached is described in this paper.

The geometry definitions in CityGML are based on the Open Geospatial Consortium's GML standard—currently version GML 3.2.1 is used instead of the later version 3.2.2 which was ratified as ISO19136. The reasons for using the older GML version were the development timeframe of the current version 2.0 of CityGML as well as a still unresolved bug in GML 3.2.2. GML3.2.1 uses ISO19107 geometry types as the basis for geometric representations and does not allow any other geometries.

CityGML implements a subset of this ISO19107 geometry model and allows a choice between direct expression of geometric representations through GML data types as well as implicit representations and re-use of geometries through X-links.

CityGML 2.0 specifies a normative XML schema rather than an information model expressed in a conceptual schema language such as UML. The specification contains a number of UML class diagrams as explanations which are not normative. In more recent developments at the OGC and the Special Interest Group 3D a UML model for CityGML has been developed and agreed upon. It hasn't been published, though is available on request. The UML model was created to allow a clearer separation of conceptual model from encoding and to have a starting point to develop future versions of the CityGML standards based on UML. This UML model may be normative in future versions. The integration of LADM and CityGML in this paper is based on a simplified UML notation (figure 1).

A number of feature classes in CityGML that are relevant for expression of land ownership rights are given as follows:

- Building / BuildingPart: Representation of a physical building in different Levels of Detail.
- *_CityObject*: As the boundary of legal spaces may defined by or mered to any physical feature, all features with a physical representation in CityGML might be of relevance to express this relationship.
- Landuse: defines land areas of a particular use and could be used to represent parcels or ownership extends, though this would stretch the meaning of landuse beyond its general meaning and is not recommended.

It should be noted that not only ownership rights or legal extends are not specified, also the vertical separation of buildings into storeys is not covered by CityGML and can currently only be implemented by ADE or CityObjectGroup. A possible introduction of a story model into CityGML 3.0 will need to be considered in the future, particular to address physical and related legal spaces within a building.

2. INTEGRATION OF LADM AND CITYGML THROUGH THE DEVELOPMENT OF A CityGML LADM ADE

One usecase for the representation of legal property ownership in 3D is given by (Ammar and Dixit 2013).

Both LADM and CityGML are compatible with ISO19107 which ensures an overlap of allowed geometry types. The ISO19152 specification makes it clear that LADM is not a data product specification in the sense of ISO19131 but a conceptual model that provides a formal language to describe land administration regarding their parties, administrative and spatial units as well as sources and representations.

CityGML, on the other hand, is a data encoding that was created to exchange data. It is based on a conceptual model that is described in the standard, but conformance to CityGML is specified only on the encoding level, not the conceptual model. From the feature classes modelled in the CityGML specification a preference to explicitly type objects with a semantic definition (such as buildings, roads, bridges, etc) can be inferred. This is in contrast to LADM which is not intended to be an application schema in its own right. There are two ways to create a CityGML ADE for land administration:

> 1. Create a country/region specific application schema (LADM profile) that also utilises concepts taken from CityGML 's conceptual model. In a second step, different encodings of the application schema can be created. The 3D encoding will be expressed as a CityGML ADE.
>
> 2. Directly implement LADM in an ADE, making some assumptions about the typing of feature classes.

Approach number one provides a foundation that also allows 2D encodings outside of CityGML to serve existing 2D data and processes. It would be the preferred method for a national or regional cadastral information model. This paper, however, follows the simpler approach number two in order to illustrate the key suggestions.

2.1 Mapping of concepts

The main approach presented in this paper is to model LA_BAUnits not as a general, abstract feature but as a feature with a particular meaning. Instead of creating a general BAUnits feature, a Parcel feature is created which serves as the administrative unit to register land.

The approach also allows multiple geometries to represent the LA_SpatialUnits associated with the LA_BAUnit and allows the parcel to be X-linked to a representation of an LA_RRR instance in an external system (outside of CityGML).

Figure 1 describes the classes to be defined in a LADM ADE for CityGML. These have the namespace prefix LADM-ADE. The figure demonstrates this for parcels only but other types of BAUnits can be similarly implemented.

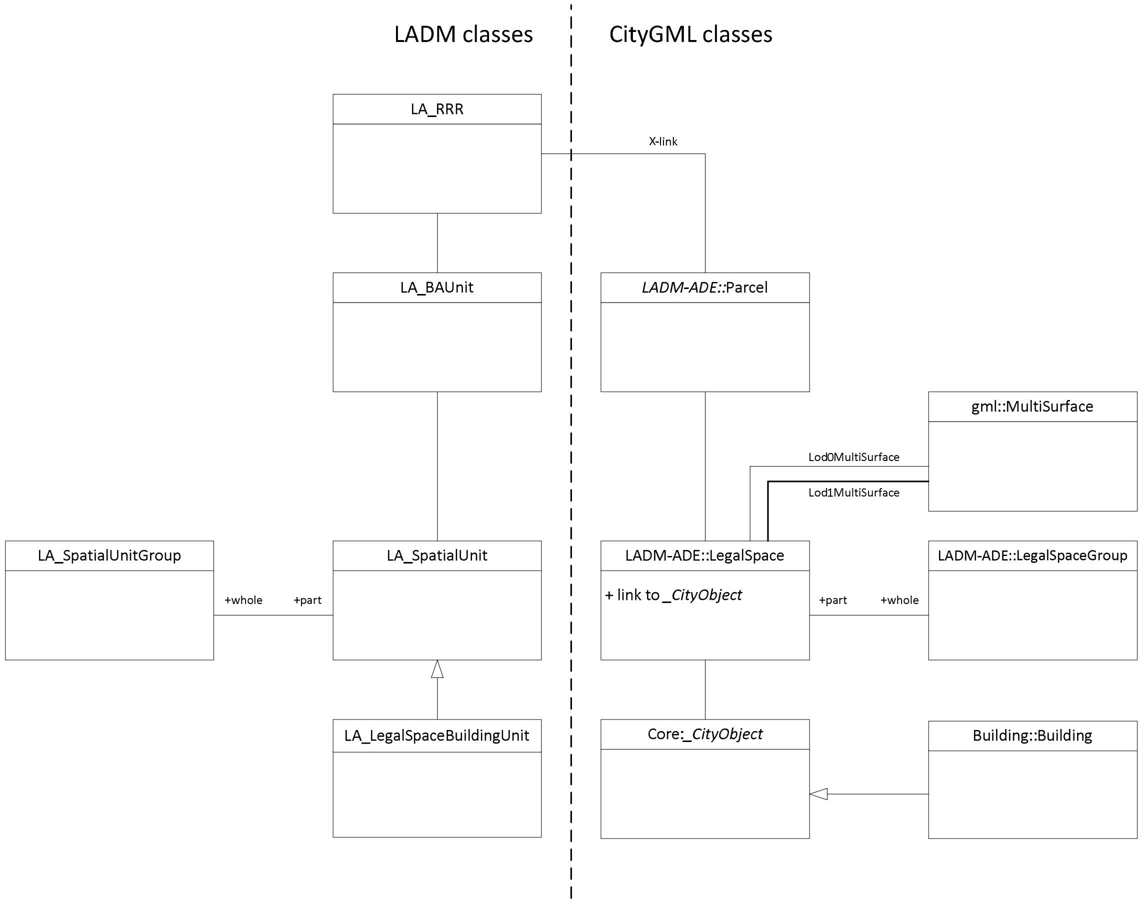

Figure 1. Feature classes in a CityGML LADM ADE and their corresponding LADM feature in simplified UML class diagram notation

Rather than having a direct counterpart for LA_BAUnit, we suggest to directly create an instantiable object class with a semantic definition such as Parcel. Instances of this class can be linked to suitable instances of LA_RRR qualifying the right associated with the Parcel. The Parcel can be represented by one or more SpatialUnits. LA_SpatialUnit is implemented as the class LegalSpace which can have MultiSurface representations in different LoDs. A planimetric representation (i.e. a floorplan polygon with a given height) in LoD0 and a block-representation (extruded and heighted block) in LoD1 appear to be useful in practise.

It should be noted that CityGML 2.0 does not allow the definition of different LoD representations within buildings as these have to be LoD4. However, the definition of different LoDs in the indoor space is currently being worked on by the OGC CityGML SWG and is expected to be implemented in CityGML 3.0. The definition of legal spaces may serve as a good use case for a consistent future LoD approach in CityGML that is independent of a space being physically in- or outside of a building.

2.2 CityGML ADE development

User communities are encouraged and guided to create extensions to the CityGML standard and to date a variety of ADEs have been created in fields such as utility networks, noise modelling, solar potential, energy efficiency of buildings as well as national implementations, for example in the Netherlands, Germany or Bahrain.

Whilst the ADE is formally defined by its XSD schema, a UML representation can also be used to model the ADE and to derive the XSD following the model driven approach. The features Parcel, LegalSpace and LegalSpaceGroup will be implemented as feature classes in the ADE.

These three feature classes defined in the LADM-ADE namespace would also inherit from VersionedObject in LADM to allow version management using LADM's approach. It is suggested that this is implemented as an ADE addition to the CityGML core module in order to give all features classes in CityGML this ability. Figure 2 shows how *_CityObject* can be amended by an ADEElement that inserts the properties for version control.

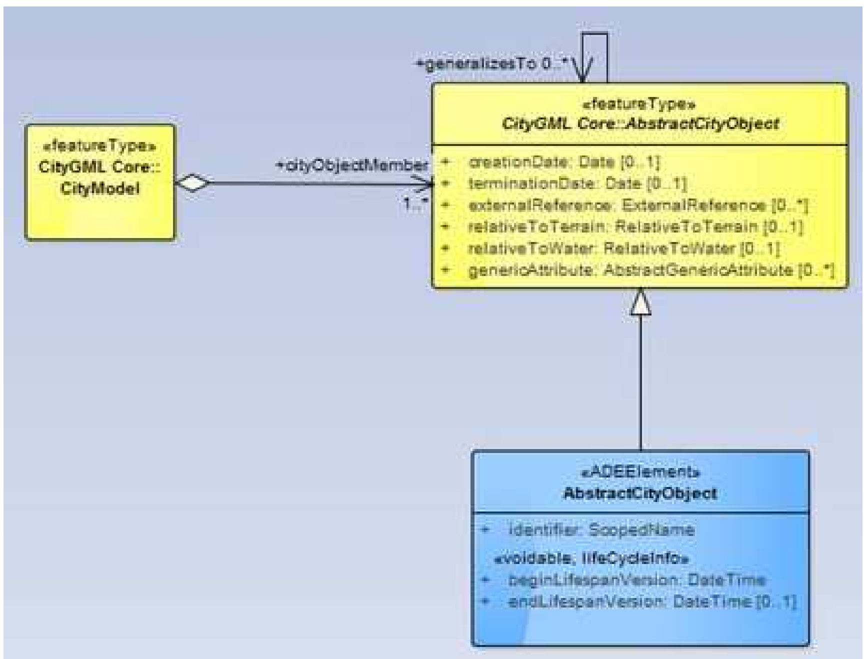

Figure 2: Extension of *_CityObject* in the CityGML core module with verion information

Any LADM-ADE developed in more detail should be tested for conformance with ISO19152. At least the conformance level one (clause 2.4 in Annex A of ISO19152) should be achieved.

2.3 Relationship between physical and legal

We suggest to model features with legal and physical representations independently and allow to establish an n:n relationships between these. Whilst the relationship between a LegalSpace and a Building is the most obvious one to be useful, relationships between LegalSpace and any _*CityObject* should be allowed. In order to implement the high level approach depicted in Figure 1 it may be beneficial to model an additional relationship class to link LegalSpaces with _*CityObjects*.

2.4 Access rights

Legal rights, such as easements or access rights can be modelled in an similar way to Parcels following LADM's conceptual model. A feature representing an access right (SolarPanelSpace, for example) can be modelled. The right to install and service solar panels on roofs (solar cadastre), for example, can simply be implemented by linking to a suitable specialisation of LA_RRR that expresses these rights.

3. INTEGRATION OF CONCEPTS

The implementation of ISO19152-conformant features in a CityGML ADE is only one of the possible approaaches to combine the capabilities of CityGML and LADM. The advantage of this approach is that a practical solution to capture, store and exchange land administration information, particularly legal spaces, by using both standards without modifications to LADM and allowed extensions of CityGML. A different approach would be to create an explicit overlap between the two standards and embed LADM concepts in CityGML and vice versa. This could happen in the normative parts of the specifications or, at least to start with, in the informative parts or annexes. The developments in both standards would ideally be synchronised.

Both standards are subject to the maintenance and publication procedures that are particular to the relevant standardisation organisations owning the standards. Whilst revisions of a standard in the Open Geospatial Consortium's process are linked to change requests that can be submitted by anybody on the OGC portal (www.opengeospatial.org), revisions of ISO standards have a default maintenance cycle of 5 years and require a New Work Item Proposal to be submitted by member states and agreed by the technical comittee.

It is suggested that in the next revision of ISO19152 an informative annex that explains how relevant parts of LADM can be encoded in CityGML is added to the specification. The next periodic review of the specification will be due in 2017, though an earlier start might be possible if the case can be made. A further step could be to specify an encoding for LADM similar to the encoding specified in ISO19135-2 for the item registration procedures covered by ISO19135. A 3D encoding could then be specified based on CityGML. However, it may be beneficial to evaluate first if there is a clear market demand for such an encoding. In the meantime, CityGML ADEs can be used to experiment with encodings and develop better requirements.
From a CityGML perspective the representation of Land Administration is currently subject to consideration in CityGML 3.0. The development phase started in mid 2014 and is expected to last until at least summer 2015. Suggestions in the form of change requests are processed by the OGC CityGML SWG. A change request to include LADM concepts as a Land Administration module in version 3.0 can be made by anybody.

The flexibility of LADM to allow country or regional profiles suggests that the development of country or regional ADEs taking into account specific requirements of the local cadastre and registration systems may be a more suitable approach than including a dedicated land administration package in future versions of CityGML.

4. CONCLUSION

The paper demonstrated how the OpenGeospatial Consortium’s CityGML standard can be used to provide an encoding for 3D land administration information. The basic principles of the integration by mapping key feature classes in both standards are shown. The same approach will be applicable for country or region specific profiles of ISO19152 and practical experimentation with this is encouraged.

More work needs to be done to develop and test one or more CityGML ADEs for land administration in a practical use case. This could be done in an OGC Interoperability Experimenent or one or more separate projects, ideally in different countries.

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BIOGRAPHICAL NOTES

Carsten Rönsdorf is Head of Advisory Services for Ordnance Survey International, a subsidiary of Britain’s National Mapping Agency, and provides advice to government agencies across the Middle East. Carsten has been at Ordnance Survey for more than 12 years and was previously responsible for developing and managing Ordnance Survey's core data asset, the National Geographic Database, as well as managing the product engineering group.
Having been involved in geospatial 3D since 1996, he has led the standardisation of the Open Geospatial Consortium’s CityGML standard since 2007 and is particularly keen on stressing the need to integrate 2D and 3D in order to sustain 3D investments and maximise business value.

Debbie Wilson is a Senior Information Architect and is custodian of the National Geographic Data Model at Ordnance Survey. Debbie also provides advisory and training services with Ordnance Survey International working with National Mapping Agencies to improve how they create, manage and maintain their various data models and how to develop exchange models based on open standards such as ISO TC211,GML and CityGML.

Jantien Stoter is professor Spatial Data Infrastructure, at the Faculty of Architecture and the Built Environment, Delft University of Technology (TU Delft) and obtained her PhD degree (3D Cadastre) in 2004. She combines her professorship with jobs as researcher at both the Kadaster and Geonovum. Jantien is chair of the EuroSDR Commission "Data Specifications" and leader of the national 3D SIG (Special Interest Group) and the EuroSDR 3D SIG. Her research areas are 3D, automated generalization and information modelling.

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