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Towards integration of 3D legal and physical objects in cadastral data models

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ABSTRACT

Digital 3D cadastres are often envisaged as the visualisation of 3D property rights (legal objects) and to some extent, their physical counterparts (physical objects) such as buildings and utility networks on, above and under the surface. They facilitate registration and management of 3D properties and reduction of boundary disputes. They also enable a wide variety of applications that in turn identify detailed and integrated 3D legal and physical objects for property management and city space management (3D land use management).

Efficient delivery and implementation of these applications require many elements to support a digital 3D cadastre, such as existing 3D property registration laws, appropriate 3D data acquisition methods, 3D spatial database management systems, and functional 3D visualisation platforms. In addition, an appropriate 3D cadastral data model can also play a key role to ensure successful development of the 3D cadastre.

A 3D cadastral data model needs to reflect the complexity and interrelations of 3D legal objects and their physical counterparts. Many jurisdictions have defined their own cadastral data models for legal purposes and have neglected the third dimension, integration of physical counterparts and semantic aspects.

To address these problems, this paper aims to investigate why existing cadastral data models do not facilitate effective representation and analysis of 3D data, integration of 3D legal objects with their physical counterparts, and semantics. Then, a 3D cadastral data model (3DCDM) is proposed as a solution to improve the current cadastral data models. The data model is developed based on the ISO standards. UML modelling language is used to specify the data model. The results of this research can be used by cadastral data modellers to improve existing or develop new cadastral data models to support the requirements of 3D cadastres.

Introduction

Background

Digital 3D cadastres can be used by those who are engaged in the land development process including land registries, surveyors, architects, developers, planners, real estate agents, local governments, and owners corporations. Digital 3D cadastres can provide important information for different aspects of land and property management (Rajabifard et al., 2012). First, they represent the spatial extent of ownership boundaries in the third dimension of height where layered and stratified ownerships exist. Second, they facilitate registration of 3D property rights. Third, they support land development processes including issuing of permit plans in dense urban areas especially for large scale developments such as bridges and tunnels which cross above or under other developments. Fourth, they provide reliable information for decision makers. Last but not least, they are utilised as a basic layer to integrate with other information layers such as 3D city models (CityGML), Building Information Models (BIM), transportation and utility networks, land use controls, and delivery of services for different applications.

Land administration systems must deliver accessible, exchangeable, complete, and valid information about people to land relationships in 2D and 3D reflecting various ownership models and they must manage the huge amount of information in cadastral databases (Lemmen, 2012). Cadastral data models can provide appropriate elements (classes, attributes, relationships) about these aspects. However, in the context of land and property

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management, the prerequisite is overlaying 3D physical objects, such as building models, with their corresponding 3D legal objects, such as volumetric ownership models (Aien et al., 2011; Erba, 2012).

For this purpose, 3D cadastres should be equipped with integrated cadastral data models that can maintain both 3D legal and physical objects. In this paper this data model is called 3D cadastral data model and is not based on the definition of 2D land parcels. Use of this data model enables 3D cadastres to serve multiple 3D applications such as land and property management, virtual legal 3D cities, housing transactions and land market analysis, land and property taxation, public communication (tools for real estate agencies), city space management (3D land use management) and 3D site location.

Problem description

There is no an integrated cadastral data model that can maintain both 3D legal and physical objects. 3D physical objects can be achieved by using 3D city models such as CAD files, CityGML (Gröger et al., 2012), or BIM (Isikdag and Zlatanova, 2009); however, these do not support legal or cadastral information. By contrast, cadastral data models, such as ePlan and LADM, maintain legal information, but they do not maintain 3D physical objects. Integration of 3D legal and physical objects in these data models would facilitate implementation of previously mentioned 3D applications.

Integration of 3D legal objects with their physical counterparts is far from easy. Since legal and physical objects are often maintained separately, integration inevitably leads to geometrical inconsistencies. Semantic information can help to reduce the ambiguities for geometric integration, provided it is coherently structured with respect to geometry (Stadler and Kolbe, 2007). Therefore, integration of 3D legal and physical objects and their interoperability requires semantically enriched information in 3D cadastral data models. Semantically enriched data means enriching the content and context of the data by categorising or classifying data in relationship to other data. In one level of semantics, for example, a 3D object can be defined as a residential unit or a car park using appropriate names and attributes in a 3D virtual city model. In more detailed and enriched level, various parts or structures of the unit or car park including its walls, floors and ceilings can be identified. Semantic aspects of the data model allow for ad-hoc combination of distributed sources. Ambiguity affecting integration of models will be reduced if more information is provided by the semantic layer.

Since land administration requirements differ among the various jurisdictions, various unique cadastral data models have been developed around the world. Examples of current cadastral data models include:

- The core cadastral data model (Henssen, 1995),
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996),
- ArcGIS Parcel Data Model (Meyer, 2001),
- DM.01 (Steudler, 2005),
- The Legal Property Object Model (Kalantari et al., 2008),
- ICSM Harmonised Data Model (ICSM, 2009),
- ePlan (ePlan, 2010),
- South Korean 3D Cadastre (Lee and Koh, 2007; Park et al., 2010), and
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152, 2012).

These models do not efficiently facilitate representation and analysis of 3D data; they are not semantically enriched; and they do not integrate physical counterparts of legal objects.

Methodology

This paper explores how existing cadastral data models address these problems and proposes a conceptual 3D cadastral data model (3DCDM) as a solution capable of supporting 3D data, integrating 3D physical objects with their corresponding 3D legal objects, and featuring semantically enriched objects. The 3DCDM model represents 3D legal objects and connects legal and physical objects together. This practice can be used as an extension in the existing cadastral or city data models.

In this regard, the 3DCDM model is equipped with the concepts of the Legal Property Object and the Physical Property Object. The first facilitates modelling of all existing interests as legal objects. The second considers all 3D city models such as buildings, tunnels, and utilities as physical objects. 3D geometric primitives of GML (Geographic Markup Language) such as Solid and MultiSurface are used to define the Legal and Physical Property Objects. The 3DCDM model supports semantics that define every aspect of legal and physical objects, and therefore, it facilitates their integration.

The remainder of the paper presents the model in detail. Section “Need for a 3D cadastral data model” describes the need for developing a 3D cadastral data model. Section “3D legal objects in cadastral data models” shows how to use 3D parcels as the building block in 3D cadastral data models. Integration of physical and legal objects is illustrated in Section “Integration of physical counterparts of legal objects in cadastral systems (land registration perspective)”. Section “The 3D Cadastral data Model (3DCDM)” presents the conceptual model of the 3DCDM in brief. Research conclusions are presented in Section “Conclusion”.

Scope and delimitation

This paper investigates why existing cadastral data models do not facilitate efficient representation and analysis of 3D data, integration of 3D legal objects with their physical counterparts, and semantics. All above-mentioned data models are considered in the scope of this paper; however, because of space limitations, the most important and more advanced data model, LADM, is reviewed in more detail.

Since the main contribution of this paper is to describe the importance of integration of 3D legal and physical objects in one model, only the basic concepts and theories that used to develop the 3DCDM model are described. The paper describes the possibility of integration of 3D legal and physical objects in one model as a basis for further research and as a prelude to development of a complete model on the basis of that research.

Need for a 3D cadastral data model

Management of stratified land rights, restrictions and responsibilities (3D RRRs) is an important challenge for current land administration systems that are equipped with cadastres capable of maintaining 2D spatial information.

Many elements, including legal, institutional, and technical elements, are required to effectively add the third dimension of height into the current cadastres (Stoter, 2004; Paulsson, 2007, 2013; Paulsson and Paasch, 2013). However, data modelling is one of the key and primary steps towards successful implementation of 3D cadastres (Aien et al., 2013). The main purposes of 3D cadastral data models involve: