Design of 3D cadastre model in the Russian Federation

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1. Introduction

With an aim to introduce 3D cadastre registration in the Russian Federation, the Russian Government commissioned 3D cadastre modelling project. After the initial analysis of the Russian legislation, an inventory of possible use cases in Russia, and the examination of 3D Cadastre 'solutions' in other countries, the project is currently in the phase of the design of a 3D Cadastral model, which will then be followed by the development of a prototype system. The project is based on experience of the Netherlands (Stoter, 2004; Stoter and Van Oosterom, 2005) and other countries (van Oosterom et al, 2011).

The Russian and Dutch partners in this government-to-government project are: Federal Service for State Registration, Cadastre and Mapping (Rosreestr), Federal Cadastre Centre (FCC) "Zemlya" and the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster) in consortium with Delft University of Technology (TUD), Grontmij Nederland B.V., and Royal Haskoning B.V. Our analysis showed that the cadastral law in the Russian Federation is quite generic concerning 3D situations: it neither explicitly mentions 3D, nor does it prohibit 3D volumetric parcels for registration. However, the Russian Federation has a strong drive towards a 3D cadastre for better registration of complex buildings, or other types of constructions, and subsurface networks (e.g., cables and pipelines).

Rosreestr is responsible for all tasks related to the registration of rights, recording of parcels (cadastral map) and geodetic and (topographic) mapping. Rosreestr has about 6,500 offices and 60,000 staff members. Since the start of the Russian Federation approximately 80 million parcels have been registered together with associated rights and restrictions (responsibilities) and the involved parties. Therefore Rostreestr maintains probably the world's largest cadastral system. Both information on parcels and the legal and administrative information can be accessed online by the public (http://maps.rosreestr.ru/Portal/). Rosreestr falls under the authority of the Ministry of Economic Development of the Russian Federation being the project counterpart.

This paper starts with an overview of the current cadastral (legal and spatial) model in the Russian Federation and relates this to the terminology of the Land Administration Domain Model (LADM; ISO DIS 19152, 2011). Section 3 discusses the extension of the model into 3D, covering both the conceptual and technical aspects. The various types of data used for the developments of the prototype system are presented in Section 4. The paper ends with concluding remarks in Section 5.

2. Current cadastral model

The current cadastral parcel registration system is 2D polygon-based, in the terminology of the LADM (ISO DIS 19152, 2011). The database contains the full history of the parcel since its creation. The scale of the cadastral maps differs for pragmatic reasons from 1:2,000 in urban areas up to 1:10,000 in rural areas. The Russian Cadastre registers more than land parcels. According to article 1 of the Federal Law 'On State Cadastre for Real Estate' the Russian cadastre (maintained by Rostreestr) registers five types of objects: 1. Land (parcels), 2. Buildings, 3. Apartment Units, 4. Other structures (bridges, pipelines etc.), and 5. Unfinished objects, i.e. objects under construction (buildings, bridges, pipelines, etc.). The implementation of this model, both the administrative (legal) and spatial parts, is realized via the two existing databases of Rosreestr: the 'Cadastre' database and 'Registration' database.

3. 3D cadastre model

In the first subsection the 3D extension is discussed with respect to the conceptual model. In subsection 3.2 the technical, implementation oriented, model is discussed. Then the actual data representations within this model are discussed in the next subsections for the various formats: 3D PDF, XML and Oracle database.

3.1 Conceptual model 3D Cadastre extension

The design of the 3D Cadastral model is based on an analysis (of the geometric part) of the current Cadastre registration (as in the first phase of the project it has become clear that there is no need to change the legal/administrative part of the model). As a reference model the ISO 19152 Draft International Standard (DIS) Land Administration Domain Model (LADM) has been used. This already includes a 3D spatial profile.

Based on the requirements derived from the potential use cases, it was decided that the 3D registration is based on two objects 1. 3D polyhedron volume (flat planes) or 2. 3D multicurve with diameter (curved surfaces around pipelines). A topologically structured 3D Cadastre, is not conform the current 2D Russian Land Registry, which has no topology. The motivations in favour of the selected approach, besides that it does support the needs of the analysed cases, are that this approach is in line with the existing 2D registration and should be relative easy to implement. The 3D volume parcels have their own geometry, similar as in the current 2D database (via polygons). However, this time the geometry is represented by a polyhedron (volume bounded by flat faces) or multicurve with diameter. So, the advantages are clear: relatively easy implementable with current technology (database, GIS/CAD), and similar to polygon approach in 2D. A drawback is that it does not support a topology structure (for better quality guarantees) and no curved faces. This means that during data entry careful checks have to be implemented to validate that 3D volume parcels are well formed and non-overlapping. Because curved faces are not supported (except via multicurves with diameters for pipelines and cables), curved boundary surfaces need to be approximated by a series of flat surfaces. This is not a serious limitation and quite a practical and easy to implement solution.

The model is used for the specification of the rules for the initial registration of 3D parcels, for the extended database schema, and for the dissemination and visualization of the 3D parcels (in combination with the existing 2D parcels).

3.2 Technical model for database and submission

The technical model will play an important role in the draft guidelines for the registration of new 3D parcels. It is crucial to develop guidelines (possibly in the legislation on cadastre) describing how in the future in Russia, 3D parcels must be submitted for registration. These guidelines are based on experiences in other countries; especially the Queensland 'Directions for the Preparation of Plans'. Chapter 10 of these directions describes exactly how a volumetric parcel should be described so it can be registered. Based on this example and after analyzing the Cadastre in the Russian Federation, the guidelines are defined for the registration of new 3D parcels/cadastral objects (Vandysheva et al, 2011).

The preference is to store the 3D parcels in the same database table as the 2D parcels, so no database schema change is needed. However, an alternative option would be to introduce a new table for these 3D objects. It is possible to derive from the 3D geometry: 1. the 2D contour of intersection of 3D object with the surface z=0 and 2. the 2D projection contour of the 3D object on the surface z=0. These 2D contours (polygons) do not have to be submitted as they can be computed. The GEOLOC attribute (SDO_GEOMETRY) can contain multiple geometries. So, it is possible to store these derived 2D polygons together with the 3D polyhedron in a single GEOLOC attribute. It has to be decided whether these are computed on the fly or stored explicitly. In case they are stored, the preference would be to store multiple geometries in single SDO_GEOMETRY (again no database schema change). The new 3D parcels have to be validated against the existing area's (2D parcels) and 3D objects: are the rights properly transferred. The mentioned guidelines are intended for the initial registration.

Again, note that when a single new 3D parcel that crosses multiple land parcels, this requires the transfer of the ownership (or other rights) of the involved 3D spaces from the existing parcels to the single new 3D parcel).

3.3 Documents in 3D PDF

The nice aspect of 3D PDF is that it can integrate both the legal text and the associated drawing in one document, which is then submitted for registration of a transaction. With a standard Acrobat PDF reader, it is not only possible to see the text and a fixed impression of the 3D drawing, but it is also possible to interact with the 3D drawing: rotating, scaling, slicing, selecting, etc. However, it is not possible to directly extract the 3D geometry, for subsequent storage in the database. For this purpose, also the XML document with data has to be submitted (see next section).

3.4 3D data in XML

The actual encoding of the 3D Parcel (as part of the initial registration/survey plan) will be done in the XML standard format based on the integration of LADM-3D and CityGML (OGC standard for 3D city objects based on GML (XML encoding)). This solution allows explicit links between a 3D cadastral (i.e. legal) object (e.g. as in LA_LegalSpaceBuildingUnit LADM) and its physical counterpart (e.g. part of building CityGML). In the initial phase of the project, it is proposed not to include the explicit associations.

A 3D parcel is encoded with a generic CityGML class (to extend the CityGML model) and this is tagged with the corresponding LADM class name; e.g. for legal space building unit: <generic:class>LA_LegalSpaceBuildingUnit</generic:class>. For the Russian Federation the appropriate Russian tags should be used here, that is:

- RF_LandParcel,
- RF_LegalSpaceBuilding,
- RF_LegalSpaceBuildingUnit,
- RF_LegalSpaceOtherConstruction, and
- RF_LegalSpaceUnfinished.

3.5 3D data in the Oracle database

The existing database schema of the Russian cadastre (see Section 2) does not (or hardly) need to be adopted. In the legal/ administrative side there are no changes at all. But also because of the selected technical solution (polyhedron-based), there are also no (or hardly any) changes at the geometric side of the database. The 3D polyhedrons do fit in Oracle spatial SDO_GEOMETRY type (as well as 2D polygons do). Oracle does call this a geometry subtype and the name for a polyhedron is a 'solid'. This is available since Oracle version 11. Perhaps one additional attribute could be added: 'diameter' (if equal to -2 then this is a normal 2D polygon, if equal to -3 the this is a normal 3D polyhedron, if larger or equal to 0 then this specifies the diameter of a 'multicurve').

It is expected that spatial indexing (the R-tree in Oracle) could remain two dimensional (as the x- and y coordinates are by far the most selective). However, it may be of interest to investigate the performance effect of using a three-dimensional index, when large quantities of 3D data are loaded in the database as in case of a dense urban area.

4. 3D sample data for the prototype

In this section the test data is presented for three selected cases. Besides (2D) cadastral parcels and related administrative (legal) information, each case also includes terrain elevation, reference topographic data and 3D models. The data for the selected 3D cases are from Nizhegorodskaya Oblast, which has been selected as pilot region in this project. The following three different cases have been selected for the prototype:

1. Case 1 is the Teledom building (near the television tower) building, 9/1 ul. Belinsky. The building has interesting overhangs (possible above neighbour parcel with shops and also possible above public road/ footpath); see Figure 1.

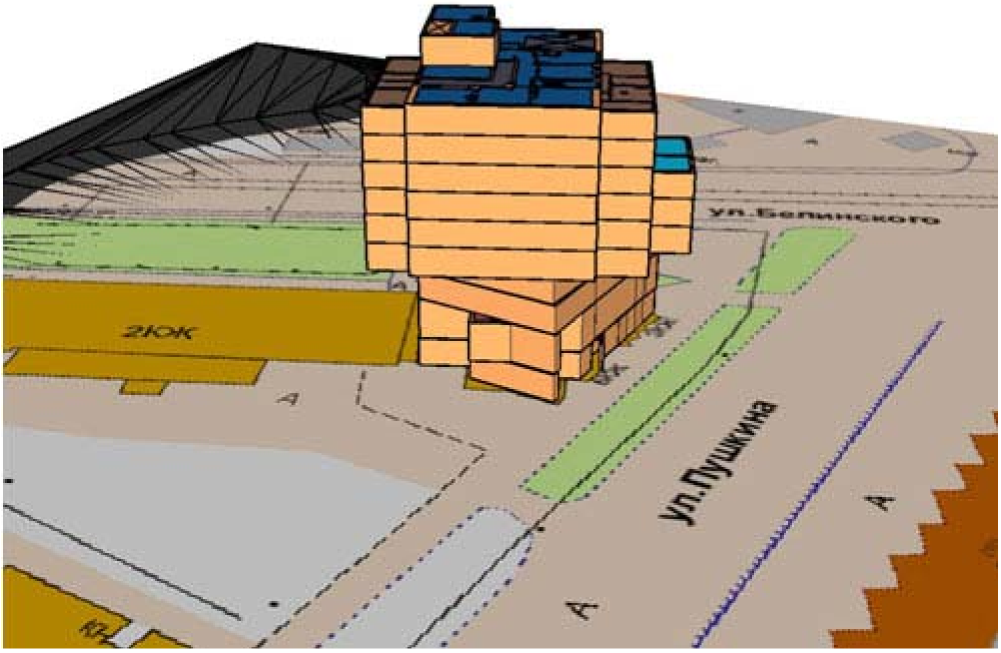

Figure 1. Teledom building placed on DTM draped with topographic map for orientation

2. Case 2 is the apartment complex, 66a Ulitsa Nevzorovykh. This case provides a more "normal" 3D configuration with property rights for 88 units for housing and 7 units for non-residential purposes; see Figure 2.

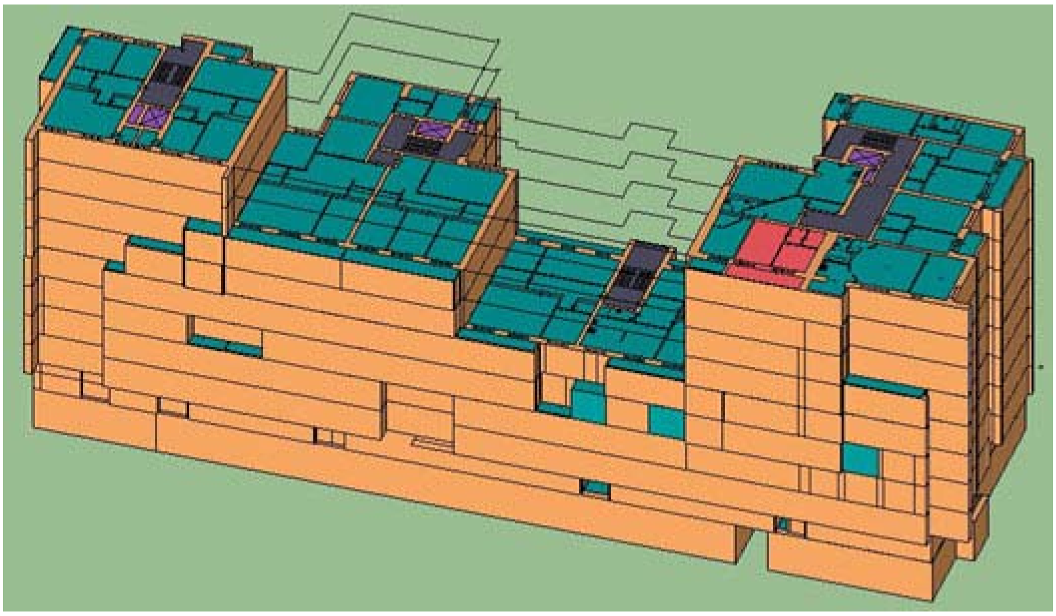

Figure 2. The apartment complex 66a Ulitsa Nevzorovykh

3. Case 3 is a short underground gas pipeline of low pressure, located at the address: Nizhniy Novgorod, Nizhegorodskiy district, from Piskunov str. to Verhnevolzhskaya naberezhnaya, 7 (see Figure 3). The pipeline crosses land parcel with cadastral number 52:18:0060085:21, on which complex of museum buildings is located. Pipeline got two exits on surface (hatches), for which two (very small and hardly visible in the Figure) land parcels are allotted 52:18:0060085:150 and 52:18:0060085:216.

Figure 3. Top: Cadastral map fragment including the pipeline, bottom: two different 3D views

5. Conclusion

In this paper the designed conceptual and technical models for 3D cadastre in the Russian Federation have been described and documented. The technical model is reflected in the PDF document and XML data of the survey plan for the initial registration. The database schema does not need to be adapted because of the selected technical solution (polyhedron-based or multicurve with diameter-based), which fits in Oracle spatial SDO_GEOMETRY type (as well as 2D polygons do).

Further, the prototype is now being developed. After completion this prototype can be used to illustrate and test the possible future workflow around 3D parcels in Russia: accepting newly registered 3D parcels, and correctly storing them into the database for possible future access. The initial test data, including selected 3D cases, is from Nizhegorodskaya Oblast, which has been selected as pilot region in this project. The experiences from the pilot will be used to prepare the guidelines for the future 3D registration: both the legal aspects and the technical workflow.

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References

- ISO (2011). ISO 19152. Draft International Standard (DIS), Geographic information - Land administration domain model (LADM), Geneva, Switzerland, 20 January 2011.
- Queensland Government (2008). Department of Environment and Resource Management. Registrar of Titles Directions for the Preparation of Plans, 19 May 2008 http://www.derm.qld.gov.au/property/titles/rdpp/pdf/regdir37.pdf
- Stoter, J.E. (2004). 3D Cadastre. PhD thesis, TU Delft, 344 pages.
- Stoter, J.E., Van Oosterom, P.J.M. (2005). Technological aspects of a full 3D cadastral registration. In: International Journal of Geographical Information Science IJGIS, 19 (2005) 6, pp. 669-696.
- Stoter, J.E., Van Oosterom, P.J.M. (2006). 3D Cadastre in an International Context: Covering legal, organisational, and technological aspects, published by Taylor & Francis.
- Stoter, J.E., Vosselman, G., Goos, J., Zlatanova, S., Verbree, E., Klooster, R., Reuvers, M. (2011). Towards a national 3D Spatial Data Infrastructure: case of the Netherlands, accepted for Journal of Photogrammetry, Remote Sensing and Geoinformation Processing (PFG), Volume 2011, Issue 5.
- Van Oosterom, P., Stoter, J. Ploeger, H., Thompson, R., Karki, S. (2011). World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014, FIG Working Week, May, Morocco.

- Vandysheva, N., Tikhonov, V., Van Oosterom, P., Stoter, J., Ploeger, H., Wouters, R., Penkov, V. (2011). 3D Cadastre Modelling in Russia. Proceedings FIG Working Week 2011, Marrakech, 19 p.