Recent research on 3D modelling of cadastral data in Slovenia

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Abstract

New trends in the field of land administration systems are strongly pointing towards 3D cadastres. The Slovenian land administration system is based on two connected databases – the Land Cadastre and the Building Cadastre. The latter was legally introduced in 2000 and allows registration of buildings, parts of buildings and apartments. Both cadastres are based on 2D spatial data models and 2D graphical representations. Such an approach does not meet all the requirements for transparent registration of legal facts in the complex built environment. In the past decade, lots of data on buildings and parts of buildings have been gathered and saved in the Building Cadastre database. This data can be beneficiary for 3D reconstruction of real property units, which can be further used for other purposes such as 3D visualisation and analyses. Additionally, new LIDAR datasets became available nationwide. In this contribution, we inspect the Slovenian Building Cadastre data for 3D reconstruction purposes. We present the process of 3D building reconstruction in CityGML LoD 1 (Level of Detail) using Slovenian cadastral and LIDAR data.

Keywords: 3D cadastre, CityGML, 3D reconstruction, LIDAR

1 Introduction and related work

Traditional ways of defining a real property unit in the 2D space are becoming increasingly challenging, as the complexity of the built environment is advancing. If the land administration system wants to follow the needs of the society, it has to support not only horizontal, but also vertical division of real property units. In many countries, including Slovenia, this is currently achieved using 2D data models. In many cases, that concept causes troubles and ambiguities in defining the extent of real properties and their spatial relations. There is an increasing need for development and implementation of 3D data concepts in land administration systems (Stoter 2004, Paulsson 2007, Aien 2013, van Oosterom 2013). In this contribution, existing data and initial efforts in 3D modelling of Slovenian cadastral data are presented. This presentation is limited to LoD 1 (Level of Detail 1) 3D models as defined in the CityGML standard (OGC CityGML 2008) – the extruded building footprint with flat roof.

3D modelling of spatial data and development of data models for 3D reconstruction in land administration domain has been the subject of many research activities. Many countries are developing and implementing 3D cadastral models in the practice (van Oosterom et al. 2011, Stoter et al. 2013, Drobež et al. 2016, Kitsakis et al. 2016). The common objective is to develop a standard approach for 3D cadastral data models.

The study of El-Mekawy and Östman (2012) shows that widely accepted CityGML standard is not suitable for the complete 3D cadastral data model, as it was initially developed for topographical purposes. However, the usability of the CityGML for cadastral purposes has been investigated in multiple studies, which shows that it can be adapted to the land administration needs due to its flexibility and extensibility. (Dsilva 2009, Çağdaş 2013, Gozdz et al. 2014).

2 Methods and materials

For the 3D reconstruction, we are using two national datasets with nationwide coverage: Building Cadastre and LIDAR data.

In Slovenia, the Building Badastre was introduced in 2000 due to increasing demand for legal facts registration on buildings, parts of the buildings and apartments. Basic full country coverage was established by 2006 using photogrammetric stereo acquisition of buildings' footprints and additional attribute data. More detailed data are required for registration of new buildings, or new cadastral entries of older buildings. Connection to the land cadastre is realized using land parcel and building identifier (Drobež 2016).

In 2015, the project "Laser Scanning of Slovenia" was completed and as a result, we got georeferenced and classified point cloud and digital terrain model (DTM). It is freely available with a point density of 5 points/m^2. Mountain and deep forest areas are scanned with a density of 2 points/ m^2, while some flood and landslide risk regions with 10 points/ m^2.

2.1 3D building reconstruction

The main input data for our research, i.e. 3D building reconstruction for LoD 1, are Building Cadastre footprints in vector format. Additional attributes from the Building

Cadastre, related to 3D reconstruction are height of terrain and maximum height of the building. This data is already sufficient for extrusion of footprint and getting LoD 1. There are multiple ways of LoD 1 building height determination. Apart from maximum, there are also average and median heights. The latter two can be obtained from the combination of footprint and LIDAR point cloud. The LIDAR point cloud can also be used to control the quality of cadastral height attributes, which were obtained photogrammetrically. By combining the height attribute and LIDAR point cloud, it is possible to detect and later examine any possible errors.

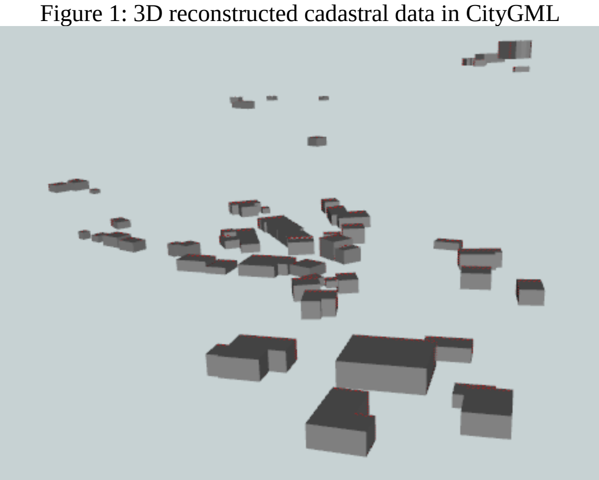
We used Safe Software's FME Desktop for processing and evaluating the results. The processing chain can be summarized in following steps:

- LIDAR point cloud separation on ground points and other points;
- Intersection of non-ground points with footprints;
- Average point cloud height calculation;
- Ground surface creation and intersection with footprints;
- Calculation of the average building height;
- Extrusion of the footprint ground surface with the building height;
- Writing of objects in CityGML class Building.

3 Results

We tested our method on a small dataset. Results can be viewed in a software that supports the CityGML format, and can be imported into 3DCityDB running on PostgreSQL database. Every object has a unique identifier and can be linked with other cadastral data in the database.

Figure 1: 3D reconstructed cadastral data in CityGML



We also successfully classified surfaces to CityGML classes GroundSurface, WallSurface and RoofSurface, which is supported at the LoD 2 and higher levels. The roof shape modelling is more challenging and cannot be fully automated. Software solutions for this task are mostly using the basic roof shapes that are transformed and combined to get the best fit to LIDAR point cloud. Nevertheless, the result still needs many manual corrections and additional modelling.

The time needed for reconstruction mostly depends on the point cloud density as most time demanding process is clipping the point cloud and surface modelling for building height determination.

4 Conclusions

With the presented 3D reconstruction approach, the first step towards the physical implementation of a 3D cadastre in Slovenia has been illustrated. A huge challenge is merging data of different origins and consequently different data quality. Furthermore, we are investigating the possibilities of linking attribute data from the real property database (database for taxation purposes based on cadastral data) with 3D models. For this purpose, parts of the buildings have to be modelled in the 3D environment (real property units), which is another challenge for the future research.

5 References

Aien, A. (2013). 3D Cadastral Data Modelling. Doctoral Dissertation. Melbourne, Centre for Spatial Data Infrastructures and Land Administration, Department of Infrastructure Engineering, School of Engineering, The University of Melbourne (350 pp.).

Çağdaş, V. (2013). An application domain extension to CityGML for immovable property taxation: A Turkish case study. *International Journal of Applied Earth Observation and Geoinformation*, 21, 545–555. https://doi.org/10.1016/j.jag.2012.07.013

Drobež, P., Kosmatin Fras, M., Ferlan, M., Lisec, A. (2016). Transition from 2D to 3D real property cadastre: The case of the Slovenian cadastre. *Computers, Environment and Urban Systems* 62, 125 – 135. https://doi.org/10.1016/j.compenvurbsys.2016.11.002

Dsilva, M.G. (2009). Feasibility Study on CityGML for Cadastral Purposes. Master's Thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

El-Mekawy, M., Östman, A. (2012). Feasibility of Building Information Models for 3D Cadastre in Unified City Models. *International Journal of E-Planning Research (IJEPR)*, 1, 35–58. 10.4018/ijepr.2012100103.

Gozdz, K., Pachelski, W., van Oosterom, P., Coors, V. (2014). The possibilities of using CityGML for 3D representation of buildings in the cadastre. In: van Oosterom, P.(ed.), Fendel, E. (ed.) (2014). *Proceedings of 4th International Workshop on 3D Cadastres*, Dubai, UAE, 9–11 November 2014; pp. 339–361.

Kitsakis, D., Paasch, J., Paulsson, J., Navratil, G., Vucic, N., Karabin, M., Andréa Flávia T. C., A., & El-Mekawy, M. (2016). 3D Real Property Legal Concepts and Cadastre: A Comparative Study of Selected Countries to Propose a Way Forward (Overview Report). *5th International Workshop on 3D Cadastres*, 2016, Athens, pp. 1-24. (http://www.gdmc.nl/3dcadastres/literature/3Dcad_2016_11.pdf Accessed 2.2.2017).

OGC CityGML (2008). *OGC City Geography Markup Language (CityGML) Encoding Standard*. Open Geospatial Consortium.

van Oosterom, P., Stoter, J., Ploeger, H., Thompson, R., & Karki, S. (2011).World-wide in- ventory of the status of 3D cadastres in 2010 and expectations for 2014. *Proceedings of the 2011 FIG Working Week, Bridging the Gap between Cultures, Marrakech, Morocco, 18–22 May 2011*.

van Oosterom, P. (2013). Research and development in 3D cadastres. *Computers, Environment and Urban Systems*, 40, 1-6. http://dx.doi.org/10.1016/j. compenvurbsys.2013.01.002.

Paulsson, J. (2007). 3D property rights – An analysis of key factors based on international experience. Doctoral Dissertation. Stockholm, Royal Institute of Technology (KTH) (351 pp.).

Stoter, J. (2004). 3D cadastre. Doctoral Dissertation .Delft, TU Delft, Netherlands, Geodetic Commission (327 pp.).

Stoter, J., Ploeger,H.,& van Oosterom, P. (2013). 3D cadastre in the Netherlands: Developments and international applicability. *Computers, Environment and Urban Systems*, 40, 56–67.
http://dx.doi.org/10.1016/j.compenvurbsys.2012.08.008.