FIG publication 3D Cadastres Best Practices

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FIG publication 3D Cadastres Best Practices

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SUMMARY

At the end the two most recent 4-year terms (2010-2014 and 2014-2018) of the joint commission 3 and commission 7 FIG Working Group on 3D Cadastres, it was decided to collect the best known practices in a single FIG publication. Key authors were invited to lead a chapter on one of the following topics:

- Chapter 1 Legal foundations (Dimitrios Kitsakis),
- Chapter 2 Initial Registration of 3D Parcels (Efi Dimopoulou),
- Chapter 3 3D Cadastral Information Modelling (Peter van Oosterom),
- Chapter 4 3D Spatial DBMS for 3D Cadastres (Karel Janečka), and
- Chapter 5 Visualization and New Opportunities (Jacynthe Pouliot).

The mentioned lead authors have each teamed-up with a group of authors to produce their chapters. A lot of inspiration was found in the earlier 3D Cadastres activities of FIG, such as the various 3D Cadastres workshops, the two 3D Cadastres questionnaires, and the presentations and publications at the 3D Cadastres sessions at every FIG Working Week and Congress. The results is a quite extensive FIG publication of about 250 pages, which has been language checked by native English speakers. The publication is further completed with a foreword by the current FIG president Chryssy Potsiou, and introduction by the editor Peter van Oosterom and other front and back materials.

Based on this long version also a shorter version is produced (about 80 pages). The short version will become available as FIG publication both in hard-copy (paper) and soft-copy (pdf online). The long version will only be published in soft-copy form and in the style of the FIG proceedings.

Both versions are (expected to be) available at the FIG congress 2018 in Istanbul, Turkey. Every chapter will be shortly introduced by one of the authors at the FIG congress 2018.

FIG publication 3D Cadastres Best Practices

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1. HISTORIC BACKGROUND

The FIG publication '3D Cadastres Best Practices' has quite a long history. Many 3D Cadastral activities have been conducted during the past two decades: five FIG 3D Cadastres workshops, sessions at FIG working weeks and congresses, three special issues in international scientific journals, several 4-year terms (2004-2008, 2010-2014 and 2014-2018) of the joint commission 3 and commission 7 FIG Working Group on 3D Cadastres, and two questionnaires (2010 and 2014). An overview of the workshops organized so far, which are all published in FIG proceedings:

- International FIG Workshop on 3D Cadastres, 28-30 November 2001, Delft, The Netherlands;
- 2nd International Workshop on 3D Cadastres, 16-18 November 2011, Delft, The Netherlands;
- 3rd International FIG Workshop on 3D Cadastres, 25-26 October 2012, Shenzhen, China;
- 4th International FIG 3D Cadastre Workshop, 9-11 November 2014, Dubai, United Arab Emirates;
- 5th International FIG Workshop on 3D Cadastres, 18-20 October 2016, Athens, Greece.

Closely related to these workshop are the special issues of international scientific journals. Three times the initiative was taken to invite selected authors, based on review of full workshop papers and presentations / discussions at the workshop, to submit a significantly extended / changed version to the special issue. After submitting, the paper has gone through the peer review process of the journal. This resulted in the following three special issues as indicated by their introductions/editorials:

- Lemmen, C.; van Oosterom, P. 3D Cadastres, In: Computers, Environment and Urban Systems, 2002, 27, 337–343.
- van Oosterom, P. Research and development in 3D cadastres, In: Computers, Environment and Urban Systems, 2013, 40, 1-6.
- van Oosterom, P.; Dimopoulou, E. ISPRS International Journal of Geo-Information (ISSN 2220-9964). In: ISPRS International Journal of Geo-Information, 2018, 7(2), 5.

The first more concrete versions of texts towards the FIG publication '3D Cadastres Best Practices' was in the form of four overview reports, each presented at the "5th International FIG Workshop on 3D Cadastres", organized in Athens, Greece, 18–20 October 2016:

1. Dimitrios Kitsakis, Jesper Paasch, Jenny Paulsson, Gerhard Navratil, Nikola Vucic, Marcin Karabin, Andréa Flávia Tenório Carneiro and Mohamed El-Mekawy: 3D Real Property

Legal Concepts and Cadastre: A Comparative Study of Selected Countries to Propose a Way Forward.
2. Efi Dimopoulou, Sudarshan Karki, Roic Miodrag, José-Paulo Duarte de Almeida, Charisse Griffith-Charles, Rod Thompson, Shen Ying and Peter van Oosterom: Initial Registration of 3D Parcels.
3. Karel Janecka and Sudarshan Karki: 3D Data Management.
4. Jacynthe Pouliot, Frédéric Hubert, Chen Wang, Claire Ellul and Abbas Rajabifard: 3D Cadastre Visualization: Recent Progress and Future Directions.

Discussions during and after the 2016 Workshop resulted in the decision to split Chapter 3 into two parts: one on information modelling and one on data management. The author teams were further reinforced and each produced a next version of their chapters, which were reviewed by colleagues from to other author teams. These actions were conducted before the FIG Working Week, Helsinki, Finland, 29 May - 2 June 2017 and discussed at the working week by representatives of each of the chapters. The review comments were processed in the second half of 2017 by the authors teams and all chapters were proof read by native English speakers and finally edited to get an uniform style.

2. CONTENT OF THE FIVE CHAPTERS

In this section the titles, authors and summaries of the five chapters are given for a quick content overview: Chapter 1: Legal foundations, Chapter 2: Initial Registration of 3D Parcels, Chapter 3: 3D Cadastral Information Modelling, Chapter 4: 3D Spatial DBMS for 3D Cadastres and Chapter 5: Visualization and New Opportunities.

2.1 Chapter 1: Legal foundations

The author team consisted of the following persons: Dimitrios Kitsakis, Jesper Paasch, Jenny Paulsson, Gerhard Navratil, Nikola Vučić, Marcin Karabin, Mohamed El-Mekawy, Mila Koeva, Karel Janečka, Diego Erba, Ramiro Alberdi, Mohsen Kalantari, Zhixuan Yang, Jacynthe Pouliot, Francis Roy, Monica Montero, Adrian Alvarado, and Sudarshan Karki.

Summary: The concepts of three-dimensional (3D) real property have been the subject of increased interest in land use management and research since the late ‘90s. Literature provides various examples of extensive research towards 3D Cadastres as well as those that are at various stages of implementation of 3D cadastral systems. In most countries the legal aspects of 3D real property and its incorporation into 3D cadastral systems have not been so rigorously examined. This paper compares and discusses 3D property concepts in 15 cadastral jurisdictions, based on the authors’ national experience, covering Europe, North and Latin America, Middle East and Australia. Each of the legal system in these cadastral jurisdiction are based on different origins of Civil Law, including German, Napoleonic and Scandinavian Civil Law, which can prove useful to research in other Civil Law jurisdictions interested in introducing 3D cadastral systems. These jurisdictions are at different stages of introducing and implementing a 3D

cadastral system. This contributes to the detection of the 3D real property concepts that apply as well as deficiencies that prohibit introduction of 3D cadastral systems, while highlighting challenges that may have not yet surfaced in individual jurisdictions. This paper aims to present the different legal concepts regarding 3D real property in the examined countries, focusing on the characteristic features of cadastral objects described as 3D within each country's legal and cadastral framework. The analysis of the case studies revealed that the countries are on different stages of 3D Cadastral implementation, starting from countries with operational 3D cadastral systems, to others where there is yet no interest in introducing a 3D cadastral system. This paper presents the nature of 3D cadastral objects in each country, as well as differences in the regulatory framework regarding definition, description and registration. The paper continues the legal workshop discussions of the 4th International Workshop on 3D Cadastres in Dubai 2014 by analysing the legal concepts of 3D cadastres in the above-mentioned countries. The outcome is an overview and discussion of existing concepts of 3D property describing their similarities and differences in use, focusing on the legal framework of 3D cadastres. The article concludes by presenting a possible way forward and identifies what further research is needed which can be used to draft national and international research proposals and form legislative amendments towards introduction of national 3D cadastral systems.

2.2 Chapter 2: Initial Registration of 3D Parcels

The author team consisted of the following persons: Efi Dimopoulou, Sudarshan Karki, Miodrag Roić, José-Paulo Duarte de Almeida, Charisse Griffith-Charles, Rod Thompson, Shen Ying, Jesper Paasch, and Peter van Oosterom.

Summary: Registering the rights of a 3D parcel should provide certainty of ownership, protection of rights and unambiguous spatial location. While not all cadastral jurisdictions in the world maintain a digital cadastral database, the concepts of such registration hold true regardless of whether it is a paper-based cadastre or a digital one. Similarly, the motivations and purpose for the creation of a 2D cadastre for individual jurisdictions applies to 3D cadastre as well. It provides security of ownership for 3D parcels, protects the rights of the owners, and provides valuable financial instruments such as mortgage, collateral, valuation and taxation. The current life cycle of the development of a land parcel includes processes start from outside the cadastral registration sphere, such as zoning plans and permits, but has a direct impact on how a certain development application is processed. Thus, in considering the changes required to allow a jurisdiction to register 3D, it is important to note the sphere of influence that could have an impact on 3D registration. These include planners, notaries, surveyors, data managers and registrars; however for the purpose of this paper, the research is focused on the core 3D aspects that are institutional, legal and technical. This paper explores approaches and solutions towards the implementation of initial 3D cadastral registration, as derived by current procedures of registration of 3D parcels in various countries worldwide. To this end, the paper analyses the categorisations and approaches of 3D spatial units and examines the validation requirements (constraints) on a cadastral database, at various levels of maturity. In this view, 3D data storage and visualization issues are examined in relation to the level of complexity of various jurisdictions, as provided by the results of the country inventory combined with a worldwide

survey in 2010 and updated in 2014 (Van Oosterom, et al., 2014). It appears that significant progress has been achieved in providing legal provisions for the registration of 3D cadastres in many countries and several have started to show 3D information on cadastral plans such as isometric views, vertical profiles or text environment to facilitate such data capture and registration. Moreover, as jurisdictions progress towards an implementation of 3D cadastre, much 3D data collected in other areas (BIM, IFC CityGML files, IndoorGML, InfraGML and LandXML) open up the possibility of creating 3D cadastral database and combining with the existing datasets. The usability, compatibility and portability of these datasets is a low cost solution to one of the costliest phases of the implementation of 3D cadastres, which is the initial 3D data capture.

2.3 Chapter 3: 3D Cadastral Information Modelling

The author team consisted of the following persons: Peter van Oosterom, Chrit Lemmen, Rod Thompson, Karel Janečka, Sisi Zlatanova and Mohsen Kalantari.

Summary: In this chapter we address various aspects of 3D Cadastral Information Modelling. Of course, this is closely related to the legal framework and initial registration as presented in the first two chapters. Cadastral data models, such as the Land Administration Domain Model, which include 3D support, have been developed for legal information modelling and management purposes without providing correspondence to the object's physical counterparts. Building Information Models and virtual 3D topographic/ city models (e.g. LandXML, InfraGML, CityGML, IndoorGML) can be used to describe the physical reality. The main focus of such models is on the physical and functional characteristics of urban structures. However, by definition, those two aspects need to be interrelated; i.e. a tunnel, a building, a mine, etc. always have both a legal status and boundaries as well as a physical description; while it is evident that their integration would maximise their utility and flexibility to support different applications. A model driven architecture approach, including the formalization of constraints is preferred. In the model driven architecture design approach as proposed by the Object Management Group the information model, often expressed in the form of a UML class diagram is the core of the development. This so-called Platform Independent Model (PIM, as presented in the current chapter) is then transformed into Platform Specific Model (PSM). This could be a relational database schema for a spatial DBMS (as will be discussed in the next chapter), or XML schema for a data exchange format or the structure of maps, forms and tables as used in the graphic user interface of a spatial application. Constraints have proved effective in providing the solutions needed to avoid errors and enable maintenance of data quality; thus the need to specify and implement them. This chapter explores possibilities of linking 3D legal right, restriction, responsibilities spaces, modelled with the Land Administration Domain Model (ISO 19152), with physical reality of 3D objects (described via CityGML, IFC, InfraGML, etc).

2.4 Chapter 4: 3D Spatial DBMS for 3D Cadastres

The author team consisted of the following persons: Karel Janečka, Sudarshan Karki, Peter van Oosterom, Sisi Zlatanova, Mohsen Kalantari, and Tarun Ghawana.

Summary: Subdivision of land parcels in the vertical space has made it necessary for cadastral jurisdictions to manage cadastral objects both in 2D as well as 3D. Modern sensor and hardware capabilities for capture and utilisation of large point clouds is one of the major drivers to consider Spatial Database Management Systems (SDBMS) in 3D and organisations are still progressing towards it. 3D data models and their topological relationships are two of the important parts of 3D spatial data management. 3D spatial systems should enable data models that handle a large variety of 3D objects, perform automated data quality checks, search and analysis, rapid data dissemination, 3D rendering and visualisation with close linkages to standards. This chapter asserts that while there has been work done in defining 2D and 3D vector geometry in standards, it is still not sufficient for 3D cadastre purposes as 3D cadastral objects have a much more rigorous definition. The Land Administration Domain Model (LADM), which is an ISO Standard, addresses many of the issues in 3D representation and storage of 3D data in a database management system (DBMS). The chapter further discusses the various approaches to storing 3D data such as through voxels, or point cloud data type and elaborates on the characteristics of a 3D DBMS capable of storing 3D data. Approaches for spatial indexing to improve the fast access of data and the various available options for a 3D geographical database system are presented. Several spatial operations on and amongst 3D objects are illustrated with linkages to the current standards including the LADM. Next, construction of 3D topological and geometrical models based on standards and including their characteristics is discussed. Current 3D spatial database managements systems and their characteristics, including some comparison between selected DBMS including the hardware capabilities are elaborated in detail. Finally, the chapter proposes a 3D topology model based on Tetrahedron Network (TEN) synchronised with LADM specifications for 3D cadastral registration. This topological model utilises surveying boundaries to generate 3D cadastral objects with consistent topology and rapid query and management capabilities. The definition for validation of 3D solids also considers the automatic repair of invalid solids. Point cloud and TEN related data structures available in SDBMSs are also investigated to enable storage of non-spatial attributes so that database updates would store all spatial and attribute information directly inside the spatial database.

Chapter 5: Visualization and New Opportunities

The author team consisted of the following persons: Jacynthe Pouliot, Claire Ellul, Frédéric Hubert, Chen Wang, Abbas Rajabifard, Mohsen Kalantari, Davood Shojaei, Behnam Atazadeh, Peter van Oosterom, Marian de Vries, and Shen Ying.

Summary: This chapter proposes a discussion on opportunities offered by 3D visualization to improve the understanding and the analysis of cadastre data. It first introduce the rationale of having 3D visualization functionalities in the context of cadastre applications. Second the publication outline some basic concepts in 3D visualization. This section specially addresses the visualization pipeline as a driven classification schema to understand the steps leading to 3D visualization. In this section is also presented a brief review of current 3D standards and technologies. Next is proposed a summary of progress made in the last years in 3D cadastral visualization. For instance, user's requirement, data and semiotics, and platforms are

highlighted as main actions performed in the development of 3D cadastre visualization. This review could be perceived as an attempt to structure and emphasise the best practices in the domain of 3D cadastre visualization and as an inventory of issues that still need to be tackled. Finally, by providing a review on advances and trends in 3D visualization, the paper initiates a discussion and a critical analysis on the benefit of applying these new developments to cadastre domain. This final section discusses about enhancing 3D techniques as dynamic transparency and cutaway, 3D generalization, 3D visibility model, 3D annotation, 3D data and web platform, augmented reality, immersive virtual environment, 3D gaming, interaction techniques and time.

3. THE FUTURE OF 3D CADASTRES, THE NEXT STEPS

The FIG publication '3D Cadastres Best Practices' hopes to provide a clear and comprehensive overview to both the newcomers and experts in the 3D Cadastres community. For sure this is just a snapshot of the current state and our knowledge must further evolve with the many challenges that are ahead of us, including the emerging mega-cities due to further urbanization. Many developments are ahead of us and to name just a few: revision of LADM (with potentially more detailed 3D spatial profiles), Marine Cadastre, deep integration of 3D space and time (4D Cadastre), new data acquisition techniques (including VGI), growing information infrastructure (of which Land Administration is a part), and new visualization and dissemination techniques (including VR and AR). Already, the next step of our on-going journey is planned: the 6th International FIG Workshop on 3D Cadastres, to be organized in Delft, The Netherlands, 2–4 October 2018. And also this time a special issue on 3D Cadastres is planned: to be published in Land Use Policy (2019 or 2020).

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It was a great pleasure to be involved in the creation of the FIG publication '3D Cadastres Best Practices'. This was mainly due to the constructive and open collaborations of all involved. First of all I would like to thank the lead authors, the authors of chapters in the publication, but also the authors of papers at past FIG 3D Cadastres workshops and other FIG events, for their continuous contributions to the field of 3D Cadastres. Next, it is important to remember the hard work the reviewers (programme committees members) have put into all their constructive comments and adding many ideas and views to those of the original authors. Many, many thanks for this often rather invisible task. Finally, I would like to thank Sudarshan Karki for the English proof reading of an incredible amount of pages and Dirk Dubbeling for the last checks and formatting to make sure the publication gets an uniform look and feel. Great teamwork, thanks for the many years of collaborations.

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BIOGRAPHICAL NOTES

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'.

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