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Editorial

3D Cadastres

This is a further theme issue of the international journal *Computers, Environment and Urban Systems* (CEUS) on cadastral systems. However, this time it is even more specific than the two previous special issues (Lemmen & Van Oosterom, 2001, 2002): we now focus on 3D cadastres. This special issue contains a selection of papers presented at the International Federation of Surveyors (FIG) workshop on 3D cadastres, organized in Delft, 28–30 November 2001 (Fig. 1). Before going into the depth (or height) of 3D cadastres, it is good to start with a more broad perspective and have a look at some other 3D GIS.

1. 3D geo-information processing

This birds eye overview of 3D geo-information processing covers the following aspects: 3D applications, 3D data collection, 3D data sets and 3D DBMS and GIS/CAD software. Some applications in which the third dimension is essential are: taxation based on the volume of buildings, visual analyses of changes in the landscape, determination of the location of transmitters for mobile phone networks, modeling of natural resources and underground (geology), modelling and analysis of noise 'pollution' and other types of pollution, flooding of regions, 'virtual and augmented reality' and so on. Thus a 3D cadastre would not be the first 3D GIS and lessons from existing applications can be learnt. 3D data for different applications may be shared. With modern surveying technology it is not very difficult to add z-values to the x and y-values of a coordinate-set. Horizontal and vertical reference

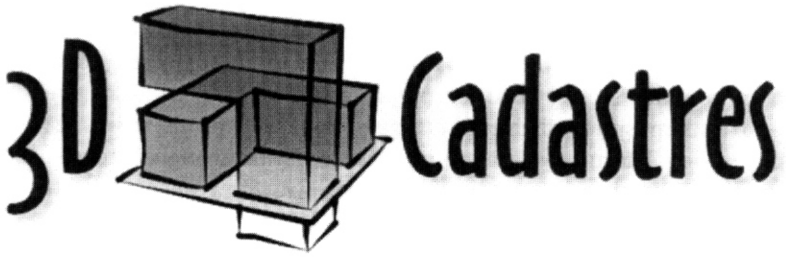

Fig. 1. Logo of the FIG workshop '3D cadastres'.

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systems are nowadays integrated (e.g. WGS84/ETRS), GPS-based survey provides z-values, airborne laser-altimetry (e.g. LIDAR) has become very effective in the collection of elevation data for large regions, and terrestrial laser-scanning is a source of 3D data collection ('3D point clouds').

There are applications with 3D requirements, and there are 3D data collection technologies, but are the necessary 3D data sets available? Not at the present time. It will be a huge task to relate the third dimension to existing 2D data sets. But in part the question can be answered positively. We take the geo-information provision in the Netherlands as an example. Rijkswaterstaat, Meetkundige Dienst (RWS/MD, in 'English, Ministry of Transport, Public Works and Water Management—Survey Department') has almost finished a nation-wide elevation model of the Netherlands with a point density of at least 1 point per 16 m^2 with 5 cm standard deviation. Though the large-scale topographic base map (GBKN, 1:1000) and the medium scale topographic base map (TOP10, 1:10,000) are 2D, the same RWS/MD has large-scale topographic data along the roads and waterways including z-values. Investigations are conducted to 'upgrade' also the topographic base maps with the third dimension. A completely different kind of 3D data is the deep subsurface of the Netherlands. TNO-NITG (in Dutch, 'Nederlands Instituut voor Toegepaste Geowetenschappen TNO', or in English the 'Netherlands Institute of Applied Geoscience TNO—National Geological Survey') produces these 3D data in several underground layers described on a 250 m grid.

After having summarised the applications and data sets of 3D geo-information, it is important also to examine the state of the art with respect to the relevant software. In the application areas described above, customised software has frequently been used, because the existing standard geo-DBMS and GIS/CAD software do not cover the 3D aspects sufficiently. However, significant progress has been made in the recent years. For example, the DBMSs Oracle Spatial, IBM Informix Dynamic Server (IDS) and IBM DB2 Spatial Extender, can all store the third dimension within their point, line and polygon spatial data-types. However, the geometric functions (area, overlap, buffer,...) are still limited to two dimensions, true 3D volume primitives are not available and there is no 3D standard available like the OpenGIS Simple Feature Specification for 2D data types. The geo-DBMS can be considered as the back-end of geo-information processing. The front-end can either be 'traditional' GIS software (strong in analysis) or CAD software (strong in data editing). In general GIS packages support (2D) editing, analysis and visualization, and in many systems 2.5D functionality is added. However, functional support in *true 3D* is still very limited. CAD packages on the other hand have supported true 3D editing and visualization for many years, but are limited with respect to analysis of information at geographical scales of measurement. In practice, and in spite of the many possible applications, true 3D geo-information processing has not yet made any great breakthrough, because of limited availability of 3D data and standard 3D software. However, on both fronts the situation is improving rapidly. An assessment of the current status of 3D geo-processing software and future prospects can be found in Zlatanova, Rahman, and Pilouk (2002).

2. The workshop on 3D cadastres

We will now focus on 3D cadastres. At present, a cadastre mostly consists of 2D geometric descriptions of land parcels linked to other records describing the legal aspects, such as ownership. In areas with high population densities and intensive use of land, there is a growing interest in using space under and above the surface. To be able to define and manage the related juridical representation satisfactorily, 3D geo-information becomes indispensable in describing and registering today's world. More and more situations occur in which the vertical dimension is relevant in the registration of the legal status of real estate objects. Cadastres throughout the world are being challenged to register such situations within the framework of existing registers and spatial data sets. It is a scientific challenge to identify and develop practical geometric descriptions. However, until now, the representation of legal boundaries of parcels used for registering the legal status is fixed in 2D space based on a national reference system. It is complex to represent the vertical dimension of real estate objects in legal documents using current cadastres in which most 3D relationships are still registered 'administratively', e.g. as an attribute of defined parcels, based on condominium or strata title legislation.

The workshop on 3D cadastres was organised under the auspices of Commission 7, Cadastre and Land Management, of the International Federation of Surveyors (FIG). The aim of the workshop was to consider the 3D issue of cadastral registration in an international context. Over 80 participants from 25 countries, from Finland to South Africa, and from Mongolia to Canada, participated in the workshop. The prospect of registering property in three dimensions efficiently (including under and above the surface) will facilitate the separate use of spaces. It should also improve legal security of complex 3D rights. As a result of the workshop this issue is now integrated in the FIG working plan 2002–2006. Besides FIG Commission 7, the workshop was also encouraged by FIG Commission 3 ('Spatial Information Management') and the Bureau of the UN Economic Commission for Europe (Working Party on Land Administration: WPLA). The main purpose of the workshop was to initiate international discussion on 3D cadastres and exchange the status, experience and (planned) developments on implementation and use of 3D cadastral registrations, concerning technical, legal and organizational aspects.

The workshop included both presentations and working sessions. The program committee selected papers for the workshop based on the extended abstracts that were submitted. About 25 proposals were accepted and authors submitted full papers; all draft papers were published in the workshop proceedings (Van Oosterom, Stoter, & Fendel, 2001). These full papers have been reviewed once more and have been assessed and ranked by the program committee. After the workshop, the authors of the seven best papers were invited to extend and improve their papers based on the remarks of the reviewers and on the discussions during the workshop. This resulted in the current special issue of CEUS on 3D cadastres. As mentioned above, the workshop on 3D cadastres also included working sessions. For each of the following three aspects, that is, technical, legal and organisational aspects, two working sessions were organised and on the third and last day of the workshop the chairpersons presented the results. The overall objective was to provide feedback to the FIG Commissions 3 and 7. A report of these presentations has been prepared and can be found on the 3D cadastre web site www.gdmc.nl/3DCadastres (Fendel, 2002). Although the background of the contributing groups was remarkably different, their statements and questions were quite similar. We will now give a representative selection of these statements and questions:

- Is it possible to create a generally accepted definition of a '3D property'? The concept of a 3D property depends mainly on the national legal system. Despite the differences between countries there is at least one common background: in all cases there are rights pertaining to the use of a certain volume of the 3D space.
- The visualisation issue is very important for interpretation of the problem. Virtual and legal objects can be used to show people what the property looks like; this could even be a volume of 'empty' space.
- According to the law in most countries the legal objects are already 3D, and a property includes everything below the surface parcel down to the centre of the earth and everything above the parcel: however the current spatial registration is 2D.
- As full 3D data collection is expensive, it may be important to realise that 3D data are not required everywhere. The question is whether and how it will be possible to make the transition to 3D data where it is really needed.
- Though creation of full 3D data may not be justifiable for cadastral purposes alone, this aspect may be crucial when considering multi-purpose use of 3D data. For example, city management and city planning requires 3D representations. Sharing of 3D data is an extension of the concept of spatial data infrastructures.
- Right of superficies, lease, condominium, apartment ownership and encumbrances has been discussed in relation to 3D objects. Is it is possible to enforce these rights; e.g. to build a tunnel under several properties? Is it possible to enforce a right of superficies? Is it possible to expropriate only a part of the volume below the surface in the public interest? Such legal possibilities will make the 3D use of land more attractive.
- Like 2D registration, the 3D registration of properties is not an aim in itself. The main objective, from a legal point of view, is to secure these rights, and to provide a basis for transactions. By doing this, the true 3D use of space is possible in practice, and attractive to the land market.
- Should the registration of empty volumes, e.g. a volume without a construction (or other type of object), be possible? There is no overall agreement about the necessity to register empty volumes. This mainly depends also on the legal possibilities.
- Although every country has its own specific laws, it is to be hoped that this should not result in the development of completely different systems for each country. Where systems are developed, it is important to examine their common aspects. In fact the 3D geometrical and topological representations of

objects are common to systems in all countries. Only the legal relationships of the subjects (persons) to property are different.
- Society will require 3D models more and more. A crucial question is whether the cadastre should be the organising framework to take the leading role in these developments. Another possibility could be to develop it as part of the spatial data infrastructure.
- Economic factors have to be considered as well. From an economic point of view it is possible that it is not feasible to create a 3D cadastre now. Of course, organisational complexity will increase over time: but on the other hand technological possibilities will likely increase as well.

3. Overview of the papers

Issues raised during the working sessions provide the context for the papers presented in this theme issue. The paper by Volker Coors (Fraunhofer Institute for Computers Graphics, Germany) presents a data model for 3D geometry and topology. This model is very well suited to topological queries. It is also suited to visualization and can be used in a network context based on progressive refinement techniques. Although the paper does not have a specific focus on cadastral systems, it summarises the problems encountered in Germany when converting the current automated legal parcel map (ALK, Automatisierte Liegenschaftskarte) to 3D.

The paper of Moshe Benhamu and Yerach Doytsher (Technion, Israel Institute of Technology), describes the situation in Israel. In Israel efforts are being made to develop a 3D cadastre. This can be explained by the fact that only limited parts of the country are suitable for human settlements. For this reason there is a pressing need for efficient use of the available space. The authors propose several alternatives and favour the 'integrated data model' consisting of one surface layer (2D) space and two 3D spaces related respectively to the space above and below the surface, all in one database and linked to the surface. The authors also present a list of criteria, which can be used to evaluate alternative models.

Helge Onsrud (National Mapping Authority of Norway), describes the situation from the legal point of view. Norway is probably one of the first countries in the world where the law provides regulations for establishing and registering properties under and above the surface (implementation is expected in 2004). These properties are called 'construction properties', which implies that there must be a specific construction either present, or to be built in the near future. The Law Committee in Norway did not see serious problems in the establishment of neighboring properties vertically above each other instead of normal neighbor situations horizontally next to each other. The 3D 'construction properties' will be visualized on the 2D cadastral map with reference to construction drawings. As long as the number of 3D properties constructed below or above each other is limited this will work fine, otherwise alternative solutions will have to be found.

Institutional aspects, or 'the humanly devised constraints that shape human interactions (the rules of the game)', of 3D cadastres are the subject of the paper by

Paul van der Molen (Kadaster/ITC, the Netherlands). The role of institutions and the imperatives of appropriate legal frameworks and transparent public-administrative structures are highlighted. It is argued that the development of adequate geometric 3D descriptions must go together with the development of institutional settings. The paper analyses the current multi-use of land, including the ground level, above the surface, below the surface and time-dependant multi-use, and makes a clear distinction between the real object and legal object. Legal (3D) objects should be represented on the cadastral map in case of (vertical) separation of ownership. In case there is no separation of ownership the 3D object might be represented on the cadastral map for orientation purposes. Also a call for further investigations to identify new 3D property rights is made.

Roland Billen (University of Liège, Belgium) and Siyka Zlatanova (Delft University of Technology, the Netherlands), present a new theory, the 'dimensional model' for 3D objects, to represent spatial relationships. Every object can be considered to be composed of 'dimensional elements': 0D, 1D, 2D and 3D. Relations, like 'total', 'partial' or 'non-existent' between dimensional elements of two objects are described. This can be done at different 'levels of detail/complexity'. The model is illustrated using cadastral examples, in which (mixed) 2D and 3D situations are analysed by posing queries based on the dimensional model. Furthermore, the implementation of the dimensional model is described based on tools such as the Oracle DBMS, PL/SQL, Java, and VRML.

A joint research on 3D Cadastres in the Netherlands is described by Jantien Stoter (Delft University of Technology, the Netherlands) and Martin Salzmann (Kadaster, the Netherlands). First an overview is given of the current 3D situations in practice and how these are handled. Then three possible solutions to register 3D situations are presented and combined with their conceptual data models: first, full 3D cadastral registration (partitioning of 3D space into '3D parcels'); second, hybrid solution (2D parcels and 3D physical objects are linked); and third, 3D tags in the current cadastral registration (references to 3D descriptions outside the information system such as CAD drawings). Based on the cadastral needs and the technical possibilities the authors conclude that for the short- to medium-term future the hybrid solution is the most appropriate. A prototype implementation of the hybrid solution based on an integrated 2D/3D geo-DBMS approach is presented.

Rebecca Tse and Chris Gold (Hong Kong Polytechnic University) propose a TIN (Triangulated Irregular Network) model for a 3D Cadastre. The TIN is a 3D surface model and the authors argue that this model might be sufficient for a 3D Cadastre and that a complete 3D partitioning of space is not needed. One reason for this is that the internal boundaries between two volumes would be unobservable or immeasurable and therefore not very practical. By contrast, in a surface model all boundaries are observable and indicate the volumes contained (boundary representation). The TIN model is implemented by using the quad-edge data structure and the Euler operations to edit the model, which ensures that the Euler formula for valid topological structure is maintained. This includes one Euler operation, which enables the creation of holes (tunnels) and outside connections (bridges) within the TIN surface representation.

4. Conclusion

The guest editors would like to thank the program committee members and the organising committee members for their efforts to make the workshop on 3D cadastres a success. The names of the members of the two committees can be found on the 3D cadastres Web site (www.gdmc.nl/3Dcadastres).

The papers in this special issue reflect technical, legal and organisational aspects of 3D cadastres. The guest editors are pleased to observe that for the first time in the series of theme issues on cadastral systems, the technical papers are now in the majority. After this very specific theme issue of CEUS on cadastral systems focusing on the 3D aspect, the next special issue of CEUS on cadastral systems will be a 'normal' one again. As usual we would like to encourage authors to submit their cadastral papers to the guest editors.

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