Towards a 3D Cadastre

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ABSTRACT

In the Dutch cadastral registration a cadastral object (real-estate object) can be a complete parcel, part of a parcel or a condominium right (apartment). The geometry of these legal objects are all based on a planar map which partitions the 2D space.

In intensively used areas there is a tendency to use space above and under the surface (e.g. constructions on top of each other; infrastructure above and under the ground; an increasing number of cables and pipes; apartments above shops/offices/other apartments).

From a legal point of view the current registration has proved to be still sufficient to register rights concerning 3D physical objects. However, the Netherlands' Kadaster wants to assure a sustainable, uniform and efficient registration in the future. Therefore, a research is carried out at the Department of Geodesy in collaboration with the Netherlands' Kadaster to develop a prototype of a land information system that can take the relevant 3D information into account. Information on 3D real-world objects (location, geometry, function, legal aspects) should be maintained and at least be accessible at cadastral offices.

In this paper we describe the approach taken in the Netherlands and we will relate our results with the findings of the workshop on 3D Cadastres, which was organised in Delft, the Netherlands in November 2001. This workshop was supported by the FIG. We start by giving three possible solutions of the problem and look at the solutions from both a cadastral and a technical perspective. An important contribution of this paper is the description of a conceptual data model including 3D physical objects and the relationships to subjects and the traditional (2D) objects.

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1. INTRODUCTION

In major urban centres (and especially their business districts), land use is becoming so intense, that different types of 'land' use are being positioned under and above each other. This puts the practicality of the currently used concept of 2D cadastral parcels to the limit. Examples of existing 3D situations are:

- Constructions on top of each other;
- Infrastructure above and under the ground;
- The increasing number of cables and pipes (as well as the increasing number of owners of cables and pipes due to privatisation processes);
- Apartments.

These physical 3D objects do in general not correspond with legal objects that are explicitly defined. Therefore they cannot be defined as a cadastral object in the cadastral map and cannot be used as a base for registration (see Figure 1). Considering the increasing occurrences of complex 3D-situations, practitioners and scientists are searching for solutions. These investigations deal with the definitions of 3D legal and 3D physical objects, their registration in cadastres and the required modelling. In November 2001 a workshop supported by the FIG was dedicated to this subject (see Van Oosterom et al, 2001). In this paper we describe the approach taken in the Netherlands. We will relate our results with the findings of the workshop.

From a legal point of view the current registration is still sufficient to register the right of property of real-world objects. In the Netherlands we have a nation-wide, parcel-based cadastre. This corresponds to the 'classical' 2D-cadastre (see FIG, 1995). The Netherlands' Kadaster is however more and more confronted with the limitations of the current registration possibilities to register spatially complex property rights. Moreover, the Kadaster wants to assure a sustainable, uniform and efficient registration in the future and thus looks for better ways to register 3D situations.

Therefore, a research is carried out at the Department of Geodesy, Delft University of Technology in collaboration with the Netherlands' Kadaster to study the issue of 3D cadastral registration in a fundamental way. The aim is to develop a prototype of a land information system that can take the relevant 3D information into account.

The paper is organised as follows. We start by giving a sketch of three possible solutions to register 3D objects and 3D situations. We will give a conceptual data model related to every solution. Next we look at the issue from both a cadastral perspective and a technical

perspective. We then compare our approach with the findings of the workshop on 3D cadastres and end with conclusions.

Figure 1: The cadastral map on the location of the metro in Amsterdam: the metro, which is drawn on top of the map, is not visible on the cadastral map

2. POSSIBLE SOLUTIONS

Starting from the existing registration we see three possible solutions to register 3D situations:

1. *A full 3D cadastral registration.*
   This means introduction of the concept of (property) rights in 3D space. The 3D space (universe) is subdivided into volumes (or 3D parcels) partitioning the 3D space (without overlaps or gaps). The legal basis, real estate transaction protocols and the cadastral registration should support the establishment and conveyance of 3D rights. From a practical point of view it seems best to maintain the 2D parcel as default (with an implicit third dimension); only in complex 3D situations the full 3D parcel would be used. It might also be considered if a limited definition of 3D property rights would fulfil a need (e.g. one or more property layer(s) underground or above ground level and one at ground level).

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2. *A hybrid solution.*
   This means preservation of the 2D cadastre and the registration of the situation in 3D by registering 3D physical (topographical) objects within the 2D cadastral registration. This results in a hybrid solution of 2D parcels and 3D physical objects in which relationships between the parcels and the 3D objects are maintained (dashed line in Figure 2B). Implicit relationships exist through the spatial definition of the objects and can be retrieved by spatial functions. In this case the legal and factual registrations are combined (hybrid solution). By intersection of e.g. a 3D building plan with the 2D cadastral parcels indications of the 3D property rights can be derived. The exact legal situation has to be derived from the official documents. These documents then have to contain precise 3D information.

3. *3D tags in the current cadastral registration system*
   This means preservation of the 2D cadastre with external references to representations of (digital) 3D situations. Complex 3D situations are registered using ad hoc solutions. The reference can be implemented in various ways. The simplest solution is to tag 3D situations in the registration (administrative register and the cadastral index map) whereupon the user then has to consult the (digital) public registers to find the detailed information. A more advanced option is to add a reference to a 3D (digital) description in the registration. The description may be available in analogue or digital form (e.g. a CAD-drawing). In the latter case the information might even be included in the database. The projected outlines of the 3D (physical) object could also be registered in the cadastral map.

These solutions are applicable to situations under as well as above the ground.

2.1 Data Models

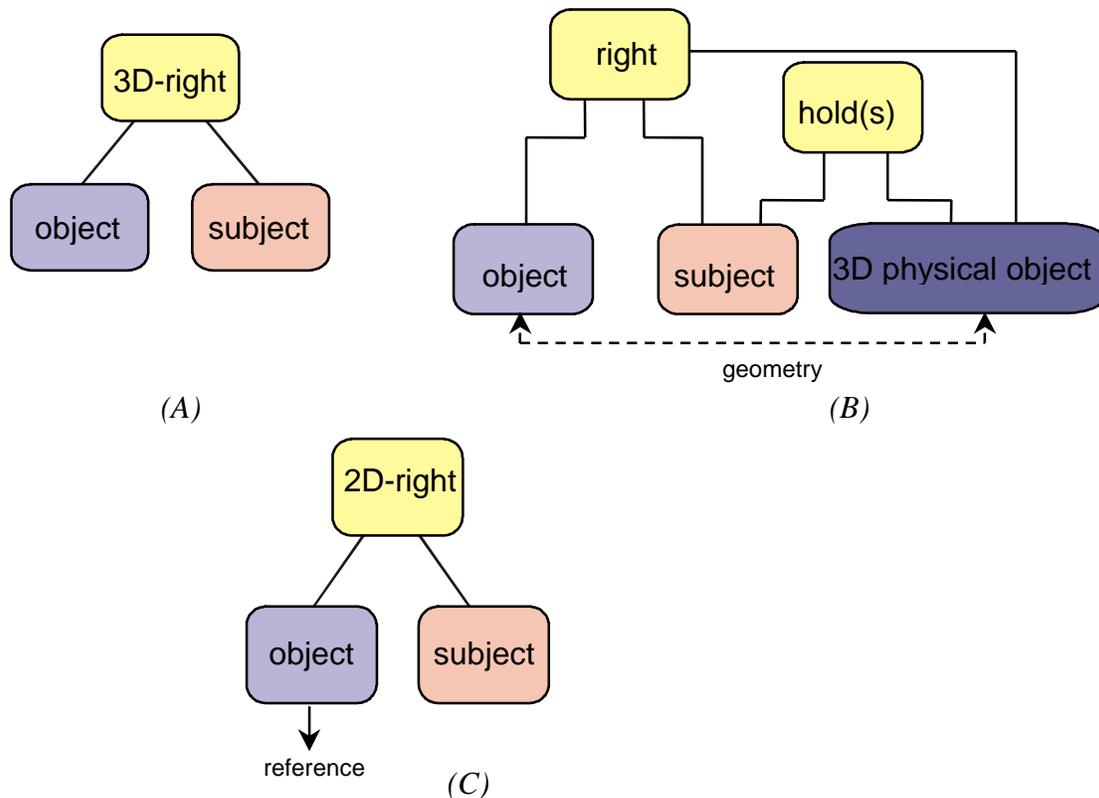The possible solutions sketched above have conceptual data models as presented in Figure 2.

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Figure 2: Data models corresponding to the possible implementations of 3D-Cadastres: (a) full 3D-Cadastre; (b) Hybrid solution; (c) 'classical' 2D-Cadastre with references

The models are at the basis of all modelling efforts. Subjects are natural or non-natural persons. Objects are ground parcels, part of parcels and apartments in the 2D and hybrid solution and 3D legal objects in the full 3D solution.

3. CADASTRAL PERSPECTIVE

3.1 Present Situation

For a proper understanding of the view of the Netherlands' Kadaster an insight in the current situation is helpful. In practice most 3D situations have been registered using apartment rights or the right of building. In the case of apartment rights information is available using the legally prescribed (paper) drawings. Although not strictly 3D, a drawing of each vertical layer is provided. In case a "right of building" is established in general no drawings are available.
In the case of tunnels the above lying parcels are expropriated so that the holder of the tunnel obtains the right of property of the concerning parcels. Sometimes the right of building is given back to the former owners.

Lately a solution has been implemented for underground objects (tunnels etc.). It consists of a mark in the administrative registration of the existence of an underground object. The deed, which has led to the registration, may be accompanied by a paper drawing. The outlines of the

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underground object may be depicted in the cadastral map. The inclusion of digital 3D drawings is not possible at the moment.

In practice this solution has been used in just a few cases. This is partly due to the fact that notaries are not aware of the benefits of this registration and partly to the fact that many underground situations relate to infrastructure where the owner of the parcel is also the owner of the underground object (e.g. a subway-tunnel under land owned by the municipality). In the latter case often no reference to an underground object is at all made in the deed, let alone that a drawing is provided!

3.2 Cadastral objectives

The main objective of the Kadaster is to warrant legal security in real-estate (transactions). This means that complex situations have to be registered in a correct way and that the registration should provide insight (i.e. optimal accessibility) into the actual (legal) situation in a simple, straightforward and sustainable manner. At the moment the accessibility of the registration in 3D situations is poor. At first sight even the professional (notary, real-estate agent or cadastral employee) may not be aware of a 3D situation; let alone the public at large and the non-cadastral-specialists (e.g. planners and contractors). It is therefore mainly from an information point of view that there exists a need for a better insight in 3D situations. The better the accessibility of the registration in complex 3D situations, the better the legal security of the real estate is warranted.

3.3 Cadastral view on proposed solutions

A full 3D approach would result in a renewal of the cadastral registration. From a legal point of view, first the concept of 3D legal objects needs to be introduced. This requires a change of law (civil code), which is a lengthy process.

Furthermore, from a practical point of view, a 3D cadastre is useful in densely built-up areas. For most of the country, however, a 'classical' 2D cadastre based on parcels serves its purpose well. Therefore the Kadaster will not opt for a full 3D cadastre in the short to medium-term future.

The approach where 3D physical objects are stored in the 2D cadastral registration is a very promising one. It is very advantageous from the point of view of accessibility. Both the 2D and 3D information is available directly and can be combined automatically. A practical bottleneck in the short-term is the existing data model of the registration, which is 2D only. Point of attention is that users should be aware that the registration of 3D physical objects is not identical to the definition of 3D legal objects.

The approach with external references to 3D situations is followed at the moment, apart from the fact that we do not store the 3D situations in the database as so-called 'local' files, but separately on paper drawings. It has proven to be practical with apartment rights. There seems no reason why it should not be feasible for other 3D situations. Given the current cadastral data models this option is a good starting point. It is, however, not a practical solution in the

medium to long run, because it will not enable a lasting, sustainable, and consistent registration of 3D situations.

The hybrid solution is the topic of our research.

4. TECHNICAL PERSPECTIVE

A technical perspective on the proposed solutions comprises the discussion on how to implement 3D geo-objects in the current cadastral DBMS in which the 2D parcels are stored. The spatial implementation of 3D objects in the DBMS is complex and depends on technological developments. The discussion on how a 3D data model should be implemented cannot be considered isolated from the available and implemented data models in 2D (Van Oosterom and Lemmen, 2001). Hereby the geometry as well as the topology should be considered.

This paragraph starts with a description of the optimal solution for maintaining 3D objects in the cadastral DBMS followed by a description of the state of the art. Based on these two aspects the technical perspective on the proposed solutions is given.

4.1 2D and 3D geo-objects in one DBMS: the optimal solution

The integrated architecture in which the geometric as well as the administrative data of objects are stored and maintained in one geo-DBMS should be the starting point for 3D cadastral registration (Stoter and Van Oosterom, 2002).

An ideal case would be to have spatial data on all objects relevant to the Cadastre in 3D (parcels, tunnels, apartments, cables/pipes etc.). The availability of 2D and 3D geometric data types in a DBMS will offer the integrated storage of spatial data within the DBMS and to perform spatial functions in 2D and 3D at the SQL level. The support of geometric data types in a geo-DBMS includes spatial operators (or geometry functions), spatial indexing and clustering. Topology structure management is also important for the maintenance of planar or volumetric partition of space.

The advantages of a full functional support of topology structure of geographical objects within the DBMS are:
−   It avoids redundant storage of shared edges, vertices and faces in a planar partition of space;
−   It is easier to maintain consistency of the data after editing and updating operations;
−   It is the natural data model for certain application; e.g. during surveying an edge is collected (together with non-geometric attributes belonging to a boundary) and not a polygon;
−   The topological structure can be used efficiently in certain operations (e.g. find neighbors);
−   It facilitates complex operators (map overlay, split/merge operations).

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When the topology of objects is maintained, the geometry of objects can be obtained by the "realisation" of topology. This means that geometry is being generated from the stored topological relationships. Many concepts have been developed in this area. At the moment there is no implementation in mainstream DBMSs, but work on this is in progress (Van Oosterom et al., 2002).

4.2 2D and 3D geo-objects in one DBMS: the state of the art

Mainstream DBMSs (Oracle, IBM DB2, Informix, Ingres) have implemented spatial data types and spatial functions more or less similar to the OpenGIS Consortium (*OGC, 1998*) Simple Features Specification for SQL (*OGC, 1999*). The purpose of this specification is to define a standard SQL extension that supports storage, retrieval, query and update of simple spatial features. Topological relationships between objects can be retrieved by the use of spatial functions. Topology structure management (partitions) or linear networks is not available within DBMSs. Therefore it is still difficult to update geometry in DBMSs, because of the risk of inconsistencies. OGC specifications (*OGC, 2001*) are until now 2D, although efforts are being made to extend these to 3D. Also the implementations of spatial data types in mainstream DBMSs are basically 2D.

To illustrate this, the implementation in Oracle spatial 9i (Oracle, 2001) has been studied. The supported spatial features in Oracle are point, line and polygons (including arcs, box and mixed geometry sets). Z-values can be used to represent 3D features (3D points, 3D lines and 3D polygons), but 3D models are not supported: topological structures are not recognised (this is also true in 2D), nor can spatial objects in 3D (3D volumetric types) be represented and manipulated. An experiment showed that the z-value, defined in a 3D geometry type is not used in spatial queries. As a consequence of the lack of topology 3D (and 2D) neighbors cannot be detected.

Apart from the modelling aspects, also the collection of 3D data should be considered. It is becoming easier to collect data in 3D (by means of GPS). However, it will take a tremendous job to recollect all data available at cadastres (parcel boundaries) in 3D nowadays.

5. TECHNICAL VIEW ON POSSIBLE SOLUTIONS

The 2D classical registration with references to 3D situations is the current practice and not a fundamental solution for the future.

The hybrid solution, with the current 2D Cadastre as starting point and an extension to register 3D situations seems a feasible solution from a practical point of view. 2D data are available in large amounts and are often still suffice and the implementation of an extension to maintain 3D geo-objects seems possible. The implementation will be based on techniques available to represent 3D physical objects. Support of 3D topology will not be available very soon. However, the hybrid solution does not require a full partition of space and support for "3D

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overlap detection" (a topological relationship). Therefore a limited support of topology (only within objects and not between objects) will be sufficient for the hybrid approach.

The solution of a full 3D Cadastre with support of 3D parcels is too comprehensive to be a realistic solution. Technical implementations for full 3D support (geometrically as well topologically) do not exist yet and are still in their initial stages. Furthermore the collection of all the data needed in 3D will take a lot of effort.

6. DISCUSSION

In our project we currently aim at a solution that is practical from a cadastral and technical point of view. We start from the representation of 3D physical objects to improve accessibility of information in complex situations. The introduction of a 'full' 3D cadastre is a long-term objective. If we compare this approach with the ones discussed at the workshop in Delft (Van Oosterom et al., 2001) we see the following:

– Many countries face the complexity of 3D situations, a good example is Israel (Doytsher et al., 2001). The approaches taken differ from country to country and are dependent on institutional aspects and the legal system (Van der Molen, 2001);

– The definition of 3D rights is complex. However, if it is limited to specific, well-defined cases (in particular constructions and apartments) where separation of ownership is allowed, it can successfully be implemented. In these cases a 'full' 3D-cadastre can be implemented in the short- to medium-term. This approach is taken into account in e.g. Norway (Onsrud, 2001) and Sweden (Julstad and Ericsson, 2001);

– From a legal point 3D legal objects are possible if separation of ownership is allowed. A proper description of the 3D right (e.g. a drawing) is sufficient for administrating the right. This situation exists in many countries for the right of apartment (or for appropriate condominium rights) and for right of building. For accessibility purposes it is seen as very beneficial if also the cadastral registration (including the cadastral map) supports 3D situations;

– Techniques will be available to represent 3D physical objects efficiently in the short- to medium-term. Creating and maintaining 3D topology structure, however, will not be possible very soon.

This shows that our hybrid approach starting with improving accessibility is practical and more important feasible (albeit not very advanced from a legal point of view). Overlooking the international developments the definition of 3D rights in specific cases warrants closer consideration. For representation purposes the hybrid approach seems to be the most promising taking into account the state of the art of technology.

This hybrid solution has been worked out in (Stoter and Salzmann, 2001).

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7. CONCLUDING REMARKS

Experiencing the increasing occurrences of complex 3D situations we have set out to look for practical solutions in improving the cadastral registration. We are currently pursuing a hybrid solution where we register 3D physical objects in relation with 2D rights. We have arrived at this approach by confronting cadastral needs with technical possibilities. We refer readers interested in a detailed confrontation of the cadastral and technical points of view to (Stoter and Salzmann, 2001). In the coming years we will implement this approach in a prototype environment based on a DBMS architecture. At the same time we will put effort in improving the possibilities and willingness of the parties in the land market to provide 3D information.

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BIOGRAPHICAL NOTES

Jantien Stoter (MSc) graduated in Physical Geography in 1994. She started her career as a GIS specialist/consultant with the District Water Board of Amsterdam and Surroundings (1995-1997). From 1997 till 1999 she worked as a GIS specialist/consultant at the Engineering Office Holland Rail Consult. Since 1999 she is an assistant professor in GIS applications, section GIS technology, Department of Geodesy, Delft University of Technology Also doing a Ph.D. on 3D cadastres. The emphasis of the research is the implementation of the facility to incorporate 3D real estate objects (geo-objects) in the current 2D geo-DBMS of the Netherlands' Kadaster.

Martin Salzmann heads the geodesy section of the Netherlands' Kadaster. He is involved in consultancy and innovation in the fields of geodesy and geo-information, the development of the geometric infrastructure of the Netherlands and quality management of cadastral working processes. He has been with the Kadaster since 1996. Martin holds degrees in geodesy (Msc and PhD) of Delft University of Technology.

Peter van Oosterom (MSc Technical Computer Sciences (1985) Delft University of Technology, PhD (1990) Leiden University). From 1985-1995 he worked as a computer scientist at TNO. In the period 1995-1999 he held the position of senior information manager at the Dutch Cadastre. On January 1st, 2000 he has been appointed to professor of GIS Technology at the Delft University of Technology, Department of Geodesy.

Paul van der Molen is since January, 1st 2002, director Kadaster International. Before that he was director Land Information and Geodesy of the Netherlands Cadastre and Public Registers Agency, head office in Apeldoorn (NL). He is a visiting professor of Land Administration and Cadastre at the International Institute of Aerospace Survey and Earth Sciences (ITC) in Enschede (NL). Currently he acts as vice chair of Commission 7 of FIG and as a bureau member of the Working Party on Land Administration (WPLA) of the UN/ECE.

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