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Towards a 3D cadastre: where do cadastral needs and technical possibilities meet?

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Abstract

In the Dutch cadastral registration a cadastral object (real-estate object) can be a complete parcel or a condominium right (apartment). The geometries 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/under the ground, increasing number of cables and pipes, apartments above shops/offices/other apartments. These physical 3D objects cannot be defined as cadastral objects in the cadastral map, which is based on 2D parcels, and cannot be used as a base for registration. From a juridical point of view the current registration is still sufficient in 3D situations. To assure that the Netherlands' Kadaster is able to address future needs, a prototype of a Land Information System which can handle 3D spatial information is being developed at the Department of Geodesy in collaboration with the Netherlands' Kadaster. This paper is written as part of the joint research of the Kadaster and the Department of Geodesy. Starting points are the needs of the Netherlands' Kadaster on the one hand and the technical possibilities on the other hand. In this research a concept is developed in which cadastral needs and technical possibilities meet. The most feasible solution for this is to start with the current 2D cadastre and to extend this with an implementation for the registration of 3D situations. The realisation of this concept is also described in this paper.

Keywords: 3D cadastre; 3D data modelling; 3D registration; Geo-DBMSs

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1. Introduction

The Netherlands' Kadaster is responsible for maintaining the public registers and the cadastral registration (including the cadastral map) concerning real estate.

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 cannot be represented as a cadastral object on the existing cadastral map and cannot be used as a base for registration. The only physical objects on the cadastral map are (the outlines of) buildings, which serve as a reference framework for the orientation.

From a juridical point of view the current registration is still sufficient to register the right of property of physical objects. The 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, consistent 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 cadastral registration in 3D in a fundamental way.

This paper is written as part of this joint research. Starting points are the envisaged need of the Netherlands' Kadaster for an improved registration in case of 3D situations while taking into account the existing registrations on one hand and the technical possibilities on the other hand. This article is started with an example of the current practise of the registration of a 3D situation. Then three possible solutions for a 3D cadastre are given together with their data models. These solutions are analysed both from a cadastral point of view and a technical point of view. This leads to a concept of the most optimal solution for a 3D cadastre. The technical realisation of this concept is also described in this article.

Related work can be found in Stoter and Zevenbergen (2001) and Doytsher, Forrai, and Kirschner (2001).

2. Example of current practise

Fig. 1 shows an example of a 3D situation. Three parcels are needed to register the right of property of the building. On the cadastral map (Fig. 2) you can see the

Fig. 1. Example of a 3D situation: a building above a road.

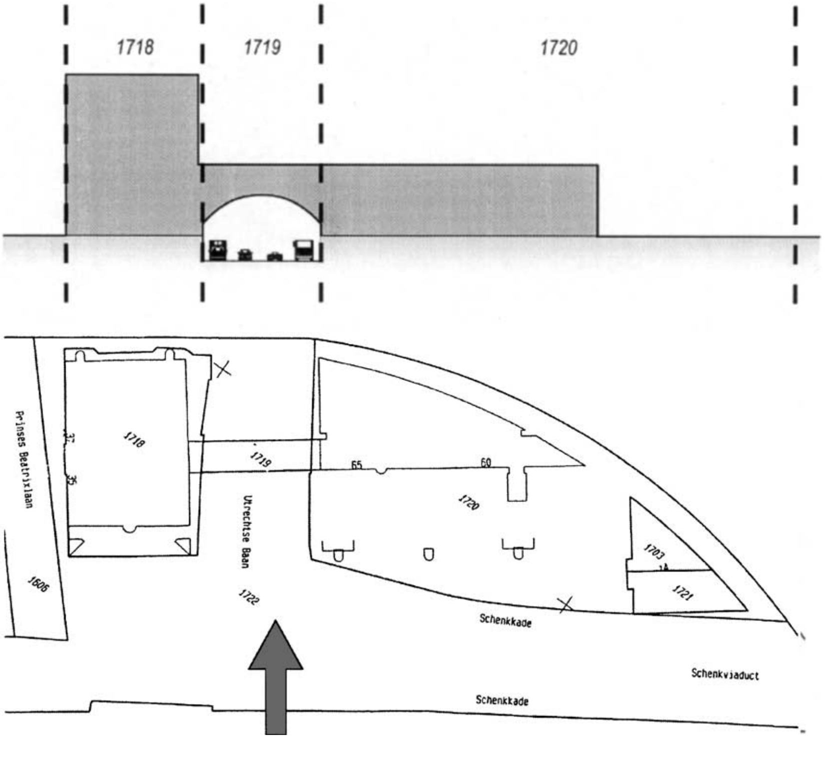

Fig. 2. Cadastral map of a construction above the surface (see Fig. 1).

outlines of the building and the surface parcels. The arrow indicates the view position of the camera in Fig. 1. The company 'Nationale Nederlanden' possesses the whole building. The rights and restrictions of the parcels concerned are as follows: The municipality holds a restricted property on parcels 1719 and 1720. 'Nationale Nederlanden' holds an unrestricted property on parcel 1718, a right of superficies on parcel 1719 and a right of long lease on parcel 1720.

3. Possible solutions

Starting from the existing registration three possible solutions to register 3D situations are distinguished. The conceptual data models corresponding to these solutions are given in Fig. 3.

1. *A full 3D cadastre:* 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

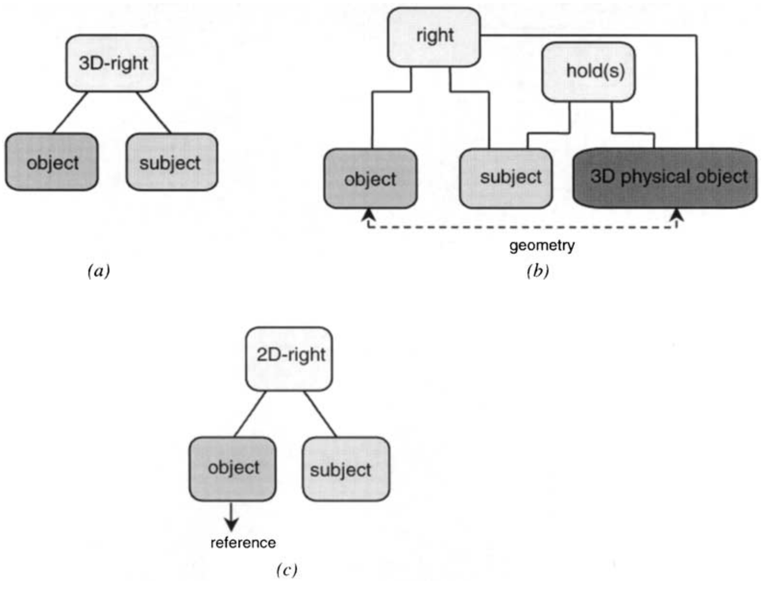

Fig. 3. Data models corresponding to the possible implementations of a 3D cadastre: (a) full 3D cadastre; (b) hybrid solution; (c) 'classical' 2D cadastre with references.

would be used. It might also be considered if in some cases a simpler definition of 3D property rights would fulfil the need (e.g. one or more property layer(s) underground or above ground level and one at ground level).

2. *A hybrid solution*: This means preservation of the 2D cadastre and the registration of the situation in 3D by registering 3D physical objects within the 2D cadastre. This results in a hybrid solution of 2D parcels (legal registration) and 3D physical objects (factual registration) in which relationships between the 2D parcels and the 3D physical objects are maintained (dashed line in Fig. 3b). 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. By intersection of a 3D physical object 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 cadastre:* 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 map) whereupon the user then has to consult the (digital) public registers to find 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 on the cadastral map.

3.1. Data models

The possible solutions sketched above have conceptual data models as presented in Fig. 3. The models are at the basis of all modelling efforts. Subjects are natural or non-natural persons. Objects are ground parcels and apartments in the 2D and hybrid solution and 3D parcels in the full 3D solution.

A 3D physical object is not a subset of a cadastral object in Fig. 3b, since 3D physical objects are maintained in addition to 2D parcels (objects). Rights and limited rights are still registered on parcels. The only right that a person can get on a 3D physical object is that he can become the holder of this object by means of a right that is established on the corresponding 2D parcel.

4. 3D cadastre: cadastral and technical view on proposed solutions

In this section the given solutions are considered both from a cadastral and a technical point of view. This leads to a conclusion where cadastral needs and technical possibilities meet.

4.1. Cadastral view

4.1.1. 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 right of superficies. 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 superficies is established in general no drawings are available.

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 (Klaasse, 1998). The deed, which has led to the registration, may be accompanied by a paper drawing. The outlines of the 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 made at all in the deed, let alone that a drawing is provided!

4.1.2. 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.

4.1.3. 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 rights needs to be introduced. This requires a change of law (civil code), which is a lengthy procedure.

From a practical point of view, a 3D cadastre is only 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 cadastre 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 rights.

The approach with external references to 3D situations is followed at the moment, apart from the fact that 3D situations are not stored 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-term future, because it will not enable a lasting, sustainable, and consistent registration of 3D situations.

4.2. Technical view

A technical perspective on the proposed solutions comprises the discussion on how to implement 3D geo-objects in the current cadastral geo-DBMS in which the 2D parcels are stored (van Oosterom & Lemmen, 2001). The spatial implementation of 3D geo-objects in the DBMS is complex and depends on technological developments. The discussion on how a 3D geo-object should be implemented cannot be considered isolated from the implementations in 2D (van Oosterom & Lemmen, 2001). With this the geometry together with the topology should be considered.

This subsection starts with a description of the optimal solution for maintaining 3D geo-objects in the cadastral geo-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.

4.2.1. 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 a 3D cadastre (Stoter & 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 (van Oosterom, Stoter, Zlatanova, & Quak, 2002):

- it avoids redundant storage of shared edges, vertices and faces in a planar or volumetric partition of space;
- it is easier to maintain consistency of the data after editing and updating operations;

- it corresponds with the method of data capture; 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 queries (e.g. find neighbours);
- it facilitates complex operators (map overlay, split/merge operations).

When the topology of objects is maintained, the geometry of objects can be obtained by the "realization" of topology. This means that geometry is being generated from the stored topological relationships. Many concepts have been developed in this area (both for 2D and 3D). At the moment there is no implementation in mainstream DBMSs, but work concerning 2D geometry and topology is in progress (van Oosterom et al., 2002).

4.2.2. 2D and 3D geo-objects in one DBMS: the state of the art

Mainstream DBMSs (Oracle, IBM DB2, IBM/Informix, Ingres) have implemented spatial data types and spatial functions more or less similar to the OpenGIS Consortium Simple Features Specification for SQL (OGC, 1998, 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) and linear networks are not available in this moment 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 in harmony with ISO/TC 211 developments. 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 geometric data types in Oracle are points, lines and polygons (including arcs, boxes and mixed geometry sets). z-Values can be used to represent 3D geometric data types (3D points, 3D lines and 3D polygons), but 3D geometric data types with a volume (spatial objects in 3D) are not supported: they cannot 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) neighbours cannot be detected.

Apart from the modelling aspects, also the collection of 3D information should be considered. It is becoming easier to collect data in 3D (by means of video, laser scanning and GPS). However, it will take a tremendous job to recollect all data related to 3D situations and to construct the relevant objects out of the collected data.

4.2.3. Technical view on possible solutions

In case of a full 3D cadastre, the whole 3D space would be subdivided into 3D parcels. A full 3D cadastre would also support the spatial registration of rights in 3D, which seems to be the final and most advanced solution. However, it is too comprehensive to be a realistic solution. Technical implementations for full 3D support (geometry as well as topology) do not exist yet and are still in their initial stages. Furthermore the collection of all the data needed in 3D (3D parcel geometry and topology) will take a lot of effort. Such a system might be a solution in 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 sufficient 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 and on new developments. Support of 3D topology is not available yet. However, the hybrid solution does not require a full partition of space. Therefore a limited support of topology (only within objects and not between objects) will be sufficient for the hybrid approach. Support for "3D overlap detection" (a topological relationship) will be needed in the medium-term future.

This solution is also a very challenging one as far as technological aspects are concerned. However, it is a more realistic solution than the first one and therefore interesting for further research.

The 2D classical registration with tags to 3D situations is the current practice in the Netherlands and not a fundamental solution for the future. The database contains references to paper drawings or digital files outside the DBMS, instead of integrating the 3D physical objects as 3D geo-objects in the 2D geo-DBMS. The problem of this solution is that the DBMS cannot guarantee consistency, nor can the 3D physical object be queried in a combined environment with the 2D parcels.

4.3. Where cadastral needs and technical possibilities meet

In conclusion, the option '3D tags in the current cadastral registration' does not give a base for efficient and sustainable registration in the future. On the other hand, a full 3D cadastre is too comprehensive and is something to be considered in the faraway future. It is more efficient to focus on a feasible solution in the nearby future. Therefore, the solution chosen in this research is to start with the current 2D cadastre and to extend this with an implementation for the registration of 3D situations. This is the concept where the researchers expect that cadastral needs and technical possibilities will meet. In the next section the technical realisation of this concept is described.

5. The realisation of a 3D cadastre

A '3D cadastre' is now defined as a system, which registers rights and limited rights on 2D parcels (legal registration), but which gives more insight in the juridical and factual situation above and under the surface in case this is relevant with respect to legal security (factual registration). This insight is obtained through spatially defined constructions on, above and under the surface as 3D geo-objects in the current cadastre. Whether these objects will be defined as juridical objects is also matter of importance. Juridical developments can be influenced by technical possibilities.

The current information system that is used by the Netherlands' Kadaster consists of (Lemmen, Oosterbroek, & van Oosterom, 1998):

- a 2D geo-DBMS for maintaining the geometry and topology of parcels (and buildings for reference purposes) called LKI ('Information system for Surveying and Mapping')
- an administrative DBMS for legal and other administrative data related to parcels called AKR ('Automated Cadastral Registration')

A link between those two subsystems exists through the unique parcel number. The geo-DBMS and the administrative DBMS will be used as starting point and will be extended with possibilities to maintain 3D geo-objects.

5.1. Administrative data model

The current administrative model is based on three key types: object, subject and right (see Fig. 3c). Objects are parcels and condominium rights which are linked to a 'mother' parcel. Subjects are legal persons with rights on parcels.

Objects and subjects have a *n:m* relationships via rights: a subject can have rights related to more than one object (e.g. a person owns three parcels) and one object can be related to more than one subject (e.g. one subject is bare owner of a parcel and another subject has the right of superficies on the parcel) (van Oosterom, Maessen, & Quak, 2000).

To be able to register 3D situations together with the parcel objects, 3D physical objects must also be defined as cadastral objects, together with the holders of these objects.

The holder of a 3D physical object is the subject responsible for the object and uses the object as if he were the owner.

In the case of physical objects under or above the surface, a few cases can be distinguished:

- the holder of the object is the *full* owner of the surface parcel(s);
- the holder of the object is the *bare* owner of the surface parcel(s): other subjects have also certain types of rights on the parcel, such as right of superficies, right of long lease, right of easement etc.;
- the holder of the object is *not* the owner of the surface parcel but has limited rights on the parcel, such as right of superficies or a right according to Administrative Law;
- the holder of the object is *not* the owner of the surface parcel and has no rights on the parcel: the legal status of the physical object is not explicitly registered.

It is evident that the last case should be avoided. For the first case the possibility to register 3D situations might not be necessary. The proposed administrative data model to register 3D physical objects has been illustrated in Fig. 3b.

Attributes concerning 3D physical objects will also be maintained in the DBMS, as well as the rights and limited rights concerning these objects (established on parcels). These rights contain the explicit relationships between the 3D geo-objects and the 2D parcels.

Juridical explicit relationships between a 3D physical object and the surface parcels exist through the holders of the 3D physical object who have to be subjects of rights on parcels. This last aspect is a precondition for the explicit juridical relationship between parcels and 3D physical objects. The rights are not established directly on a 3D physical object, but are associated with a 3D physical object. This means that a holder (subject) of a 3D physical object always must have a right on a 2D parcel. The possible relationships between 3D physical objects on the one hand and parcels on the other hand are *m:n* via rights. For example one object can intersect with several parcels and one parcel can intersect with more than one 3D physical object.

5.2. Spatial data model

The 3D physical object must be spatially defined in the current geo-DBMS, in which topological as well as geometric aspects are relevant.

5.2.1. Extension with 3D geometric data type

The relevant spatial properties of physical objects will be defined in 3D in the geo-DBMS, which are the bounding envelope. The bounding envelope can be defined by the outer and inner boundaries while disregarding internal details.

The initial preference was to define the geometric volume primitive for the 3D cadastral data model in analogy with the representation of geo-objects in the 2D cadastral data model (point, line and/or circular arc and polygon, described by a sequence of lines or arcs) and to use these spatial features in 2D as the base in 3D. The 3D geometric data type would therefore preferably be composed of polyhedrons, spheres, cones and cylinders. However, implementation experiments showed that those primitives are still complex. For example, in 2D, a circular arc can be inserted and defined with a starting point, a radius and a point on the circle. Which points do you need for sphere-patches? Although one could find points for this, it is hard to maintain this data model and complicated to survey and input these points (which points are exactly needed?). Therefore first only polyhedrons will be used to spatially define 3D physical objects in the DBMS. This is further worked out in (Stoter & van Oosterom, 2002).

Polyhedrons are solids, bounded by flat surfaces with each surface bounded by straight lines. Note that it may be difficult to describe a polyhedron correctly, as the four or more 3D points of a face have to lie in a flat surface. Before the 3D information is stored in the DBMS, it should therefore be checked if the surfaces are flat enough within a given tolerance. Non-flat surfaces are more or less undefined which is not desirable in cadastral situations.

5.2.2. Implementation of 3D geo-objects in the geo-DBMS

Given the current technical possibilities and the current 2D geo-DBMS, the 3D geo-object is implemented in two ways in order to look for the best design solutions:

1. using 3D geometric data types and topology only within objects;
2. creating a topological model between objects to maintain and retrieve 3D geo-objects.

Implementation experiments will have to show which model is better to register 3D cadastral situations.

5.2.2.1. Using 3D geometric data types. As was mentioned before, 3D (volumetric) data types are future work for DBMSs. Still you can use the advantages of the other spatial data types (3D polygons), which are supported by defining a 3D geo-object as a complex object consisting of a polyhedron with references to the faces it consists of. The faces are stored as 3D polygons. This model is partly a topological model, since the body is defined by references to the faces. The advantages of this approach are:

- with this solution it is possible to retrieve 2D topological relationships between (the projection of) 3D geo-objects and surface parcels. Once 3D spatial functions are available, also 3D relationships can be retrieved;
- 3D polygons are recognised by GIS and CAD applications that can make a database connection by means of a geometry column in a DBMS. In this way it is possible to visualise (and edit) the data in a GIS or CAD with 3D capabilities.

Disadvantage of this approach is that the topology structure between objects cannot be used (see section 'technical view').

5.2.2.2. Creating a topological model. As was mentioned before, DBMSs do not (yet) support topology (2D nor 3D). Therefore, a topological model has to be defined in a DBMS by means of user-defined references. A topological model for 3D geo-objects is currently developed at the Department of Geodesy of the Delft University of Technology (Zlatanova, 2000). A 3D geo-object is therein defined as a polyhedron consisting of nodes and faces. This topological model is used in this research and implemented on top of Oracle. The model consists of three tables: BODY, FACE and NODE and each table contains references to other tables: the BODY-table contains references to the faces and the FACE-table contains references to the nodes (with their co-ordinates).

Advantage of this approach is that the topology structure management can be used in the storage and retrieval of the data (see section 'technical view').

Disadvantages of using a self-made topological model are:

- using topology in querying can be very difficult at SQL level (topology is not recognized by DBMSs). For spatial queries it is always required to generate a realisation of the object. Therefore an extension is needed or self made spatial

functions have to be implemented, instead of being able to use the spatial queries available in the DBMS directly (although 3D spatial queries are not yet available in DBMSs);
- the data model is complicated and no standards exist for a topological data model;
- since the DBMS does not recognise topology, the consistency of the data has to be checked by other software.

5.3. Integration of 2D parcels and 3D geo-objects

The incorporation of 3D geo-objects in the DBMS based on 2D parcels consists of implicit as well as explicit relations:

- topological structure (topology within objects) will preferably be maintained explicitly (e.g. bodies, faces, edges, nodes), because of data consistency checks;
- topological relationships between two arbitrary objects (2D or 3D) will preferably be maintained implicitly, built in the geometric data model. These relationships can be derived by means of geometry functions and operators and can be used in constraints (e.g. to avoid overlaps);
- juridical relationships will be maintained explicitly.

Note that when topological relationships between objects are 'derived on the fly' the accuracy of the data is very important (when are objects inside, touching, equal, overlapping?). This is the case in 2D, but much more complicated in 3D.

By these relationships it is possible to query the data 2D, 3D, administratively and in combination with each other. The height on the surface must be known to find out whether 3D geo-objects are above, on or under the surface (see Stoter & van Oosterom, 2002).

The required queries reflect the actual need of the Kadaster for a 3D cadastre. Examples of queries are:

- which other 3D physical bjects are located on top or under a certain 3D physical object?
- which surface parcels intersect with a (projection of a) 3D physical, or vice versa: which 3D geo-object intersects with a certain parcel?
- is the owner of the parcel the same as the holder of the 3D physical object (bare or full owner)?
- what rights are established on surface parcels intersecting with a 3D physical object? Which subjects (legal persons) hold these rights?

The needed queries are collected and are being translated into prototype implementations in order to make the design of the 3D cadastre as optimal as possible.

6. Solution applied to case

The described technical solutions for the concept of a 3D cadastre using the hybrid approach can be applied to the case mentioned earlier. The property rights of the building will still be registered by means of the 2D parcels. Preferably this must be done by rights which make the holder of the object the owner of the object, e.g. by means of a right of superficies or a condominium right.

A right of long lease (as is used in this example) should not be the first choice for registration, since this does not assure a permanent right of property on the building.

Apart from the rights on the parcels, the 3D physical object (whole building) itself is maintained in the DBMS of the Kadaster with spatial and non-spatial attributes as well as the relationships between the building and the surface parcels (via rights). The information of the holder is also registered by means of the ‘hold’ relationship.

In the DBMS of the Kadaster you can find that the concerned rights are associated with a specific 3D physical object and it is possible to retrieve more information on the factual (3D) situation. This improves the accessibility of registrations in complex 3D situations.

In Figs. 4 and 5 2D cadastral data (parcel boundaries and outlines of buildings) together with a 3D physical object (building of Fig. 1) is visualized. The data is stored in an Oracle DBMS.

In Fig. 4 it is illustrated how 3D information stored in Oracle Spatial 9i as 3D geometric data types (3D polygons) can be visualized in MicroStation Geographics (Bentley, 2001). By this it is possible to make use of CAD functionalities on the data. CAD is strong in advanced visualization techniques and advanced 3D modelling and editing.

In Fig. 5 you see a VRML (VRML, 1997) presentation of the DBMS generated on top of the implemented concepts of the second solution (using the self-made topological model). A VRML file can be viewed in any web-browser with a VRML plug-in.

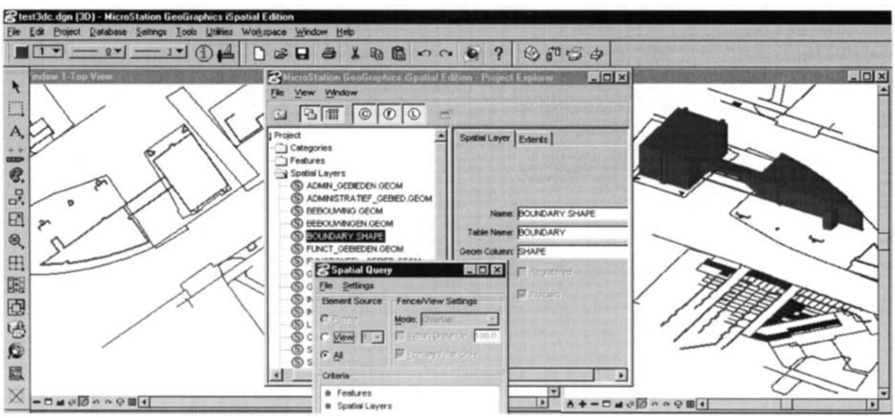

Fig. 4. Using MicroStation to visualize/edit 3D geo-objects stored in DBMS.

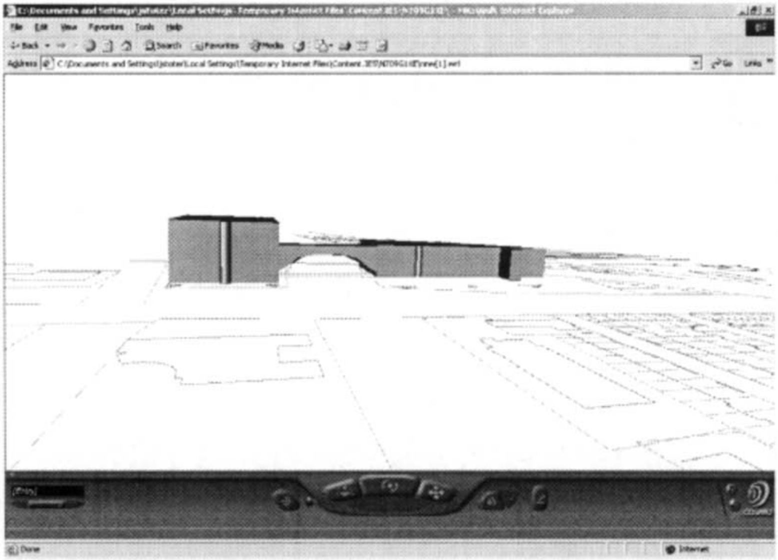

Fig. 5. A VRML representation of 2D cadastral data and a 3D physical object, all stored in the DBMS.

7. Conclusion

There is an increasing interest in using space under and above the surface. In the current cadastre in the Netherlands, which is based on 2D parcels, those factual situations are sometimes complicated to maintain. Therefore a need for a 3D cadastre occurs. In this paper the cadastral needs and ambitions for a 3D cadastre are described. Three possible solutions for a 3D cadastre are given:

- a full 3D cadastre;
- a hybrid system;
- using 3D tags in the current system.

These three solutions have been considered both from a cadastral and technical point of view in order to look for a concept of a feasible 3D cadastre based on cadastral needs and technical possibilities.

In conclusion, a full 3D cadastre might be a solution in the faraway future, when cadastral and technical developments have come far enough. At the moment this solution is too comprehensive. Adding a 3D tag in the current registration has proved to be not sufficient to get insight in the factual situation.

Therefore, the authors of this article come to a medium-solution: starting with the current 2D cadastre and extending this with the possibility to register 3D situations, while also maintaining the spatial and juridical relationships between 2D parcels and 3D physical objects. The technical realisation of a prototype of this concept is also described in this paper.

Future research will focus on further realisation of the developed concept using prototype implementations, which are based on an integrated 2D/3D geo-DBMS approach.

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