A Conceptual Data Model for a 3D Cadastre in Korea

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Abstract

Because of most current cadastral systems maintain 2D geometric descriptions of parcels linked to administrative records, the system may not reflect current tendency to use space above and under the surface. The land has been used in multi-levels, e.g. constructions of multi-used complex buildings, subways and infrastructure above/under the ground. This cadastre situation of multilevel use of lands cannot be defined as cadastre objects (2D parcel-based) in the cadastre systems. This trend has requested a new system in which right to land is clearly and indisputably recorded because a right of ownership on a parcel relates to a space in 3D, not any more relates to 2D surface area. Therefore, this article proposes a 3D spatial data model to represent geometrical and topological data of 3D (property) situation on multilevel uses of lands in 3D cadastre systems, and a conceptual 3D cadastral model in Korea to design a conceptual schema for a 3D cadastre. Lastly, this paper presents the results of an experimental implementation of the 3D Cadastre to perform topological analyses based on 3D Network Data Model to identify spatial neighbors.

Keywords : 3D GIS, 3D Cadastre, 3D Spatial data models, 3D Network data models

1. Introduction

Cadastre is normally a parcel-based land information system containing a record of interests in land including rights, restrictions and responsibilities (Stoter and Oosterom, 2006). Most of existing cadastral systems deal with 2D geometric descriptions of land parcels linked to administrative records, such as ownerships. In other words, individualization of property started originally with a subdivision of land using 2D boundaries, which makes a 2D parcel to be the basic unit in existing cadastre registrations. However, this cadastre system may not reflect the current tendency to use space above and under the surface. Recently, population density has increased significantly, which have resulted in using lands more intensively. The land has been used in multi-levels, e.g. constructions of multi-used complex buildings, subways and infrastructure above/under the ground. This cadastre situation of multilevel uses of lands cannot be defined as cadastre objects (2D parcel-based) in the cadastre systems. This trend has requested a new system in which right to land is clearly and indisputably recorded because a right of ownership on a parcel relates to a space in 3D, not any more relates to 2D surface area. To represent and manage the 3D cadastre objects, 3D geo-spatial technologies should be utilized. Because the representation of legal boundaries of parcels is fixed in 2D space, geo-spatial scientists have challenges to represent the vertical dimension of 3D real estate objects in legal documents using current cadastres (Lemmen and Oosterom, 2003). The 3D cadastre system should pay sufficient attentions to 3D property situations and represent the boundaries of property in all dimensions.

Stoter and Oosterom (2006) identified the basic needs for the 3D cadastre as follows: 1) to have a complete registration of 3D space to which these rights apply, although the current cadastre already registers rights that entitle persons to volumes as attribute of defined parcels, and 2) to have good accessibility to the legal status of stratified property including 3D spatial information as well as to public law restrictions. Based on these requirements, the 3D cadastre system should incorporate

the functionalities 1) to register 3D spatial information on space rights on parcels including geographic and thematic data, 2) to maintain the relationships between the external database containing objects of interest for the cadastre (such as infrastructure objects, tunnels, subways, etc.) and the location of these objects in the cadastral registration, and 3) to retrieve and view the legal status of 3D situations, to answer such a question that "are all intersecting parcels encumbered with a right for the infrastructure object?"

With the goal being to overcome the limitations of current 2D cadastre systems and to develop a 3D cadastre system, this article focuses on developing a 3D spatial data model to represent geometrical and topological data of 3D (property) situation in 3D cadastre systems, and a conceptual 3D cadastral model in Korea to design a conceptual schema for a 3D cadastre. This article first reviews 3D cadastre models developed in an international context, then proposes a conceptual 3D cadastre model in Korea to deal with 3D property situations on multilevel uses of lands. This is followed by a description of a 3D spatial data model for 3D cadastre to represent geometrical and topological data of 3D geo-objects. The final section discusses the outputs derived from this study.

2. 3D Cadastre Models

2.1 Components of 3D Cadastre Model

A 3D cadastre is defined as a system, which registers rights and restricted rights on 2D parcels and 3D property situations above and under the surface in the 3D aspect of rights. The 3D property situations refer to situations in which different property units (with different types of land use) are located on top of each other within complex structures. The current administrative model is based on three components: object, subject and right (Stoter and Salzmann, 2003). Objects are parcels and apartment rights linked to a 'mother' parcel, and subjects are legal owners with rights on parcels. In order to register 3D property situations together with parcel objects, 3D physical objects (tunnels, apartments, subways, cable/pipes etc.) should be identified and represented as cadastre objects, together with these objects' ownerships. Therefore, the components of 3D cadastre models include 3D parcels, 3D right-objects, and 3D physical objects, which are linked to administrative data including ownerships, as seen in Fig. 1. These components are a 3D property unit (or 3D real estate object), which is a bounded amount of space to which a person is entitled by means of rights (ownerships).

Individualization of property started with subdividing the surface into property units using 2D boundaries, called parcels, which make the cadastre map a 2D map. To ensure completeness and consistency, 2D parcels may not overlap and gaps may not occur (forming a planar partition). Based on the spatial definition of 2D parcel in the current planar approach, the 3D spatial parcel is defined as an envelop bounding the ownership space, called a 3D property unit (Stoter and Oosterom, 2006). According to the Korean Land Law, similar to judicial systems of many countries, proprietary right in the 3D parcel is unrestricted and it extends from the center of
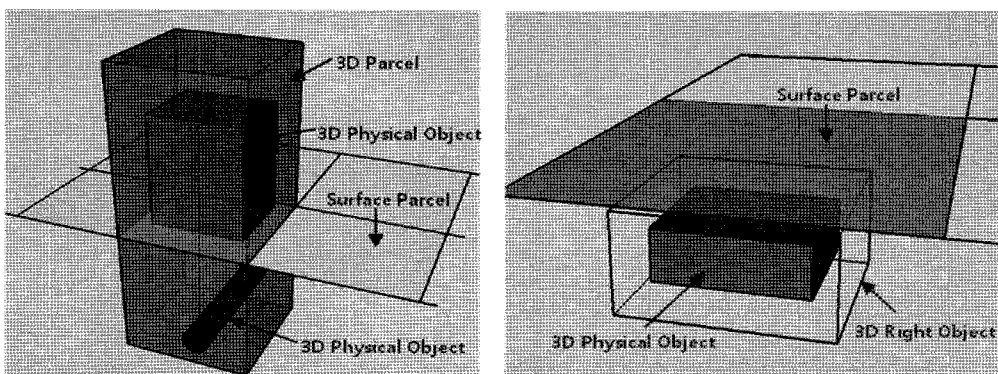

Fig. 1. Components of 3D Cadastre Model

the earth into the sky (Benhamu and Doytsher, 2003). However, in order to utilize all land space and spatial registration of property rights, the possibility of restricting the parcel volume is considered in the land compensation regulations.

A 3D right-object is a 3D representation of a right that is established on a 2D parcel and concerns a 3D property situation, for example a right of easements for tunnels or pipes in the 3D space. The boundary of 3D right-objects starts with the parcel boundary and is extended into 3D by means of defining the upper and lower limits of the right. The 3D right-objects are associated with, and contain a reference to the physical objects, which consist of actually built constructions, such as tunnels and apartments. The registration of a 3D physical object consists of two kinds of rights belonging to this particular 3D physical object, which are a right of (infrastructure) easement and apartment rights. In order to register the 3D physical objects, a tunnel is subdivided into parts according to the 2D (or surface) parcels, while the apartment is considered as a compound physical object containing a set of apartment units (property units), which are associated with a registered right for each apartment (Stoter et al., 2004). However, this approach requires considerable adjustments of the current cadastre registration system, technically and administratively. For the implementation of this system, a finite number of physical objects need to be defined and registered in the cadastre system. From the technical point of view, it is more difficult to represent and to maintain spatial and non-spatial characteristics of 3D physical objects in the system because the spatial representation and analyses of physical objects are more complex than those of 3D right-objects. In order to resolve these problems, this study proposes to develop a spatial data model to represent cadastre objects, especially 3D physical objects in the 3D cadastre system.

2.2 Conceptual Models for a 3D Cadastre

In recent years, there have been growing interests in finding cadastre solutions for multilevel use of lands (Kim, et al, 2005; Yang, et al, 2004; Benhamu and Doytsher, 2003; Biller and Zlatanova, 2003; Molen, 2003; Seo et al. 2006; Stoter et al., 2004; Stotoer and Oosterom,

2006; Stoter and Ploeger, 2003; Stoter and Salzmann, 2003; Tse and Gold, 2003). The 3D cadastre have been proposed to determine the location and 3D boundaries of parcels, right-objects and physical objects in space, and to serve the legal and physical objectives to be utilized for basic mapping, planning land use and spatial environmental planning (Benhamu and Doytsher, 2003). In the systems, the 3D right-objects should contain a reference to the physical objects associated with in the 3D cadastre. All 3D right-objects belong to one 3D physical object can be derived, and a 3D physical object also can be queried spatially and administratively, for example, which parcels are intersecting with a 3D physical object.

In the proposed systems, three possible solutions have been developed and implemented to register 3D property situations in cadastres: 3D tags in 2D cadastre, hybrid solutions, and full 3D cadastre (Stoter and Salzmann, 2003). The 2D classical registration with tags to 3D situations is to preserve 2D cadastre with external references to presentations of digital 3D situations such as CAD drawings. The solution is the current practice in many countries including the Netherlands and the United States and not an appropriate way for the future. This solution requests to maintain the database consistency between 2D cadastre and external databases, and cannot support to query the 3D physical objects (for example, apartment) in a combined environment with the 2D parcels (Stoter and Salzmann, 2003).

The hybrid solution is to integrate the 2D cadastre registration into the registration of the 3D situations, which means that 2D parcels and 3D physical objects are linked (Benhamu and Doytsher, 2003; Molen, 2003; Stoter and Oosterom, 2006). In this approach, 2D parcels and 3D physical object registrations are combined in the same DBMS. The relationships between 3D parcels and 3D physical objects exist through the spatial definition of the objects (using object ids) and can be retrieved by spatial functions. In other words, the 3D property rights of 3D parcels can be indicated by intersecting a 3D physical object with the 2D parcels (Stoter and Salzmann, 2003). This approach seems a feasible solution because 2D data are available and sufficient, and the implementation of an extension to maintain 3D physical

objects seems possible (Stoter et al., 2004; Benhamu and Doytsher, 2003).

In case of a full 3D cadastre, the whole 3D space would be subdivided into 3D parcels. The 3D space (universe) is subdivided into volumes partitioning the 3D space without overlaps and gaps. Based on the concept of property rights in 3D space, the solution would support the spatial registration of rights in 3D space, which would be the final and most advanced solution. Right and restrictions are explicitly related to volumes as seen in the case that apartment units are real estate objects defined in 3D. The full 3D approach would renew the current cadastre registration in legal way of thinking and in the technical framework. From the legal point of view, the concepts of 3D rights should be introduced and the law (civil code) should be changed. From the practical point of view, this approach is only useful in densely built-up areas, so that many countries including the Netherlands don't adopt the full 3D cadastre solution in the short- to medium-term future (Stoter and Salzmann, 2003).

2.3 Conceptual 3D Cadastre Model in Korea

Because the hybrid solution is the most appropriate in terms of the cadastre needs and the technical possibilities (Stoter and Salzmann, 2003), this paper proposes a conceptual 3D cadastre model in Korea as seen in Fig. 2. Based on the methods of object-orientation, object-object relationships of the model are represented using an UML (Unified Modeling Language) object diagram (Zeiler, 1999). Fig. 2 shows the classes of the model. A 3DCadastre class is associated with an Administrative-Data class through an association relationship, which defines multiplicities at both ends in the diagram. An owner can own one or many parcels and a parcel can be owned by one or many owners. A 3DParcel and a 3DPhysicalObject classes are associated with a 3D-Cadastre class through a composition relationship that models the case where the 3DParcel and 3DPhysical-Object classes are part of a 3DCadastre class. The composition is a strong form of aggregation in which objects from the 3DCadastre class control the lifetime of objects from the 'part' classes. The 3DParcel class associates with a 3DRightParcel and 3DRightObject classes through a composition relationship. The 3DRightParcel represents
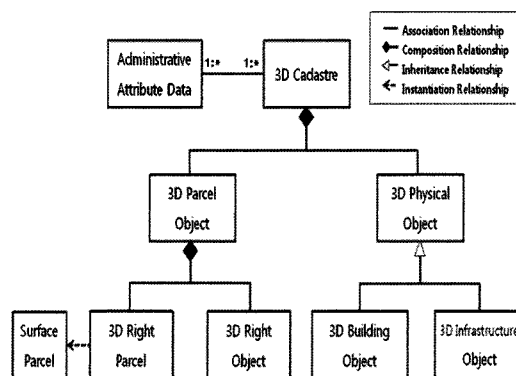

Fig. 2. Conceptual Cadastre Model in Korea

an envelop bounding the ownership space, whose proprietary right in the 3D parcel is unrestricted and it extends from the center of the earth into the sky. Since the geometric boundary of the 3DRightParcel would be indeterminate, the SurfaceObject is used to represent the property right of 3D parcel. The 3DRightObject represents a 3D right that is established on a 2D parcel with concerning a 3D property situation and the boundary of spatial objects is defined by upper and lower limits of 3D parcel right. A 3DPhysicalObject class associates with a 3DBuildingObject and 3DInfrastructureObject classes through an inheritance relationship. The specialized classes share properties and methods with the supperclass, 3D-PhysicalObject, and have additional properties and methods. A 3DBuildingObject represents a compound physical object containing a set of apartment units (property units), which are associated with a registered right for each apartment, and a 3DInfrastructureObject represents such a tunnel, which is subdivided into parts according to the 2D (or surface) parcels.

3. 3D Spatial Data Models for 3D Cadastre

3D geo-information has always been challenged due to a variety of data models, resolution and details, and ways of geometric and topological representations. To select an appropriate data structure designed for the characteristics of the applications is not easy because of objects of interest, resolution, required spatial analysis, etc. (Zlatanova et al., 2004). Different data models might be suitable for the execution of specific tasks but not
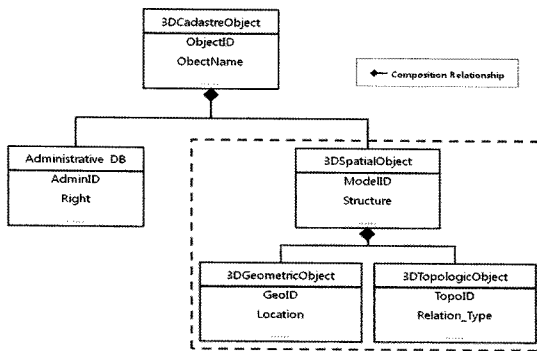
Fig. 3. 3D Spatial Data Model for 3D Cadastre

others. Therefore, Oosterom et al. (2002) proposed multiple topological models maintained in one database by describing the objects, rules and constraints of each model in a metadata table. The reasons are that metric and position operations such as area or volume computations are realised on the geometric model, while spatial relationship operations such as 'meet' and 'overlap' are performed on the topological model.

In order to represent spatial objects in the 3D cadastre system, which including 3D physical objects, 3D right-objects (property right for apartment unit), this paper proposes a 3D spatial data model, a hybrid data model consisting of two models: a 3D geometric model, and a 3D topological model as seen in Fig. 3. The 3D geometric model is used for 3D geometric representation of 3D cadastre objects consisting of a number of 3D polygonal faces defining an enclosed boundary, while the 3D topological model is proposed to represent the topological relationships among the 3D cadastre objects.

3.1 Geometrical Data Models

Most of the work on developing geometry models has been leaded by the Open Geospatial Consortium Inc. (OGC), which is the membership of organizations developing GIS data standards for describing the real world phenomena. Although the OGC has worked initially on traditional 2D GIS issues, the OGC's current abstract model incorporates many of the 3D geometry types as required in CAD and Architecture Engineering Construction (AEC) industry (Lee and Zlatanove, forthcoming). ISO has also independently developed ISO/TC 211 19107 Spatial Schema (Hering, 2001), which is

the same as the OGC Topic 1, Feature Geometry (of the Abstract Specifications). The Spatial Schema deals with two data models, which are geometry and topology. A geographic object in real world phenomena is represented by a geometric object and a topological object. The Geometrical model represents the quantitative description (coordinates and mathematical functions) on dimension, position, size, shape, and orientation of the spatial objects. Topology, in contracts, deals with the spatial relationships among the geographic features.

In the ISO/TC 211 19107 Spatial Schema, the geometry of geographic features is described by the basic class GM_Object, which has properties on a geometry and a coordinate reference system. The geometry object can be a GM_Primitive, GM_Complex and GM_Aggregare (Lee and Zlatanova forthcoming). The GM_primitive is an abstract class derived from Geometric primitive. The Spatial Schema provide a concept for representation of 3D objects as well as specific primitives such as freeform shapes (Bézier, B-spline, Cubic-spline, and Polynomial spline), spheres, ellipse, cone and triangulated surfaces. The Abstract specifications provide only conceptual guidance in preparing Implementation specifications (Reed 2006). The way implemented at different platforms (based on CORBA, OLE/COM and SQL) is described in three different Simple Feature Implementation Specifications. Although the set of primitives in the Implementation specifications is rather limited to supporting only 2D primitives, i.e. point, line and polygon (Fig. 4), a real simple 3D object (tetrahedron, polyhedron, sphere, cone, etc.) is still to be included (Lee and Zlatanova, forthcoming).

According to the Spatial Schema, 3D cadastre objects are represented by primitive or composed types, which are points and point clusters, lines, compound lines, n-point polygons, compound polygons, and circles. 3D objects can be represented using either the simple geometry type 'polygon' (with 3D coordiantes) or the geometry type 'collection' (or 'multipolygon') (Zlatanova et al., 2004). Using the first approach, one or two more columns have to be introduced in the relational table, to be able to specify that a polygon belongs to a particular 3D cadastre objects. One 3D cadastre object is represented by several rows in the geometry table. In the second case, a 3D cadastre object is described in
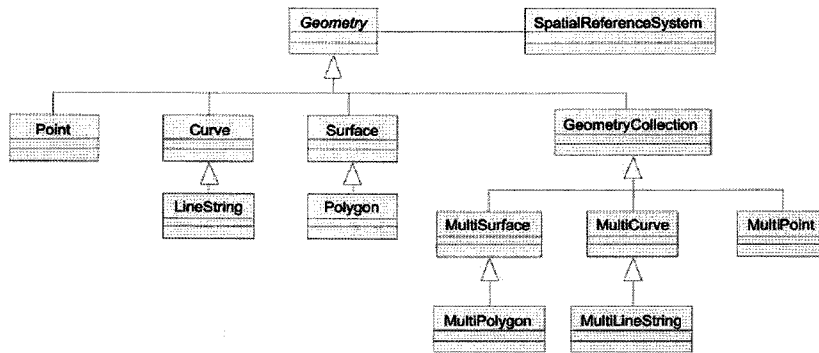
Fig. 4. Simple feature Specifications for SQL (SFS) (from Lee and Zlatanova, forthcoming)

one row, since all the information about the polygon is decoded in the Oracle Spatial geometry type. The redundancy of coordinates cannot be avoided, while the number of records is reduced. Each triple coordinates is repeated at least three times in the list of coordinates (Lee and Zlatanova, forthcoming).

The proposed 3D geometric model in this paper is based on the first approach. The basic components of the model are points, polygons, and solids. The 3D cadastre objects are formulated by a number of polygonal faces defining an enclosed boundary. The primal classes of the 3D geometric model are PointZ, PolygonZ, and 3DGeometric. The PointZ consists of an identifier and position data in 3D (x,y,z-coordinates), and the PolygonZ consists of a set of Points *pt* and other attributes including an identifier, and total number of points. The PolygonZ is considered as a single ring without a self -intersecting loop. The 3DGeometric consists of an identifier and a list of all polygons constructing a 3D solid object representing a cadastre object (such as an apartment unit) in the 3D Cadastre registration system (see Fig. 5).

3.2 Topological Data Models

The topological model is closely related to the representation of spatial relationships among cadastre objects. Over the last fifteen years, topological models for n-dimensional objects have been developed by a number of researchers (Lee, 2007). However, the 3D topological models have not been implemented in the commercial 3D GIS systems (Zlatanova et al., 2002), except in CAD systems such as SHAPES by XOX Inc. or Geomagic-

Studio by Raindrop Geomagic Inc. OGC Abstract Specifications discuss 3D topological primitives, but Implementation Specifications for a topological model are not available yet (Lee and Zlatanova, forthcoming). In order to represent topological relationships, four approaches have been implemented: matrix-based approach, adjacency graph-based approach, topological primitives approach and geometric computation approach (Ellul and Haklay, 2006).

Most of 3D topological data models are based on the concepts used in 2D vector GISs, which is a topological primitive approach. A 3D object is defined by its topological primitives, which are point, edge, face and volume. One of data structures using this approach is boundary representations (B-rep) implemented in CAD systems. With extensions of representations of planar configurations in 2D B-reps, each volume in 3D B-reps is represented by its bounding surface (Worboys 1995). Examples of the developed data models based upon the topological primitives approach are found in 3D formal data structure (FDS) developed by Molenaar (1990), Simplified Spatial Model (SSS) developed by Zlatanova (2000) designed to serve web-oriented applications with many visualization queries by simplifying 3D FDS, and Urban Data Model (UDM) developed by Coors (2003), representing the geometry of a body or a surface by planar convex faces. In these models, topological relations are represented by their local neighbourhood relationships defined by their boundary and co-boundary cells (Pigot, 1995).

However, the topological primitives approach models are more complicated in the representations of 3D spatial objects (Zlanatova et al., 2004). As the first reason, the

models are not suitable for performing many spatial queries based on pure geometric properties, e.g. a query 'give all the features within given space', because the 3D coordinates are stored in the node table, which requires first traversal of other three tables (edge, face and body) to be able to obtain the coordinates. Second, the topological models are mostly organized (with exception of Radius Topology and Oracle Spatial 10g) in user-defined objects and tables and cannot be integrated with the commercially developed DBMS to organize data effectively. Finally, DBMS maintain spatial indexing, which is not applicable for topological models. Since the tables contain only references to id's of the objects, only a general indexing is possible. The topological primitives approach models seem not to be applicable, but the models have a number of advantages for avoiding redundant storage, for maintaining data consistency easily, and for performing specific topological operations (e.g. finding neighbors) (Penninga, 2004). However, the 3D topological data models require complex geometric computations to define local neighborhoods of primitives in well-formed 3D objects.

In order to overcome the problems in topological primitives approach, adjacency graph-based approach models have been developed (Lee, 2001). Instead of representing the topological relationships based on topological primitives (node, arc, face and body), the graph models present the topological relationships among 3D cadastre objects by drawing a dual graph interpreting the 'meet' relation between 3D and 3D cadastre objects (Egenhofer and Herring, 1990). Based on this approach, 3D Geometric Network Data Model (3D GNM) was developed to represent more than just adjacency and connectivity relationships $(G = (V(G), E(G)$ and $H = (V(H), E(H)$, respectively), among 3D spatial objects in built environ-

ments (Lee, 2001, Lee and Kwan, 2005). In the 3D GNM model, the graph H is a subgraph of the graph G because $V(H) \subseteq V(G)$ and $E(H) \subseteq E(G)$. The 3D GNM is defined as a set of nodes (3D entities in primal space) with a set of edges (spatial relationships between 3D entities in primal space) that represent the topological relationships among entities in built environments. It is derived through 3D Poincaré Duality using a graph-theoretic framework and a Straight-Medial Axis Transformation (S-MAT) modelling (Lee, 2001 and 2004). The 3D Poincaré Duality is utilized to abstract the topological relations among a set of 3D objects and to transform '3D to 2D relations' in primal space to '0D to 1D relations' in dual space. In order to represent the geometric properties (such as distances between nodes in the graph) of the dual graph, the S-MAT is utilized to identify linear features from a simple polygon (a hallway in this case).

Fig. 5 shows a 3DBuildgingObject, such as an apartment in geometrical and topological representations. The graph $G = (V(G), E(G))$ is the topological model of an apartment to represent adjacency relationships among the apartment units. The graph G is the combination of the dash and solid thick lines presented in the Fig. 5. The connectivity relationships among 3D apartment units are defined as a subset of the adjacency relationships (Lee and Kwan, 2005), as seen in Fig. 5. From the property, it is known that the graph $G = (V(G), E(G))$, which represents adjacency relationships, is a supergraph of the graph $H = (V(H), E(H))$, which represents connectivity relationships among 3D apartment units, because $V(H) \subseteq V(G)$ and $E(H) \subseteq E(G)$. In this case, because $V(G) = V(H)$, graph H is called a spanning subgraph of graph G. The graph H representing the connectivity relationships can be generated from the graph G by removing edges, which are representing only adjacency relationships among
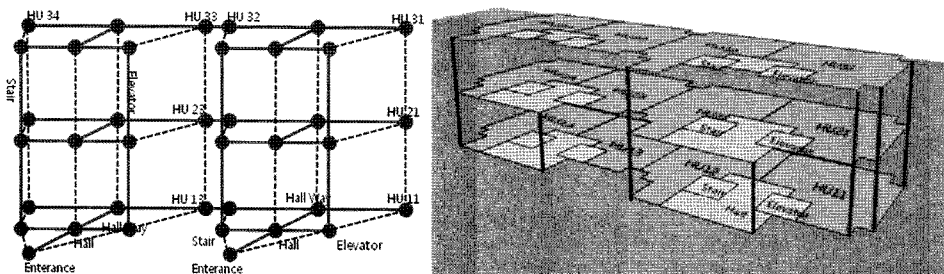

Fig. 5. Spatial Data Model for 3D Cadastre

the 3D apartment units (Lee and Kwan, 2005). The graph *H* is presented by the solid thick lines in Fig. 5.

The graph models are implemented by the commercial DBMS as well. For example, Oracle Spatial 10g represents the 3D graph organized in two to four relational tables NODE, LINK, PathNODE and PathLINK. In addition, the real geometrical properties are assigned to assign to each node or link. For example if an apartment unit is associated as a node, the 3D polyhedron (or box) can be also stored together with the node. Such a structure is quite powerful for identifying topological relationships among the 3D objects. We can use high-level languages PL/SQL or Java API to generate and analyze the graph models within the commercial DBMS.

3.3 An Example of 3D Applications for a 3D Cadastre

Not only a 3D approach to cadastre registration improve the main tasks of cadastre such as representations of 3D property units and 3D property rights in the cadastre geographic data set, but also the 3D cadastre can be used outside the cadastre domain including local land-use plans, indoor Location-based Services (LBS), 3D visualizations, 3D spatial modeling for environmental applications, geological applications, etc (Stoter and Oosterom, 2006). One of fundamental analyses in these applications is to identify the topological relationships to describe how the individual spatial objects interact. The topological structure can be used efficiently in a query to find spatial neighbors - Which other 3D spatial objects are located on top or under a certain 3D object? This neighbor information can be used in cadastre applications as well as environmentally oriented analyses including noise, air pollution, and emergency situations in urban environments.

The implementation of the 3D topological analysis is described based upon the work of Lee & Kwan (2005) in this section. This example presents spatial queries based on topological relationships among the 3D cadastre objects, $G = (V(G), E(G))$, to access the adjacency information among apartment units within a apartment, a 3DBuildingObject. The node id is associated with the apartment unit number. After selecting a node, the user runs the 'Find Adjacency Objects' function to send a request to the system. The figure shows the result of a spatial query to retrieve adjacent apartment units. Based on the sub-graph (thick lines) representing the query result, we can identify that the HU23 apartment unit is adjacent to five spatial neighbour apartment units, which are HU13, HU22, HU24, HU33 and an elevator hall. These units are sharing a vertical or horizontal wall with the HU23 apartment unit. Based on the topological information, the same result is displayed in the 3D Viewer using ArcScene of ESRI Inc. in Fig. 6. The solid object of HU23 is colored in dark, and the solid objects of adjacent apartment units to Hu23 are colored in light.
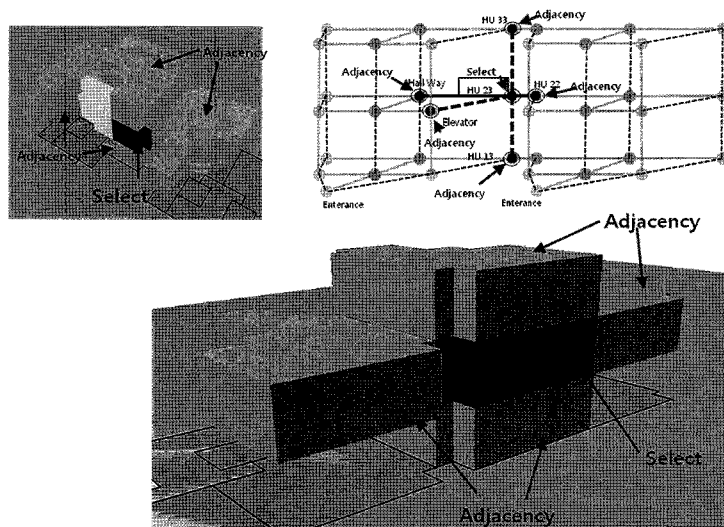

Fig. 6. Adjacency Relationships from HU23

4. Conclusion

Because of most current cadastral systems maintain 2D geometric descriptions of parcels linked to administrative records, the system may not reflect current tendency to use space above and under the surface. The land has been used in multi-levels, e.g. constructions of multi-used complex buildings, subways and infrastructure above/under the ground. This cadastre situation of multilevel use of lands cannot be defined as cadastre objects (2D parcel-based) in the cadastre systems. This trend has requested a new system in which right to land is clearly and indisputably recorded because a right of ownership on a parcel relates to a space in 3D, not any more relates to 2D surface area. Therefore, this article proposed a 3D spatial data model to represent geometrical and topological data of 3D (property) situation on multilevel uses of lands in 3D cadastre systems, and a conceptual 3D cadastral model in Korea to design a conceptual schema for a 3D cadastre.

However, this paper has some considerations, which request further researches in the future. The proposed 3D cadastral model may not reflect the current cadastral system in Korea because the current system is a dual system to maintain land ownerships and building (or physical objects) ownerships separately. In other words, the paper proposed the model based on a geo-technical aspect, not based on legal, administrative and institutional aspects. The proposed cadastral model needs to be improved by considering the proprieties of the current dual cadastral system utilized in Korea.

As another consideration, in order to register the cadastre objects including the 3D parcels, 3D physical objects, 3D right-objects in the 3D cadastre system, all real estate objects must have a survey document. The 3D information in these survey documents can be integrated in the cadastre geographic data set, which are a mix of 2.5D objects (surface parcels) and 3D objects. Full 3D data collection is expensive, which requires a new data acquisition method (Lemmen and Oosterom, 2003). Because it is not reasonable to create full 3D data for only cadastral purpose, we may have to develop multi-purpose uses of the cadastre system: for example, city management and city planning requires 3D represen-

tation of urban areas. In addition, standardizations of 3D data are another consideration of spatial data infrastructures.

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