The Journal of GIS Association of Korea, Vol. 17, No. 4, pp. 469-481, December 2009

3D Cadastre Data Model in Korea ; based on case studies in Seoul

Soyoung Park* · Jiyeong Lee** · Hyo-Sang Li***

ABSTRACT

Due to the increasing demands on the efficient use of land and the fast growth of construction technologies, human living space is expanded from on the surface to above and under the surface. By recognizing that the current cadastre system based on 2D was not appropriate to reflect the trend, the researchers are interested in a 3D cadastre. This paper proposed the 3D cadastre data model that is appropriate to protect ownership effectively in Korea. The 3D cadastre data model consists of a 3D cadastre feature model and a 3D cadastre geometry model, and the data are produced by a 3D cadastre data structure. A 3D cadastre feature model is based on 3D rights and features derived from case studies. A 3D cadastre geometry model based on ISO19107 Spatial Schema is modified to be good for 3D cadastre in Korea. A 3D cadastre data structure consists of point, line, polygon and solid primitives. This study finally purposes 1) serving and managing land information effectively, 2) creating rights and displaying ranges about infrastructures above and under surface, 3) serving ubiquitous-based geoinformation, 4) adapting ubiquitous-based GIS to urban development, and 5) regulating relationships between rights of land and registration and management systems.

Keywords : 3D Data Model, 3D Cadastre, 3D Data Structure

요 약

늘어나는 인구로 인한 토지의 효율적 이용요구 증가, 빠르게 성장하는 건축, 토목기술의 발달로 인간의 생활 공간은 지표에서 지상, 지하로 확대되었다. 기존의 2차원 지적 시스템으로는 이러한 추세를 효과적으로 반영하지 못함을 인식하여, 3차원 지적에 대한 관심이 증가하고 있다. 이 연구에서는 소유권의 법적 안전 보장이라는 지적의 주요한 목적을 위해 한국의 현황에 적합한 3차원 지적 데이터 모델을 제시한다. 제시하는 3차원 지적 데이터 모델은 3차원 지적 객체 모델과 3차원 지적 기하학적 모델로 구성되며, 데이터 구축 시 고려될 데이터 구조를 제시하였다. 3차원 지적 객체 모델은 분석된 3차원 권리와 사례 연구로부터 도출된 객체들을 기반으로 설계하였다. 3차원 지적 기하학적 모델은 국제 표준인 ISO19107 공간 스키마를 기반으로 한국의 3차원 지적에 맞게 수정되었다. 3차원 지적 데이터 구조는 점, 선, 면, 입체 요소를 기본 요소로 한다. 본 연구는 서울시의 "유비쿼터스 입체지적 기반조성" 사업의 일부분으로 수행되었으며 전체 연구의 최종 목표는 1) 토지정보의 효율적인 제공 및 관리, 2) 지상 및 지하 공간시설물에 대한 권리 설정 및 범위 표시, 3) 유비쿼터

* Master Student, 3D GIS Lab., Department of Geoinformatics, University of Seoul, Korea (soyoung331@gmail.com)
** Corresponding Author, Professor, Department of Geoinformatics, University of Seoul, Korea (jlee@uos.ac.kr)
*** P.E, Land Management Division, Urban Planning Bureau Government, Metropolitan, Seoul, Korea (lhs72@seoul.go.kr)

스 기반의 지적정보 서비스, 4) 도시 개발 사업 등에 대한 유비쿼터스 지적 기반의 구축, 5) 토지공간의 권리 관계 규정과 이에 따른 등록 및 관리 방안 마련이다.

주요어 : 공간 데이터 모델, 3차원 지적, 3차원 데이터 구조

1. Introduction

Due to the increasing demands on the efficient use of land from rapidly increase in population density and the fast growth of construction technologies, the land has been expanded in multi-levels which are above (e. g. multi-used complex buildings, highway, etc.) and under (e. g. subway, underground shopping mall, etc.) the surface. Because the living space changes from planar to three-dimensional, the existing cadastre system may have been restrictive to reflect the current tendency. For example, the current cadastre system based on 2D cannot register rights for installations in the air and in the basement. This system represents uncertain information for the right relationship. The one of important reasons that the cadastre reflects the current trend is that cadastral systems deal with geometric descriptions of land parcels linked to administrative records, such as ownerships (Lee and koh, 2007). If land registers are not managed effectively, it gives a large damage to the owner. Many countries such as the Netherlands, Israel, Greece, Norway and Sweden already have recognized this problem, and fulfilled the studies on the 3D cadastre actively as a way to solve these problems. As a solution, a 3D Cadastre system can represent rights in three-dimensional space. It will be possible for effective management, to represent right relationships definitely in real world. More studies are needed to protect the private right by reflecting trend of real world and revealing the range and limitations of the real right on the underground and above-ground space.

By rapid growth of economy from 1970s in Korea, land use (especially in major urban centre) has been becoming three-dimensional and intensive. Korean Government recognizes that the current Korea cadastre system which can register objects and information only about 2D is not appropriate to reflect this trend, and pays attentions increasingly on 3D cadastre. The city of Seoul, the capital of South Korea conducted 'Ubiquitous 3D Cadastre Project'. The contents achieved in this project are: 1) serving and managing land information effectively, 2) creating rights and displaying ranges about infrastructures above and under surface, 3) serving ubiquitous-based geoinformation, 4) adapting ubiquitous-based GIS to urban development, and 5) regulating relationships between rights of land and registration and management systems. This paper is written as a part of the project to make the project success. The purpose of paper is to propose a 3D cadastre data model to deal with 3D property in Korea.

2. Literature Reviews

2.1. Current Researches in abroad

Depending on the trend changing from two dimensions to three dimensions, many countries already have researched to deal with multi-levels property. Netherlands developed a prototype of a Land Information System which handles 3D spatial information. In this research, a proposed CCDM is Core Cadastral Domain Model involving both the legal/administrative object classes like persons and rights and the geographic description of real estate objects. The core of the CCDM as depicted in Fig.1 is the central part of the model. In the model there is no direct relationship between Person (sometimes called 'subject') and RegisterObject (e. g. parcels), but only via RRR (Right, Restrictions, Responsibilities). A Person and a ResigterObject are involved in any number of RRRs (indicated in the UML diagram with the multiplicity of '*' at the RRR-ends of the association) and an RRR involves exactly one Person and RegisterObject (indicated in the UML diagram by omitting the multiplicity, which means '1') (Oosterom et al., 2006).

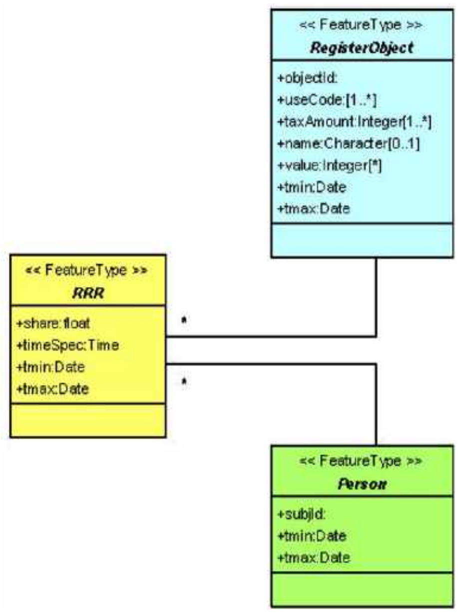


Figure 1. Core of the CCDM: Person, RRR (Right, Restriction, Responsibility) and RegisterObject (Oosterom et al., 2006)

Other 3D Cadastre data model is 'multi-layer GIS model' in Israel. This model represents the information of spatial objects to three layers (on, above and under surfaces). The information of existing 2D system is represented to 'on surface' layer. The objects installed in the air and in the basement which cannot be represented in existing system are represented to 'above surface' layer and 'under surface' layer. The most advantage of this model is to preserve current surface layer data because this model can reflect most existing data models. It means this model can make use of existing data which were built. In addition, it can use the tools of existing 2D GIS system. However, if more than 2 objects are located at the same position, the system cannot represent the information of the other objects except one. To be exact, this doesn't solve the problem of the 2D system. In addition, the cadastre system that was built using this data model may have empty layers in many areas. (Benhamu and Doytcher, 2003)

Besides the CCDM in Netherlands and the multi-layer GIS model in Israel, there are some of data model about 3D cadastre. The examples of 3D cadastre data model abroad are 'DM.01' in Swiss, 'AAA' in Germany and so on. The Norway, Greece, Sweden, Queensland in Australia and British Colombia in Canada also tried to manage 3D cadastre property effectively and proposed 3D cadastre systems.

2.2. Definition of 3D Cadastre from current researches in Korea

A 3D cadastre is a cadastre which registers and gives insight into rights and restrictions not (only) on parcels but on 3D property units (Stoter,2004). Components of 2D cadastre model (object, subject and right) are not suitable for 3D cadastre model. The components of 3D cadastre models include 3D parcels, 3D right-objects, and 3D physical objects, which are linked to administrative data including ownerships (Lee and Koh, 2007). Compared with the objects (parcels) in the current model, the 3D parcels include 3D space as well as 2D parcels. The 3D right-objects are associated with rights on parcels and contain a reference to the physical objects, which are associated with the parcel.

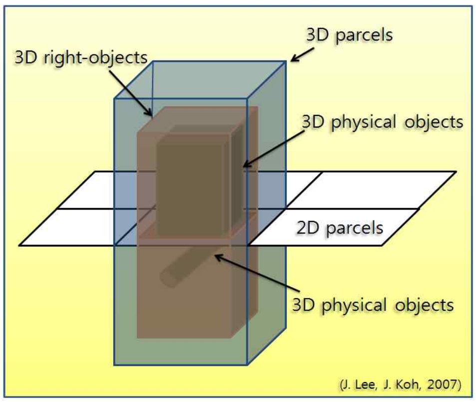


Figure 2. The components of 3D cadastre

The most important component of three components in 3D cadastre feature model is 3D right-objects. Because the main purpose of cadastre is to protect estate security. For this purpose, it should identify and represent 3D parcels and 3D physical objects as cadastre objects considered by the 3D right. The 3D right consists of two categories: 1) have objects (that is, right of ownership, apartment right, and joint ownership) as depicted in Table 1, 2) have not objects (that is, limited ownership rights) as depicted in Table 2. The limited ownership rights are real right to use other's land or building for a certain purpose. These rights are not property of objects but the usage of objects and contain the right of superficies, the right of long lease, and the right of easement. In 3D cadastre, we can establish restrictive right of superficies to use the land more effectively by registering restrictive boundaries (Stoter, 2004).

Table 1. 3D right

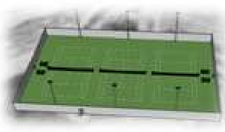
Right of Ownership
The right of ownership is the state or fact of exclusive rights and control over property, which may be an object, land/real estate or intellectual property. The right of ownership comprises exclusive use of the right of space above the parcel, ownership of the earthlayers beneath it, and ownership of buildings and constructions forming a permanent part of the land (directly or by means of other constructions)
Apartment right
The apartment right is a share in the ownership of the property involved in the division which also comprises the right to exclusive use certain parts of the building which, as indicated by their lay-out, are intended to be used as separate units. The share can also include the right to exclusive use of certain parts of the land pertaining to the building 
Joint ownership
The joint ownership is a right to land and/or a construction that can be registered similar to common area as in condominiums. Joint ownership comprises the obligation of each joint owner to give the other joint owners access to the thing held in joint ownership.  

Table 2. Limited ownership rights

Right of Superficies
The right of superficies is a real right to own or to acquire buildings, works or vegetation in, on or above an immovable thing owned by another
Right of Long Lease
The right of long lease gives the long leaseholder the permission to hold and use the parcel of the bare owner, as if he were the owner.
Right of Easement
The right of easement is a charge imposed upon a parcel, in favour of another parcel, the dominant parcel.

(Stoter, 2004)

3. Current practice analysis for the presentation of the 3D Cadastre model

To illustrate 3D situations in the Korea and to reflect the current practice as well as 3D right as depicted in

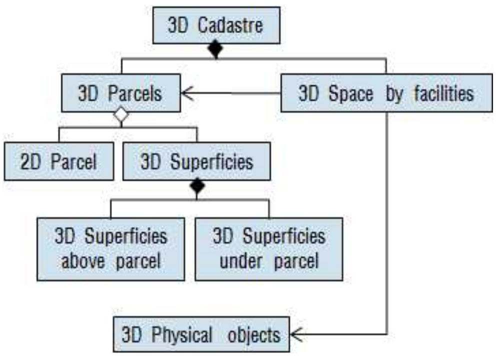


Figure 3. The core of 3D cadastre feature model

Table 1 and Table 2 to the 3D cadastre feature model, five cases in the Korea were selected and analyzed.

In the selected cases, the objects which become a feature in 3D cadastre feature model were extracted by considering the space about parcel, the space generated by rights or facilities, and the space occupied by facilities, as seen in Fig.3. Fig.3 shows the core of 3D cadastre feature model. Each feature model of the cases is based on this model.

One of the case studies is tunnel as depicted in Fig.4. This case is chosen because of the example of restrictive right of superficies for a tunnel. The tunnel is located under parcels on which public constructions (e. g. roads, a nursery, the office of a local government (or a district office), etc.) or private buildings (e. g. villas, houses, commercial building and lots) are built. It is a good example of multi-levels use. In case of the tunnel across several parcels, it is needed to register the restrictive right of superficies to the tunnel-located space. For constructions above parcels, to register the rights of ownership or the rights of superficies by owners is needed. Also, the compensation space for damages related to tunnel should be considered.

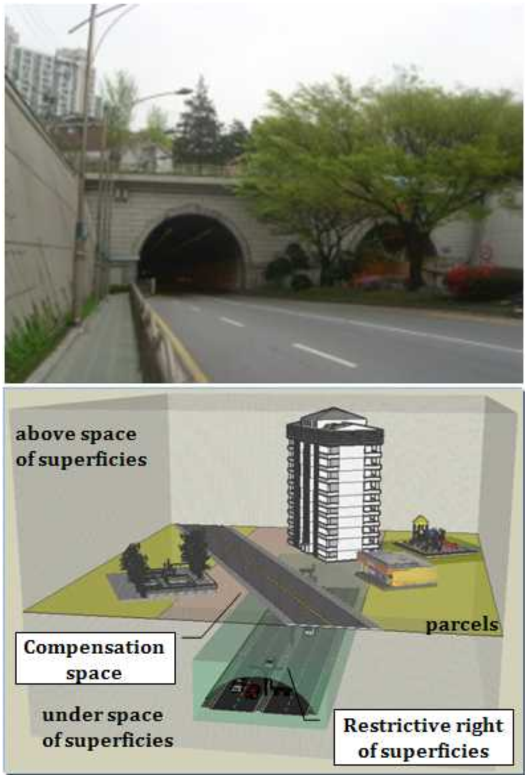


Figure 4. Tunnel and parcels above the tunnel

A feature model for the tunnel case is depicted in Fig.5. The model is designed by considering the chosen reasons and demanded objects. To reflect the space that defines the restrictive right of superficies by a tunnel, '3D Space by facilities' class has a '3D Limited superficies' subclass. And to reflect the space to compensate for the damage that can occur by a tunnel, the 3D Space by facilities class has a 'Compensation space' subclass. '3D Physical objects' class has features considered in the tunnel case as subclasses.

Other case is subway and subway station, and underground shopping center as depicted in Fig.6. In Korea, the most of underground shopping centers are located in passage that linked the subway station and the entrance. So this case is chosen because of the needs to protect a right for stores in an underground shopping center. For the subway, the subway lines space and the subway subsidiary space that contains all

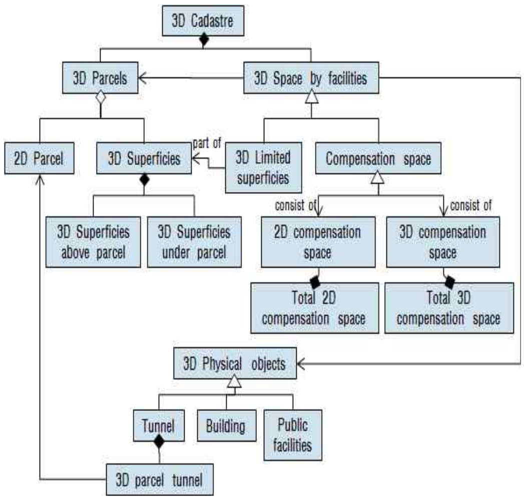


Figure 5. Feature model of 'Tunnel and parcels above the tunnel' case

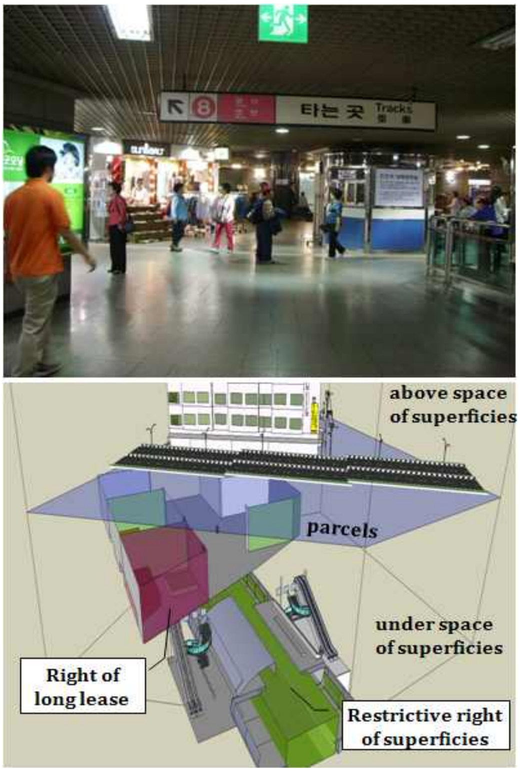


Figure 6. Subway and Subway station, and underground shopping center

the space except for subway lines are applied to the different 3D rights each other. The subway lines across several parcels should be applied to the limited right of superficies and the subsidiary space should be applied to the right of superficies under the parcel. For the underground shopping center of subsidiary space, the whole space should be applied to the right of superficies. However, each store in the underground shopping center is owned by the persons who are different from the store's users. In the most of case, the users rent the shop from the owner. So each store in the underground shopping center should be applied to the right of long leases.

A feature model for the subway case is seen in Fig.7. The model of this case is designed by putting an important point in an underground shopping center. To reflect the space that defines the right for stores in an

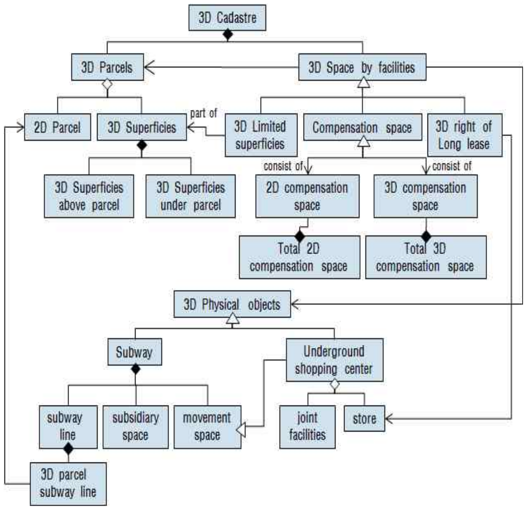


Figure 7. Feature model of 'Subway and Subway station, and underground shopping center' case

underground shopping center, '3D Space by facilities' class has a '3D right of Long lease' subclass. '3D Physical objects class' has 'Subway' class and 'Underground shopping center' class considered in the subway case as subclasses.

Other case is transmission lines and towers. This case is chosen to deal with a kind of urban infrastructures. Fig.8 shows the typical situation of the transmission facility in Korea. Mostly in the case of transmission facility, the Korea Electric Power Corporation (KEPCO) owns only the right of ownership for the part of parcels at which a transmission tower is located. Transmission lines passes on parcels owned by a nation and the person. The restrictive right of superficies for transmission lines passing above other owner-owned parcels should be registrated. And in this case, as for the owner of the parcels, the land use can have a limitation by the transmission lines. So, the compensation space for the damage that can occur by transmission towers and lines should be considered. To define the compensation space by transmission lines, it is necessary to consider the zone that represents the areas of parcels under the transmission lines.

A feature model for the transmission case is depicted

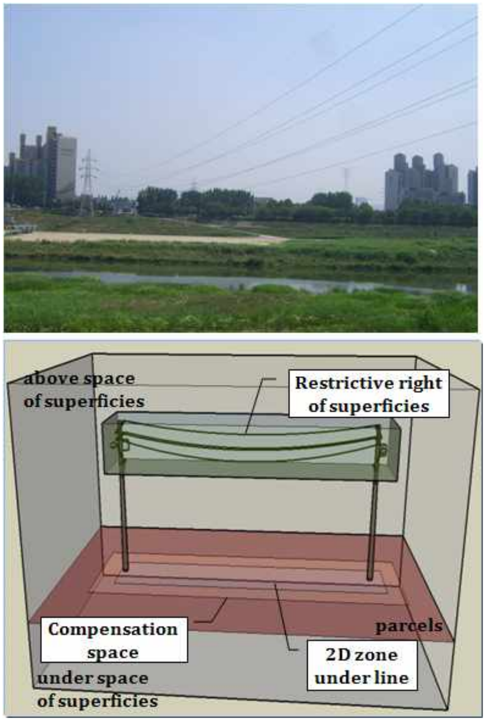


Figure 8. Transmission lines and towers

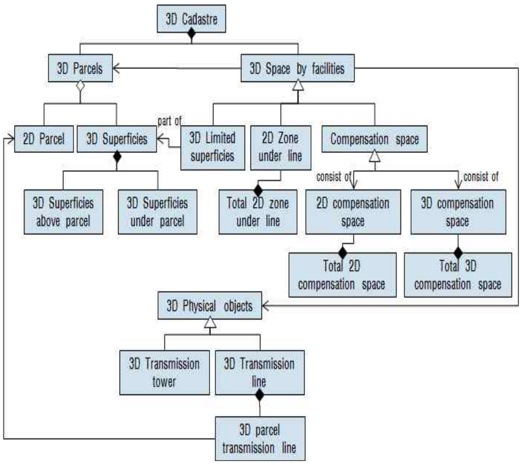


Figure 9. Feature model of 'Transmission lines and towers' case

in Fig.9. The model of this case is designed by considering mainly characteristics for the infrastructures. To reflect the space that defines a zone under transmission lines and compensation space, '3D Space by facilities' class has a '2D Zone under line' and a 'Compensation space' subclasses.

The others of case studies are: 1) skybridge, 2) apartments and commercial buildings. The case 'skybridge' is chosen for the multi-level use above the ground, and the case 'apartments and commercial buildings' is chosen as a good example of the apartments right and the joint ownership. UML diagrams for each case are designed as illustrated in Fig.10 and Fig.11. The diagrams are designed mainly for a chosen reason. In not only a chosen case but also the reality, there are complex relationships of ownership as well as a variety of spatial forms.

4. Proposed 3D Cadastre Data Model

4.1 3D Cadastre Feature Model

Feature model is a date model that defines their properties and relationships between features existed in the world. 3D Cadastre Feature Model is a model that aggregates each feature model designed from each case. Each feature model of cases are based on 3D right of 3D cadastre components and objects derived from case studies. It shows the Unified Modeling Language (UML) class diagram to facilitate the developers' understanding. 3D cadastre feature model consists of '3D Parcels' class that includes features associated with parcels and '3D Space by facilities' class that contains features that represent ownerships and other space created by structures in the real world. '3D Physical objects' class are not directly included in 3D cadastre class, but are needed for association with '3D Space by facilities' class. The highlighted classes as depicted in Fig.12 are features that have the observed data and should be established.

The '3D Parcels' class is composed of '2D Parcels' class that describes parcels in the current planar approach and '3D Superficies' class that represents a vertical ranges of parcels and is divided into the above and

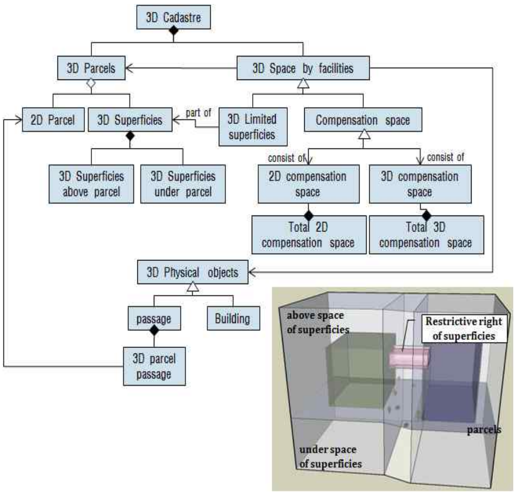


Figure 10. Feature model of 'skybridge' case

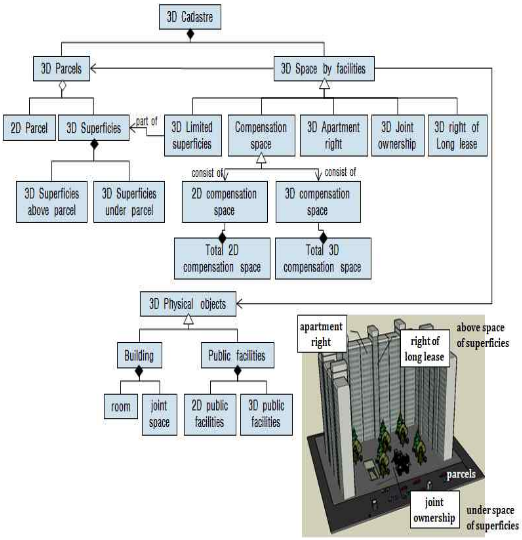


Figure 11. Feature model of 'apartments and commercial buildings' case

under. The 3D Parcels class is a common part that applied to all cases.

The '3D Space by facilities' class associates with the '3D Parcels' class and '3D Physical objects' because this features are located in three-dimension parcels and directly effected on physical objects whether it is created or not. In other words, the features included in the class are different depending on the existence of physical objects. Based on 3D right and case studies, the 3D Space by facilities involves '3D Limited superficies', '3D Apartment right', '3D Joint ownership', '3D Right of long lease', 'Compensation space', and '2D zone under line' features. The '3D Limited superficies' is a part of '3D Superficies' so the classes form a 'part of' relationship. The 'Compensation space' class consists of a 2D compensation space feature and 3D compensation space feature. Because of the needs to represent total compensation space as well as individual compensation space by parcels, the integrated compensation space feature should be needed for each compensation space classes. That is, 'Total 2D compensation space' feature is composed of each of '2D compensation space' features and 'Total 3D compensation space' feature is composed of each of '3D compensation space' features.

The '3D Physical objects' class is an aggregated object that contains existing structures in the real world. It is needed only for reference to the '3D Space by facilities' class, not an object of '3D Cadastre'. Therefore, it is more efficient that not constructing the data, but using the existing data. The features in '3D Physical object' class can be changed dynamically according to the objects of real world to represent. In this paper, the '3D Physical object' class includes the features derived from case studies: '3D Tunnel', '3D Building', 'Public facilities', '3D Subway', and '3D Transmission' features. The '3D Tunnel' feature as one of features in 3D Physical objects is located across several parcels, so the feature needs to be separated based on parcels. So '3D parcel tunnel' feature that refers to a '2D Parcels' feature represents the separated tunnels by parcels. This rule is also applied to the '3D passage', '3D subway line', and '3D transmission line'. The '3D Subway' feature consists of '3D subway line' feature that subways traveled, '3D subsidiary space' feature such as the subway platform, and '3D movement space' feature such as passages. Because in Korea the underground shopping center is located in the subway path, the feature inherits from '3D movement space' feature.

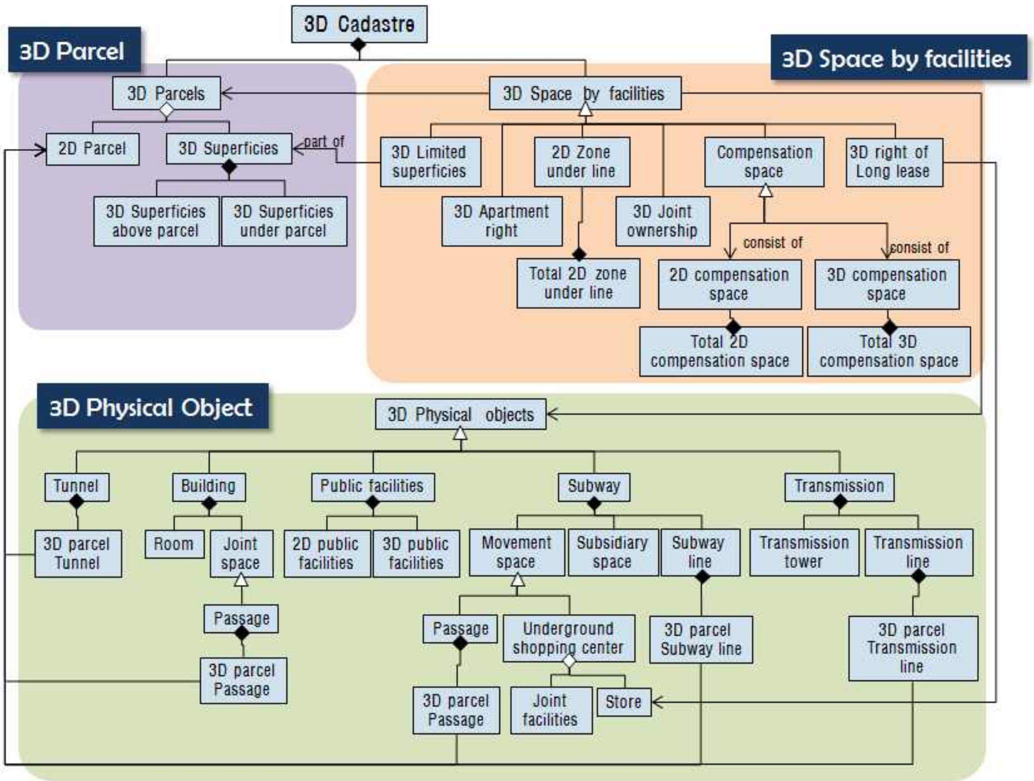


Figure 12. 3D Cadastre Feature Model

4.2. 3D Cadastre Geometry Data Model

The geometry model is a data model that defines geometric elements to represent cadastral features. The Geometrical model provides the means for the quantitative description (coordinates and mathematical functions) regarding dimension, position, size, shape, and orientation. The geometry is the aspect of geographical information that depends on the geodetic reference system (particularly relevant for 2D GIS) (Lee and Zlatanova, 2008). This relationship between data structured through it could be maintained consistency and be effective in terms of data management. Basic geometric elements defined by each geometric model are different each other, and the geometric range of an object which can be represented is determined by the defined geometric elements.

The 3D Cadastre geometry data model utilizes the geometry model described in 'three-dimension spatial information development provision' developed by Korean National Geographic Information Institute (citation). This model is based on ISO19107 Spatial Schema. The ISO19107 Spatial Schema is a conceptual data model that treats the geometric and topological primitives to represent the features. The feature can be described by vector or raster representations. But the ISO 19107 Spatial Schema standard deals only with vector data (Lee and Zlatanova, 2008).

The primitives of the model as depicted in Fig.13 are Point, Line, Curve, Surface and Solid. The Point is the basic data type for a geometric object consisting of one and only one point. The Curve is the basis for 1-dimensional geometry. A curve is a continuous image of an open interval. The Surface is the basis for 2-dimensional

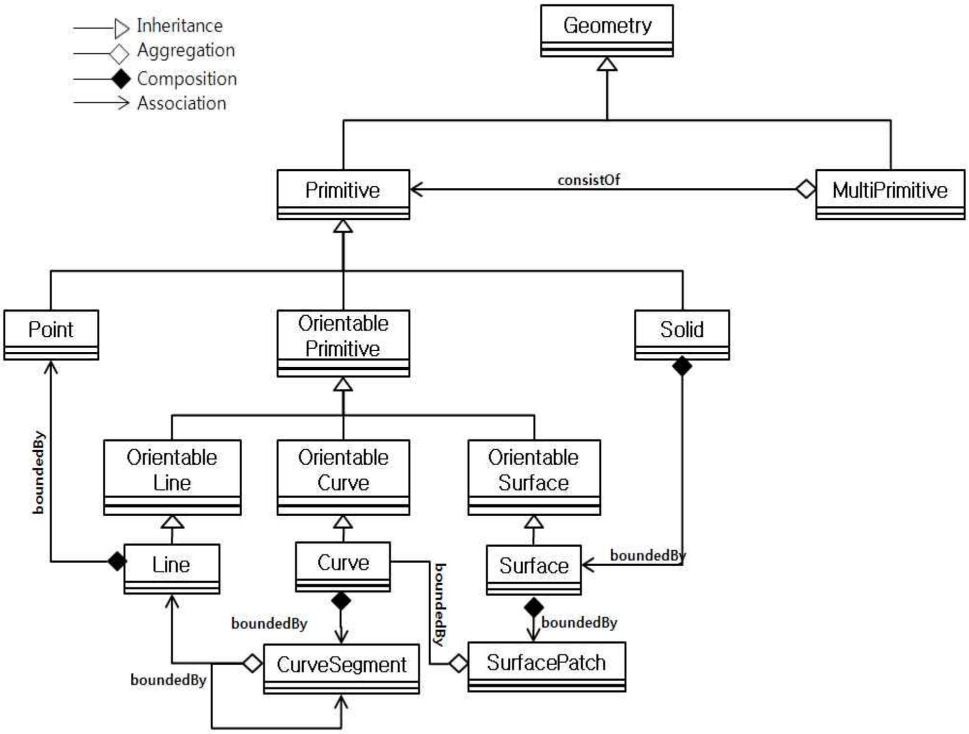


Figure 13. Geometry model prescribed in National Geographic Information Institute

geometry. The Solid is the basis for 3-dimensional geometry (ISO19107, 2003). The Line, Curve, and Surface primitive have direction. The MultiPrimitive class is a class that consists of the Primitive classes. The relationships among the primitives are that: 1) The Line primitive is composed of the Point primitives. 2) The Curve primitive is composed of one or more CurveSegments that each CurveSegment the is made up of the Line primitives. 3) The Surface primitive consists of the SurfacePatch elements that each SurfacePatch element is made up of the Curve primitives. 4) Solid consists of the Surface primitives.

There are the constraints of geometric primitives.

- The Point is defined by (x, y, z) coordinates.
- The Line is defined by start point and end point.
- The CurveSegment is defined by the straight lines or another curve segments continuously. Each straight line or another curve segments are connected to one another, with the end point of each line or segment except the last being the start point of the next line or segment in the list.
- The Curve is defined by one or more curve segments. Each curve segment within a curve is connected to one another, with the end point of each segment except the last being the start point of the next segment in the segment list.
- The SurfacePatch is defined by a set of closed boundary curves (such as a curve that begins and ends at the same point) or the underlying surface patches to which these surface patches adhere.
- The Surface is defined by a set of closed boundary curves or the surface patches to which these surface patches adhere.
- The Solid is defined by the closed boundary surfaces to which these surfaces adhere.
- GM_MultiPrimitive is defined by only a set of the GM_Primitive.

4.3. 3D Cadastre Data Structure

Data structure defines a form to save data generated through data model. The data have a different structure by a form to define. The data structure must be equal to maintain compatibility between generated data. Mutual analysis and compatible are impossible between the data saved in other data structure. Therefore, it is important that decides the data structure when the data are generated. This paper proposes 3D Cadastre data structure to build each geometric primitive. The data structure based on 'three-dimension spatial information development provision' prescribed by Korean National Geographic Information Institute is modified to be good for 3D cadastre.

Table 3. Geometry primitives data structure

```
Point{
    Double                      X, Y, Z
}
Line{
    Integer                     NumPoints
    Point[NumPoints]Points
}
Surface{
    Double[4]                   Box
    Integer                     NumPoints
    Point[NumPoints+1]          Points
}
Solid{
    Integer                     NumPoints
    Integer                     NumSurfaces
    Integer[NumSurface]         Surfaces
    Point[NumPoints]Points
}
```

Table 4. Aggregated geometry primitives data structure

```
MultiPoint{
    Integer                     NumPoints
    Point[NumPoints]Points
}
MultiLine{
    Integer                     NumLines
    Line[NumLines]  Lines
}
MultiSurface{
    Integer                     NumSurfaces
    Surface[NumSurfaces]        Surfaces
}
MultiSolid{
    Integer                     NumSolids
    Solid[NumSolids]Solids
}
```

As for the 3D Cadastre data structure, geometry primitives are structured with a base at a point. Point primitive is represented x, y, z coordinates and stored x, y, z sequentially. Line primitive is organized by the set of the coordinate values, and Points are stored by a matrix sequentially. Surface primitive is organized by the set of the coordinate values. The Surface is closed by storing the first coordinates once again to the end. In the Surface primitive, the Box matrix saves 4 vertexes of rectangle to state a minimum rectangle range that completely includes the surface. Solid primitive consists of a set of Surface primitives. A coordinates of surface are saved in Points matrix. Keys of surfaces that constitute solid are also saved in Surfaces matrix sequentially. There are MultiPoint, MultiLine, MultiSurface and MultiSolid as aggregated primitives. These aggregated primitives consist of a matrix of each primitive.

5. Implementation

This paper is written as part of the municipal project. 3D Cadastre prototype system as depicted in Fig.14 is developed as another part of the municipal project. The data model designed in this study was used for the system. Fig.14 shows the output that a system is performed. When user selects the parcel, facility or right space, the system displays the information on it such as size of area, position, and owner. Besides, this system can performs some queries, exploring, controlling layers and so on.

This system is going to be used for the municipal cadastre-related administration. Using the system, it can

Figure 14. 3D cadastre prototype system

be registered the rights relation of the buildings and facilities so the right can be managed and protected. This system may improve more administrant efficiency than before.

6. Conclusions

This paper proposed the data model for 3D cadastre to reflect the trend of cadastre object space which changes from 2D to 3D. To develop the 3D cadastre feature model, the 3D right among the 3D cadastre components and several cases are analyzed, and then features are derived from the results. As the proposed 3D cadastre geometry model was considered consistency and expansibility with other domestic data models, this paper proposed the data model that is appropriate to the 3D cadastre in Korea. This model was devised by the aim of the municipal enterprise that was going to make the 3D Cadastre data model which was good for chosen cases. The existing data model such as CCDM in Netherlands is a data model that puts an important point in the theoretical concept of the owner, propriety rights and object. On the other hand, as a data model that puts an important point in the practical aspect of certain cases, the proposed model has different approach from the existing model.

This study has some limitations. One limitation is that the 3D cadastre feature model using the objects derived from case studies is limited, not including all situations. Considering more cases, the 3D cadastre feature model should be more comprehensive. Another limitation is that only 3D cadastre geometry data model was proposed in this paper. A 3D cadastre topology data model is needed to conduct topological analysis to detect the spatial relationship among the cadastral features. In addition, 3D cadastre model should consider a temporal model to reflect the real world based on time such as transfer of ownership and parcels split. If the data model would reflect time, it could deal with histories of attributes and ownerships about spatial objects as well as ownerships of three-dimension space to manage taxes or objects' ownership. By defining feature ID keys and relationships among the features, the feature data structure would be more organized.

Acknowledgment

This paper is written as part of 'Ubiquitous 3D Cadastre Project – planning the project road map and designing the 3D cadastre system.' The author would like to thank all person involved in this study. We express our gratitude to the Seoul's cadastre department and the Korea Cadastral Survey Corp. for the cooperation and the support of this research.

Reference

[1] ISO19107, “Geographic information − spatial schema”, Geneva, Switzerland, ISO, May 2003.

[2] J. Lee and J. Koh, “A conceptual Data Model for a 3D Cadastre in Korea”, The Journal of Korean Society of Surveying, Geodesy, Photogrammetry, and Cartography, vol. 25, No. 6-1, pp. 565-574, December 2007.

[3] J. Lee and S. Zlatanova, “A 3D data model and topological analyses for emergency response in urban area”, Taylor & Francis Eds., Geo-Information technology for emergency response, pp. 143-168, 2008.

[4] J. Stoter, “Considerations for a 3D Cadastre”, TU Delft, The Netherlands, pp. 1-18, October 2000.

[5] J. Stoter, “3D Cadastre”, Ph.D. Thesis, TU Delft, The Netherlands, pp. 1-327, September 2004.

[6] J. Stoter and M. Salzmann, “Towards a 3D cadastre: where do cadastral needs and technical possibilities meet?”, Computers, Environment and Urban Systems, vol. 27, No. 4, pp. 395-410, 2003.

[7] J. Stoter and P. Oosterom, “Cadastral Registration of Real Estate Objects in Three Dimension”, URISA Journal, vol. 15, No. 2, pp. 47-56, 2003.

[8] J. Stoter, P. Oosterom, H. Ploeger and H. Aalders, “Conceptual 3D Cadastral Model Applied in Several Counties”, FIG working Week 2004, Athens, Greece, May 2004.

[9] K. Kim, S. Hwang Bo and S. Lee, “A Study on Registration 3D Cadastre”, The Journal of the Korean Society of Cadastre, vol. 23, No. 2, pp. 133-145, 2007.

[10] Korean Nation Geographic Information Institute, “three -dimension spatial information development provision”, vol.179, May 2009.

[11] Korea Cadastral Survey Corp., “Management of 3D Cadastral Research Road Map and System Design”, unpublished.

[12] P. Oosterom, C. Lemmen, T. Ingvarsson, P. Molen, H. Ploeger, W. Quak, J. Stoter and J. Zevenbergen, “The core cadastral domain model”, Computers, Environment and Urban Systems, vol. 30, pp. 627-660, 2006.

[13] Seoul Metropolitan Government, “A Study on effective 3D cadastre registration prototype”, Korea, November 2008.

[14] Seoul Metropolitan Government, “Ubiquitous 3D Cadastre”, unpublished.

[15] S. Park and J. Lee, “Comparative Analysis of 3D Spatial data Models”, The Journal of GIS Association of Korea, vol. 17, No. 3, pp. 277-285, November 2009.

[16] S. Hong and Y. Lee, “The Cubic Registration Strategy for 3D Cadastral Information System Construction”, The Journal of GIS Association of Korea, vol. 14, No. 1, pp.67-83, April 2006.

[17] M. Benhamu and Y. Doytcher, “Toward a spatial 3D cadastre in Israel”, Computers, Environment and Urban Systems, vol. 27, pp. 359-374, 2003.

Received (November 18, 2009)
Revised (December 28, 2009)
Accepted (December 28, 2009)