Construction of Geometric Model and Topology for 3d Cadastre – Case Study in Taizhou, Jiangsu

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Key words: Model, Topology, 3D Cadastre, Extrusion

SUMMARY
As the economic development of China, the demands of land resources are growing rapidly. For this reason, the land development is extending to 3D space. In order to manage the 3D space of land use, 3D cadastral management is needed urgently in China. Modeling of the 3D cadastral objects is always the core in the research of 3D cadastre.

For the sake of considering the historical cadastral registration and the full utilizing of existing 2D cadastral data, a widespread solution to construct 3D cadastre is using the existing 2D cadastral data. For most of the 3D cadastral objects are regular, simple and practical approaches based on extrusion are widely used in 3D modeling. In this paper, we aim to propose a new modeling approach for the 3D cadastral object based on extrusion. Unlike most of extrusion approaches, our approach does not allow overlapping among footprints which are used to construct one or more 3D objects. Based on this approach, we extracted 2D topological features from 2D footprints. Then we used 2D topological features and height values to present 3D topological features.

By studying the 3D cadastral situation of Pozi street in Taizhou, we have knew the requirements for 3D modeling. We applied our approach to model 3D property space and construct its topology in Pozi street. It can construct more 3D objects than extrusion based approaches before. It provides an easy and practical solution for constructing 3D model and topology in 3D cadastre. Using 2D feature to present 3D feature can save storage space. Considering the current situation of cadastral management in China, it may provide a new idea for constructing 3D cadastral objects.

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1. INTRODUCTION

With the urbanization in China, the land use not only develops towards the horizontal space but also the vertical space. In many eastern economy developed regions of China, the land use has extended to three-dimensional space. Faced with this situation, the traditional two-dimensional (2D) cadastral management mode has exposed its deficiencies and limitations on land management of vertical space (Guo et al., 2011, Ying et al., 2012). So the 3D cadastral management mode is needed to overcome these deficiencies and limitations (Karki, McDougall, & Thompson, 2010).

In the past ten years, 3D Cadastre has become a focused issue for land administrations all over the world (Nurit, 2009). Until now, several well-developed cities have attempted to explore 3D cadastral management mode in China. Shenzhen city has achieved some success in 3D cadastral management. Its 3D cadastral system moved from research and prototypes toward implementations and usages of practical systems (Guo et al., 2014). However, there are still many technical and legal problems need to be solved on 3D cadastral management in China. For example, how to balance the demand of topological structure for 3D cadastre and the cost of constructing 3D models? How to design the title certificates to make the 3D parcel and the 3D property rights are described clearly and accurately?

In China, the 2D cadastral systems of most areas have been established and applied in recent 5 to15 years. To completely replace current 2D cadastral system by 3D cadastral system is cost expensive for government. And constructing a full 3D cadastral database is an abandon of current cadastral data. It is important to utilize current cadastral data in 3D cadastre developments (Aien et al., 2011). The ISO 19152 (LADM) has been designed to allow parcel and boundary for 2D and 3D to be integrated together (Lemmen et al., 2010). However, how to construct 3D cadastral system and database based on current systems and data in practice is key issue need to be explored in countries like china.

Constructing of 3D data models and their topological relations are two important parts of 3D cadastral (Ying et al., 2011). With the development of 3D virtual reality technique and 3D GIS, construction of the 3D model is not a difficult task (Olivares García et al., 2011). We can construct a mass of complex 3D building models by light detection and ranging (LIDAR) techniques or oblique photography technique (Chiang, 2012). However, these approaches do not take consideration of current 2D parcels and provide much meaningless information such as texture for 3D cadastre. So 3D model construction approaches based on the 2D parcels are imperative for 3D cadastre.

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Jiangsu province, located in eastern coastal center of China and adjacent Shanghai which is one of the most developed cities in China. In recent years, Jiangsu has experienced rapid economic and urban development. Taizhou is a prefecture-level city in central Jiangsu Province which locate on the north bank of the Yangtze River, it borders Nantong to the east, Yancheng to the north and Yangzhou to the west. The 2010 census counted its population at 4,618,937 of whom 1,607,108 live in the built-up (or metro) area made of three urban districts, (Hailing, Jiangyan and Gaogang). In the past 20 years, the economic growth has remained stable with an average annual growth rate exceeding 10%. It is one of the central cities inside the Yangtze River Delta with its developed industry, convenient transportation and prosperous commerce. By 2008, the construction area of urban underground space in Taizhou has reached more than 100,000 square meters. And the area will add 855,000 square meters by 2020 according to the urban planning of Tahizhou.

Article 136 of the "Property Law of the People's Republic of China" says "The right to use land for construction may be established separately on the surface of, or above, or under the land. The newly-established right to use land for construction shall not damage the usufructuary right that has already been established."(Yu et al., 2012). However, the underground space rights are not registered separately for administrative and technical reasons.

Hailing district is the core urban area of Taizhou. Figure 1 shows the land use of it in 2015. The red areas, the green areas and the gray areas respectively indicate the construction land, the farming land and the unutilized land. The construction land occupied most of the area in Hailing district. Very limited land resource can be used for developing in this core urban area. Figure 2 shows the complex building of

Pozi street in Taizhou constituted by one commercial center containing four parts, four apartment buildings and a joint area.
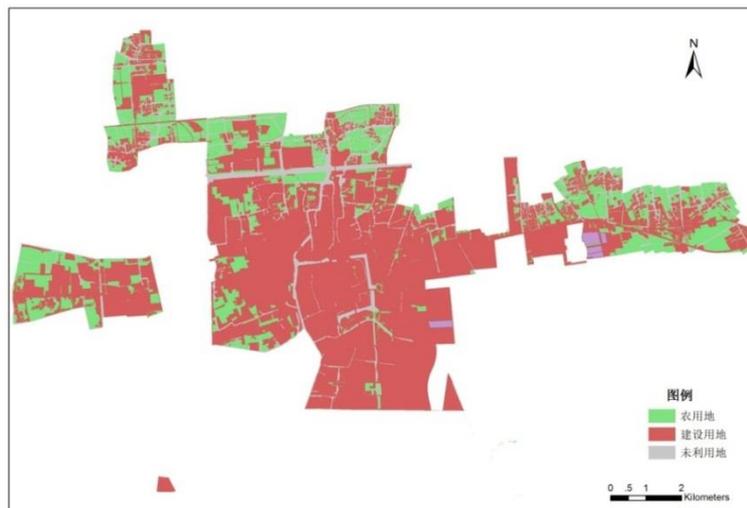

Figure 1: Land use of Hailing district in 2015

Figure 2: Example of complicated property situations of Pozi street

2. MODELING REQUIREMENTS FOR 3D CADASTRE

In recent years, the unified real estate registration regime has implemented in China (Chen, 2014). The land right was established as the core of the real estate registration. So the registration of all property rights should base on the land right. In China, the basic unit of the cadastral management is the land parcel. In current cadastral database, the representation of the land parcel is a polygon in the 2D plane. If the vertical projections of several disjoint property objects overlap with each other, their corresponding parcels will also have overlaps. However, this is not allowed in current cadastral systems and databases. So the 3D parcel is required for this situation. To meet requirements of the model construction for 3D parcels, some typical cases should be studied.

The Pozi Street is the most prosperous commercial street in Taizhou. We will illustrate two 3D cadastral situations in this area to show their modeling requirements. Figure 3 shows the image of the Pozi Street. The area of Pozi Street is circled by red lines.

Figure 3: The image of the Pozi Street

2.1 Multi-using land space

To make full use of this area, there are lots of mixed-use buildings of commerce and residence in Pozi Street. The land uses of commerce and residence exist in different layers.

Figure 4 shows an example of the 3D situation of a multi-using building. It is a combination of shops and residences in vertical space. The property right of the building is divided into several parts. All parts are owned by different individuals and commercial organizations. From the first to the fourth floor, there are department stores. The land space of this part is used for commercial purpose. Above the fourth floor, there are several apartment buildings. The land space of this part is used for residential purpose. The property rights of all the parts of the building were established on the same parcel 321202005105GB00014. Figure 5(a) shows different right holders of this parcel.

The situation of the building is a typical case of multi-using of the vertical land space above the surface. It provides an example for different land use above the surface. Figure 5(b) shows outlines of the multi-using building numbered 2707 in 2D cadastral map. The arrow indicates the view position of the camera in figure 4. In the 2D cadastral map, the rights in the vertical dimension cannot be showed clearly. The space extent of the rights for owners of the residential buildings and the space extent of the rights for owners of the commercial buildings are all projected into a planar polygon. It may result in errors of the property spaces definition on this multi-using land space.
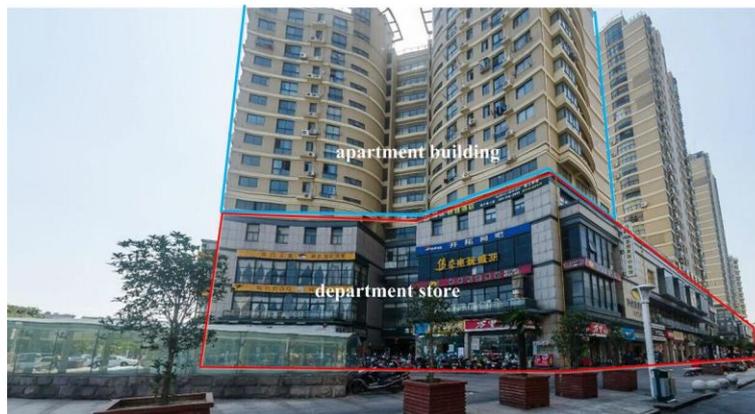

Figure 4: Multi-using land space in Pozi Street

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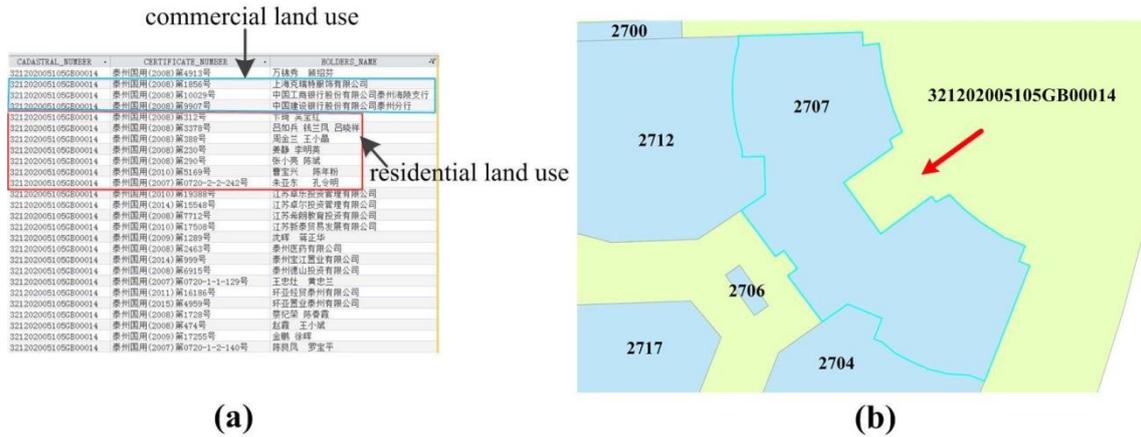Christchurch, New Zealand, May 2–6, 2016

Figure 5: (a) Different right holders of the parcel. (b) Cadastral map of the multi-using land space. The arrow indicates the position of the camera in figure 4.

2.2 Building complex

In figure 6, it is a typical 3D situation: a commercial complex over a pavement in the Pozi Street. The property right of the commercial complex was established on its relevant parcels. In current cadastral database, the property spaces of the commercial complex are presented by their 2D projections. In figure 7, we can see the projected outlines of the buildings and the planar parcels of this case in 2D cadastral map. The arrow indicates the view position of the camera in figure 6.

In the original 2D cadastral map, the jointing area connected the building 3943, 3944, 3945, 2709, 2704 and 2720 was not presented in this case. To present clearly, we drew the outlines of the joint area by dashed lines in figure 7. The firm 'Huanya real estate Taizhou Co., Ltd' is the holder of these buildings and the jointing area. The rights and restrictions of these properties (the buildings and the jointing area) are established on the parcel 321202005105GB00014.

In this case, the property spaces of these buildings can be presented in current 2D cadastral system by planar polygons. However, the property space of the jointing area cannot easily presented by a planar polygon. The municipality holds an unrestricted right of ownership of the pavement. The property space of the pavement is from the ground and to the bottom of the jointing area. The current 2D cadastral system cannot describe the situation of the property space. Some spatial conflicts may occur for the extent of some property spaces were defined inaccurately or not defined in vertical space.
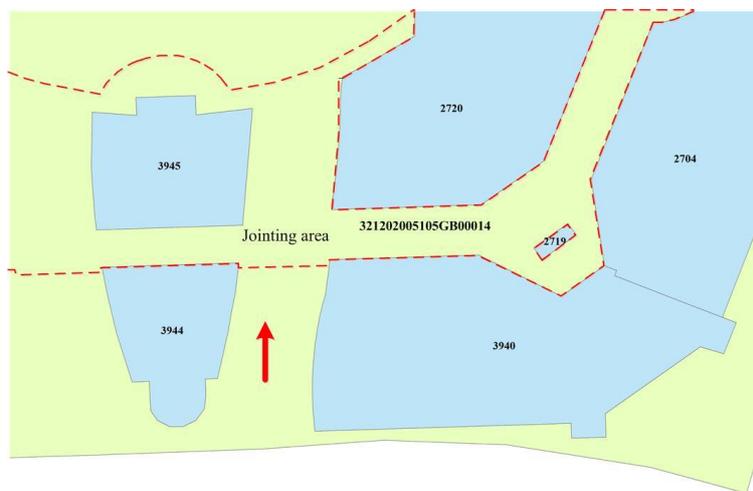
Figure 6: Building complex over a pavement

Figure 7: Cadastral map of the building complex in figure 6. The arrow indicates the position of the camera

3. APPROACHES FOR CONSTRUCTING GEOMRTRIC MODEL AND TOPOLOGY

3.1 Model construction based on Extrusion

Extrusion is a commonly used technique in GIS to construct regular 3D geometric models of real objects (Arroyo, Ledoux, & Stoter, 2015, Ledoux, & Meijers, 2011). It is also widely used in 3d cadastre for modeling 3D property units or 3D property spaces. García, Soriano, & Martín-Varés (2011) generated 3D geometric models by extrusion for each sub parcel of the parcel. Guo et al. (2014) proposed that regular 3D data can be generated by extrusion. And all the faces bounding the solid are either horizontal or vertical. There are only two horizontal faces in each 3d geometric model extruded by a single footprint. They are the top face and the bottom face.

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If a 3D parcel has more than two horizontal faces, it cannot be constructed by extruding a single footprint. It needs extruding several footprints to construct it. One solution is to extrude several paralleled footprints to construct 3D objects in different heights. Normally, these footprints can be acquired from the building information. Then union these 3D objects to form 3D parcel. This solution uses an approach of horizontal division to model the 3D parcel. In 2D cadastral database, we often only store the footprints and height information to model 3D parcel for visualization and analyzing. However, storing several paralleled footprints to construct a 3D parcel is a waste of storage space. In addition, it is hard to establish topology relationship from these footprints.

A modified solution is to merge all the paralleled footprints to form a basic footprint first. Then divide the basic footprint to several sub-footprints, each one can be extruded to one or more 3D objects (eg. extruding a sub-footprint with heights of 3-6m and 9-12m to form two 3D objects). Finally, union all the 3D objects extruded from sub-footprints to form a 3D parcel. In this solution, splitting 3D volumes to several parts to construct them respectively is one of the most important operations. Figure 8(a) shows a 3D parcel which cannot be constructed by extruding a single footprint. Figure 8(b) is the basic footprint A of the 3D parcel.
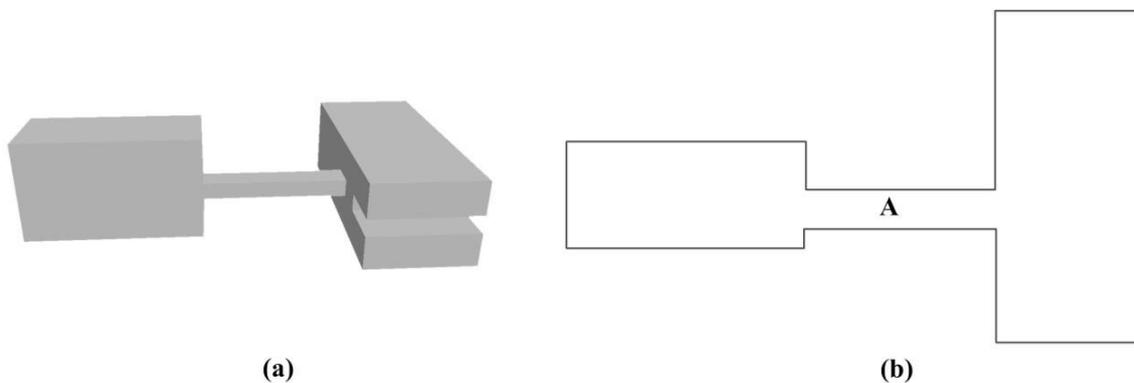

Figure 8: (a) An example of 3D parcel. (b) Basic footprint of the 3D parcel

In figure 9(a), the basic footprint is divided into four sub-footprints A_1, A_2, A_3 and A_4. We marked the height range for each sub-footprint. The height range of sub-footprint A_1 is a union of two parts which are [0m,5m] and [10m,15m]. It means A_1 should be extruded to two 3D objects. The two objects have a vertical interval from 5m to 10m. Figure 9(b) shows all the 3D objects extruded by the sub-footprints A_1, A_2, A_3 and A_4. We can get the model of the 3D parcel (Figure 9(b)) by merging these 3D objects.
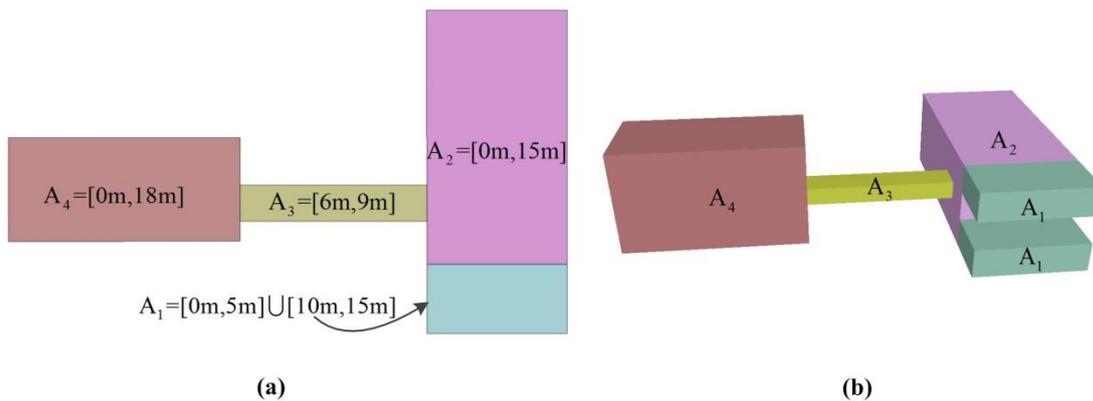
Figure 9: (a) Divided sub-footprints of the 3D parcel. (b) 3D objects extruded by the sub-footprints.

In this approach we describing in figure 9(a) and figure 9(b), we need only one layer to store the sub-footprints. And there is no duplicate storage of the sub-footprint. If use the solution of splitting the 3D parcel A horizontally that we mentioned before, the 3D parcel A should be divided into 6 parts of which height ranges are [0m,5m], [5m,6m], [6m,9m], [9m,10m], [10m,15m] and [15m,18m]. So we need 6 layers to construct the 6 parts. And there are many overlapping parts between the 6 layers.

3.2 Constructing 3D Topology

In most of current DBMSs, topology is not supported. So we must construct and storage topology by our own approach. To save the storage space and minimize the change of 2D cadastral databases, we suggest store the 2D geometry and height information instead of 3D geometry for the extrusion model. Also we could construct topology based on 2D geometry and height information for the extrusion model.

Figure 10(a) shows six adjacent 3D parcels A, B, C, D, E and F constructed by extruded footprints. Their footprints and height values are shown in figure 10(b). A is divided into two parts A_1 and A_2 which have the different height ranges of extrusion.
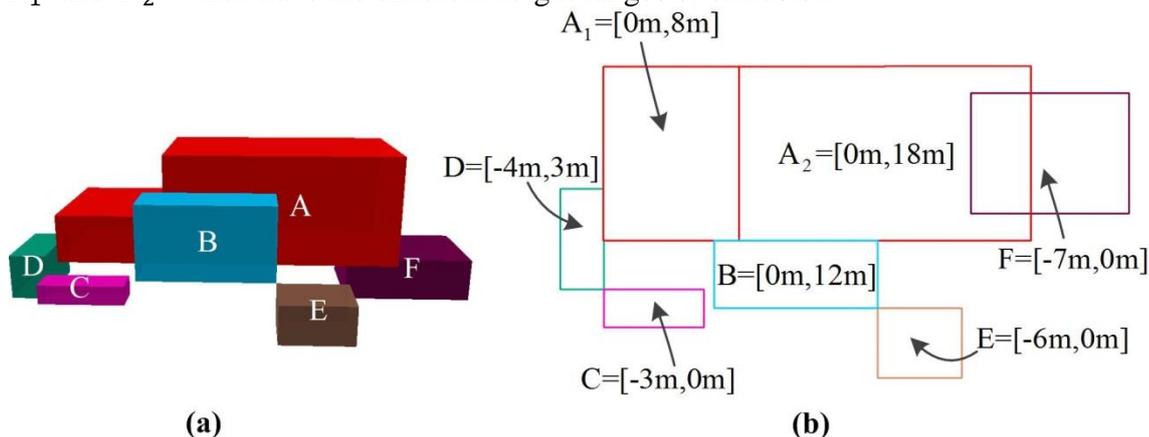

Figure 10:(a) An example of adjacent 3D parcels A, B, C, D, E and F. (b) Footprints and heights values of the 3D parcels

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According to the footprints in figure 10(b), we extracted the 2D topological features: nodes, edges and faces (Figure 11(a)). The nodes are vertexes or intersection points of the footprints. They can show the adjacent relations and the disjoint relations between the footprints. The edges are boundaries or intersect boundaries of the footprints. They consist of the nodes. The faces are footprints or the intersections of footprints. They consist of the edges. All these 2D topological features are not allowed to overlap with each other.

In figure 11(a), the black nodes and edges are intersections of the footprints. For instance, p_5, p_6, p_{10} and p_{11} are the intersection points of footprints A_1 and F. Edges p_5p_6, p_6p_{11}, $p_{11}p_{10}$ and $p_{10}p_5$ are the intersection boundaries of A_1 and F. And face $p_5p_6p_{11}p_{10}$ is the intersection area of A_1 and F.
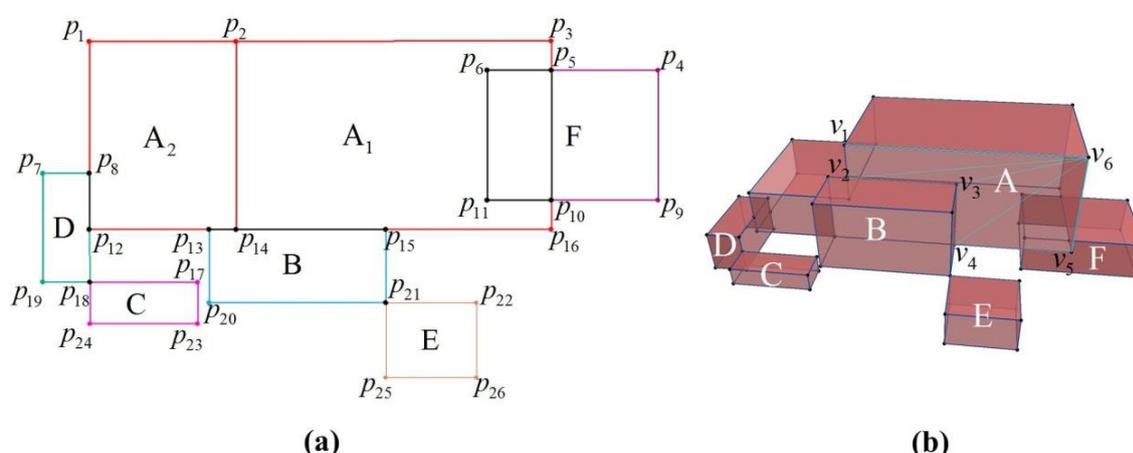

Figure 11: (a) Topological features of the 2D footprints. (b) 3D topological features constructed by 2D topological features and height values.

Although the 2D topological features can present topological relations of footprints, they cannot present topological relations of 3D parcels. To solve this problem, we combine 2D topological features and height information to present the 3D topological relations.

To present the 3D geometry by extruding the 2D geometry with the height value, there are 5 situations should be considered:
  1. The node in 2D with 1 high value presents the node in 3D.
  2. The node in 2D with 2 high values presents the edge in 3D.
  3. The edge in 2D with 1 high value presents the edge in 3D.
  4. The edge in 2D with 2 high values presents the face in 3D.
  5. The face in 2D with 1 high value presents the face in 3D.

For the 3D topological edge or face, it may be constructed by one or more extruding 3D geometries. So we may use several 2D topological features and height values to construct a topological edge or face. Figure 11(b) shows the 3D topological features constructed by the 2D topological features in figure 11(a). The 3D topological edge v_1v_6 and the face $v_1v_2v_3v_4v_5v_6$ are

constructed by more than one 2D topological feature respectively. Figure 12 shows the processes of constructing the two 3D topological features. The edge $v_1 v_6$ is constructed by the 2D topological edge $p_{14}p_{15}$ and $p_{15}p_{16}$. Firstly, we add Z value to $p_{14}p_{15}$ and $p_{15}p_{16}$ to form the edge $v_1 v_0$ and $v_0 v_6$ in 3D space (Figure 12(a)). Then we merge the edge $v_1 v_0$ and $v_0 v_6$ to get 3D topological edge $v_1 v_6$. The face $v_1 v_2 v_3 v_4 v_5 v_6$ is also constructed by the 2D topological edge $p_{14}p_{15}$ and $p_{15}p_{16}$. We extrude the edge $p_{14}p_{15}$ and $p_{15}p_{16}$ with heights of 12-18m and 0-18m respectively (Figure 12(b)). This formed two faces which are face $v_0 v_1 v_2 v_3$ and face $v_6 v_0 v_4 v_5$. Then merge the two faces $v_0 v_1 v_2 v_3$ and $v_6 v_0 v_4 v_5$ to form the 3D topological face $v_1 v_2 v_3 v_4 v_5 v_6$.
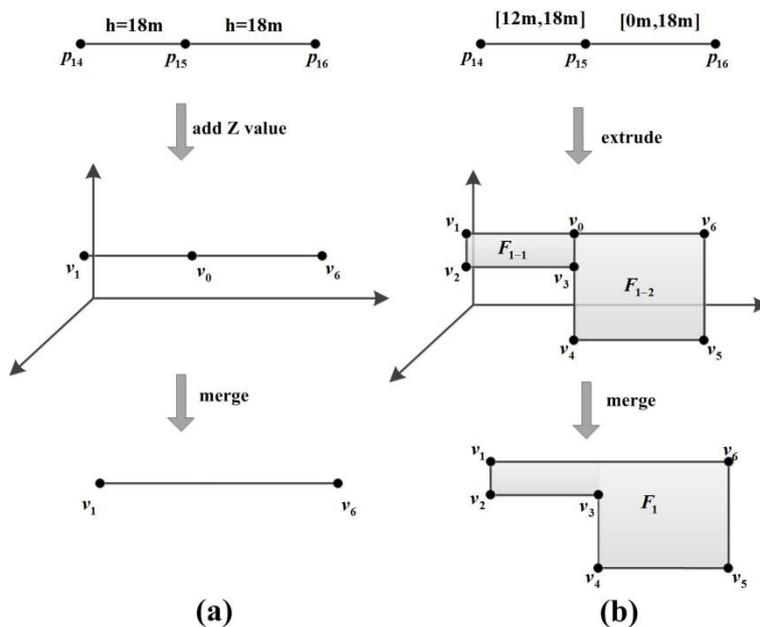

Figure 12: (a) An example of constructing the 3D topological edge. (b) An example of constructing the 3D topological face.

4. IMPLEMENT AND APPLICATION IN TAIZHOU

In this paper, we apply our approach of model and topology construction in Taizhou. In section 2, we analyze two cases in Pozi Street in Taizhou. In this section, we implement the approach of constructing 3D model and topological features in Pozi Street.

Based on our modeling approach, we implement 3D cadastral database by Personal Geodatabase of ArcGIS, the main physical structure are shown in figure 13 by UML class diagram. In previous studies such as the topological model proposed by Zlatanova (2000), topological features often consist of three tables: BODY, FACE and NODE and each table contains references to other tables. In our database, we also stored topological features like this. The structure of the footprint feature class, 2D topological feature class and the relation tables of 3D topological features are not shown in figure 13.

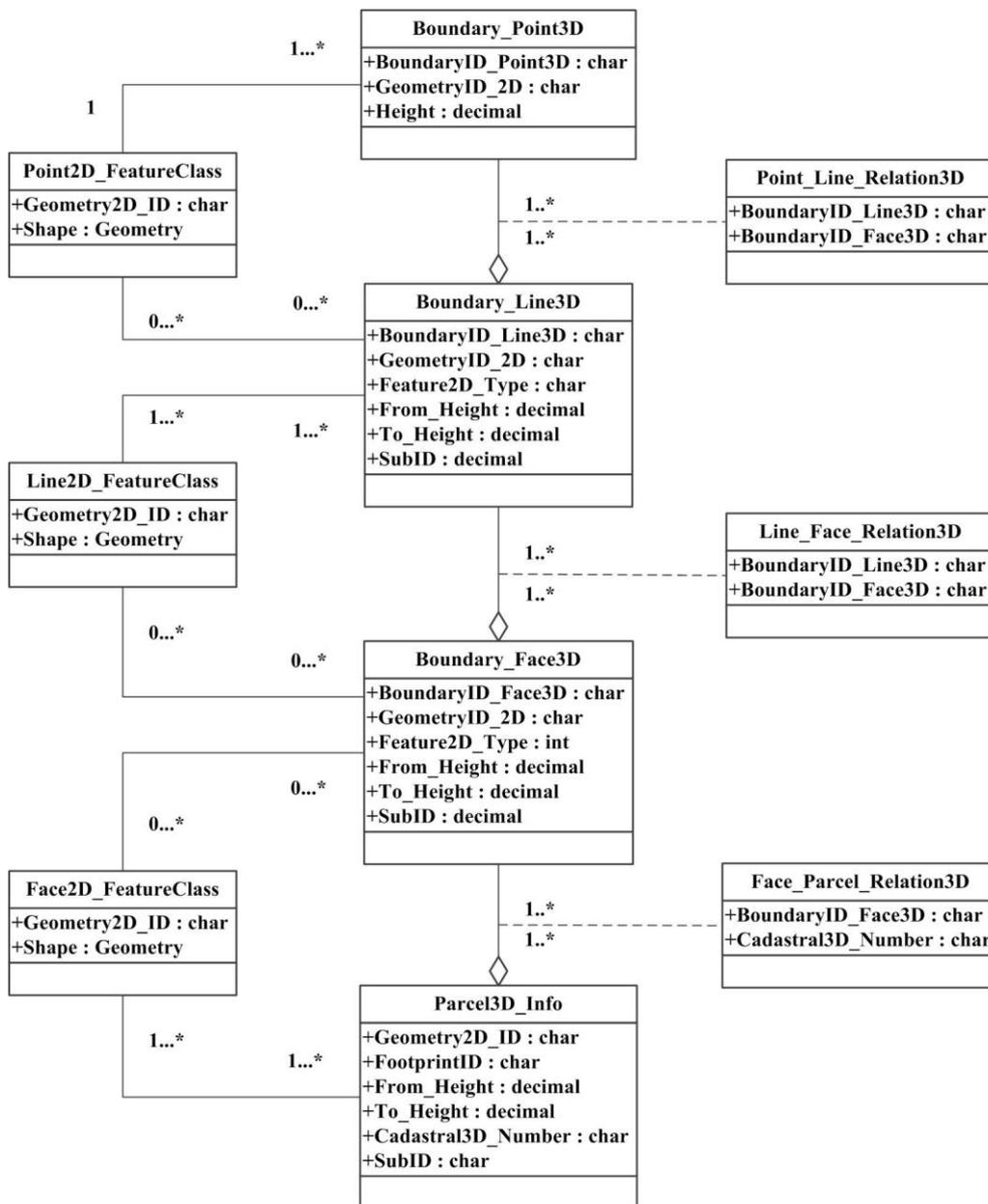Construction Geometric Model and Topology for 3d Cadastre–case Study in Taizhou, Jiangsu (7961)
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Boundary_Point3D

+BoundaryID_Point3D : char
+GeometryID_2D : char
+Height : decimal

1...*

1

Point2D_FeatureClass

+Geometry2D_ID : char
+Shape : Geometry

Point_Line_Relation3D

+BoundaryID_Line3D : char
+BoundaryID_Face3D : char

1..*
1..*

0...*   0...*

Boundary_Line3D

+BoundaryID_Line3D : char
+GeometryID_2D : char
+Feature2D_Type : char
+From_Height : decimal
+To_Height : decimal
+SubID : decimal

1...*   1...*

Line2D_FeatureClass

+Geometry2D_ID : char
+Shape : Geometry

Line_Face_Relation3D

+BoundaryID_Line3D : char
+BoundaryID_Face3D : char

1..*
1..*

0...*   0...*

Boundary_Face3D

+BoundaryID_Face3D : char
+GeometryID_2D : char
+Feature2D_Type : int
+From_Height : decimal
+To_Height : decimal
+SubID : decimal

0...*   0...*

Face2D_FeatureClass

+Geometry2D_ID : char
+Shape : Geometry

Face_Parcel_Relation3D

+BoundaryID_Face3D : char
+Cadastral3D_Number : char

1..*
1..*

1...*   1...*

Parcel3D_Info

+Geometry2D_ID : char
+FootprintID : char
+From_Height : decimal
+To_Height : decimal
+Cadastral3D_Number : char
+SubID : char

Figure 13: The main physical structure of our 3D cadastral database.

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There is explanation about main fields in table:

BoundaryID_Point3D/ : no. of the 3D Boundary Point/Line/Face constructed by 2D
BoundaryID_Line3D/   geometries
BoundaryID_Face3D
From_Height   : a height from which we extrude a 2D geometry
To_Height   : a height to which we extrude a geometry
SubID   : no. of a 3D geometry which is a part of the 3D parcel or 3D
                                        topological feature
GeometryID_2D   : no. of a 2D geometry generated by footprints

Figure 14(a) shows all the buildings structure of Pozi Street in AutoCAD. To present the geometry shape of these building planes clearly, the height values are not labeled in this drawing. Based on the drawing and property rights information in Pozi Street, we drawing the footprints of property spaces on which these buildings were established (Figure 14(b)).

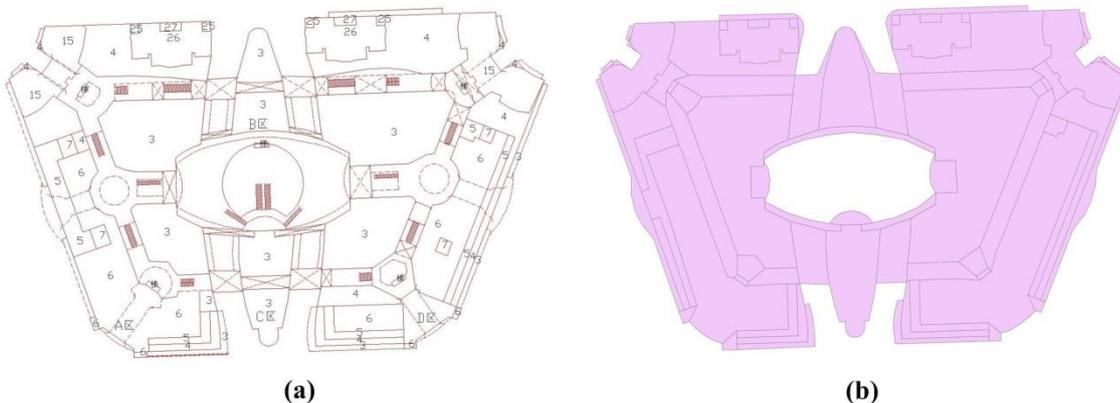(a)   (b)

Figure 14: (a) Buildings structure of Pozi Street in AutoCAD. (b) Footprints of property spaces in ArcMap.

Figure 14(b) shows the footprints of these property spaces in ArcMap. We store these footprints in polygon feature class in Geodatabase. To ensure the validity of these footprints, we use the topology tool in ArcToolbox to check the overlaps in the footprints feature class. According to the height values, we divided the Pozi street to several sub-footprints.

We extruded these sub-footprints to several 3D geometries. Then merged the geometries which are belong to the same 3D parcel or 3D property. Figure 15(a) shows the 3D property spaces in Pozi street constructed by our approach. Different colors indicate different 3D property spaces. According to 2D topological feature of the footprints and the height value, we construct the 3D topological features of these property spaces. Figure 15(b) shows the 3D boundary points, 3D boundary lines and 3D boundary faces drawn by using 2D topological features.

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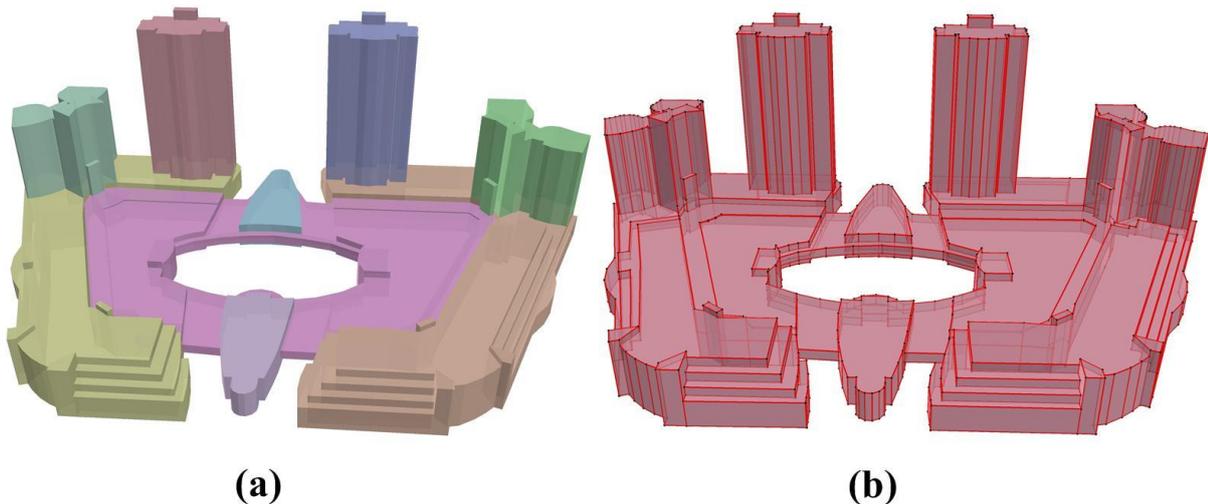Christchurch, New Zealand, May 2–6, 2016

(a) **(b)**

Figure 15: (a) 3D property spaces constructed by extruding in Pozi street. (b) 3D topological features constructed by our approach in Pozi street.

5. CONCLUSIONS

In China, real estate unified registration has been carried out in several developed cities. It has faced many challenges in managing data of real estate registration. 3D cadastral system provides possibility for managing the data of real estate registration. In 3D cadastral system, modeling 3D property or parcel and constructing 3D topological features are two of the most important parts.

This paper has proposed an approach of constructing 3D model and topology for 3D cadastre. It is practical for dense urban spaces in developing countries such as Taizhou. For comparatively complicated property, it can easily generate 3D model and topology. We apply this approach for Pozi street in Taizhou. We constructed 3D model and topology for each 3D properties in Pozi street. The 3D spatial relationship can be precisely presented by these 3D model and topological features. However, there still need a lot of practice to verify its availability.

In the future, simplifying the storage of the 3D cadastral model and topological features is a direction of our research. And how to present complicated 3D cadastral situation with practical approach is still our main research focus.

Reference
Ali, A. I. E. N., RAJABIFARD, A., KALANTARI, M., & WILIAMSON, I (2011). Aspects of 3D Cadastre- A Case Study in Victoria. Paper presented at the FIG Working Week 2011, Marrakech, Morocco.

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Arroyo Ohori, K., Ledoux, H., & Stoter, J. (2015). A dimension-independent extrusion algorithm using generalised maps. International Journal of Geographical Information Science, (ahead-of-print), 1-21.

Yu, Changbin, Lin Li, Shen Ying, Biao He, Zhigang Zhao, and Yuan Wan. Designing a Title Certificate for the Chinese 3D Cadastre.(2012) 3rd International Workshop on 3D Cadastres. 25-26 October 2012, Shenzhen, China.

Chen, L. (2014). Land Registration, Property Rights, and Institutional Performance in China: Progress Achieved and Challenges Ahead. Hong Kong Law Journal, 44(3), 841-864.

Chiang, H. C. (2012). Data Modelling and Application of 3D Cadastral in Taiwan. In 3rd International Workshop on 3D Cadastres: Developments and Practices, Taiwan.

García, J. M. O., Soriano, L. I. V., & Martín-Varés, A. V. (2011). 3d geometric modeling and Representation of the Spanish Cadastral Cartography. In 2nd International Workshop on 3D Cadastres, Delft, FIG.

Guo, R., Li, L., He, B., Luo, P., Ying, S., Zhao, Z., & Jiang, R. (2011). 3D cadastre in China: a case study in Shenzhen City. In Proceedings 2nd International Workshop on 3D Cadastres, Delft, The Netherlands, 16-18 November, 2011. International Federation of Surveyors (FIG).

Guo, R., Luo, F., Zhao, Z., He, B., Li, L., Luo, P., & Ying, S. (2014). The Applications and Practices of 3D Cadastre in Shenzhen. In: Proceedings of 4th International Workshop on 3D Cadastres. The 4rd International Workshop on FIG 3D Cadastre Workshop. Dubai, Unit Arab Emirates. Nov. 9-11, 2014

Ledoux, H., & Meijers, M. (2011). Topologically consistent 3D city models obtained by extrusion. International Journal of Geographical Information Science, 25(4), 557-574.

Lemmen, C. H. J., Van Oosterom, P. J. M., Thompson, R. J., Hespanha, J. P., & Uitermark, H. T. (2010). The modelling of spatial units (parcels) in the Land Administration Domain Model (LADM). In Proceedings of the XXIV FIG International Congress 2010: Facing the Challenges-Building the Capacity, April 2010. International Federation of Surveyors, FIG.

José Miguel Olivares García, Luis Ignacio Virgós Soriano and Amalia Velasco Martín-Varés (2011). 3D Modeling and Representation of the Spanish Cadastral Cartography. In proceedings 2nd International Workshop on 3D Cadastres, 16-18 November 2011, Delft, The Netherlands.

Karki, S., McDougall, K., & Thompson, R. J. (2010). An overview of 3D Cadastre from a physical land parcel and a legal property object perspective. In Proceedings of the XXIV FIG International Congress 2010: Facing the Challenges-Building the Capacity, Sydney, April 11-16, 2010. FIG.

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Christchurch, New Zealand, May 2–6, 2016

Nurit Peres and Moshe Benhamu (2009). 3D Cadastre GIS - Geometry, Topology and Other Technical Considerations. In proceedings FIG Working Week 2009, Eilat, Israel.

Ying, S., Guo, R., Li, L., & He, B. (2012). Application of 3D GIS to 3D cadastre in urban environment. In 3rd international workshop on 3D cadastres: Developments and practices (pp. 25-26).

Ying, S., Guo, R., Li, L., van Oosterom, P., Ledoux, H., & Stoter, J. (2011). Design and Development of a 3D Cadastral System Prototype based on the LADM and 3D Topology. In 2nd International Workshop on 3D Cadastres. Delft, the Netherlands.

Zlatanova, S. (2000). 3D GIS for urban development. PhD thesis, ITC publication 69, Enschede, the Netherlands.

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