BUILDING MODEL CREATING AND STORING IN 3D URBAN GIS

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ABSTRACT

New developments in urban planning, urban landscape, real estate management and so on, call for new demands for 3D Object Model. The building models are the most important in 3D object model. With the development of 3D data acquisition, the visualization aspect often is detail considered, however, only a few investigation about the creating and storing of 3D object model is discussed. In this paper, firstly the method of creating building model is presented, this includes the data structure and model of 3D building model. Secondly, a data structure combining the data model of building model and R-tree index, which is used to store 3D building data, is presented. Finally, a system prototype is in development, joining aspects of visualization interface and a database for building model, and several results are illustrated.

1 INTRODUCTION

In recent years, the development in 3D urban model is very rapid, especially in the fields such as reconstruction of man-made objects, 3D data acquisition, 3D data structure. The generation of 3D urban model is a relevant and challenging task, both from a practical and a scientific point of view (Gruen, 1998). In order to construct building model, the 3D data must be acquired. On the one hand, photogrammetry provides the only economic mean to acquire truly 3D data (Förstner,1999), on the other hand, airborne laser range data leading to Digital Surface Model(DSM) also can acquire 3D data. Advanced automatic stereo techniques (Bignone et al.1995, Jaynes et al.1997) specialized to urban scenes have been developed. So many approaches and systems about auto reconstruct and semi-reconstruct building model have been developed. For example: CC-GIS(Wang. XH, Gruen,1998), this system includes vector and raster as well as attribute data and uses point, line and surface describing a building. Förstner(1999) construct building model from image using automatic and semiautomatic acquisition method. Due to the complexity of buildings, especially the roof of buildings, so many researchers pay attention to the data model and structure. A serial of data structures are taken into account, for instance: CSG, BR, TIN, Grid, TEN ,FDS and hybrid structure(Martin J, 1992, Pilout M.,1994, R. Li, 1994, Molenaar M, 1992, Qingquan Li,1996).Up to now, many methods describing the roof of buildings are presented. Although these methods are very efficient in reconstructing buildings and visualization, they are not efficient in query and spatial analysis. In some fields such as urban planning, design, the task of creating new building model according to design or planning is of vital importance in many aspects such as estimation of effects impact and their integration in existing settings, aesthetic assessment of an existing neighborhood, evaluation and cognition of complex spatial circumstance and so on. Discussions about creating building model go far beyond reconstruction and visualization, moreover, the method of creating building model is related with its data model and structure, so a viable data model of building model is very important.

The increasing complexity of building requires the data management and storing to be powerful and efficient. Because of the incompleteness of building data in 2D GIS database, especially about the information of roof, balcony, chimney and textures of every surface of building, the method of creating, storing, retrieval as well as user interface have to be incorporated. At the same time, the complexity and large amount of building data require the efficient management mechanism of spatial data. The traditional Relational Database Management System(RDBMS) has several weakness in managing 3D geometry data and attribute data. Modern urban management has to deal with complex requirements and maintains more complex data. For the visualization, query and analysis purposes of large 3D data, it is necessary to designed a data structure to store building model data.

The following sections are arranged as follow. Firstly, the data model and structure of building method and the method of creating building model are presented. Secondly, the data structure for managing 3D building data are presented. Finally, a system to visualize and create the 3D building models, joining aspects of visualization interface and a data structure for managing building model data is developed, and several results are illustrated

2 3D BUILDING MODEL

Because of the incompleteness of buildings data in 2D GIS database, especially the data about roof, balcony, chimney and textures of every surface of buildings, appropriate data model and structure must be developed to express building model. In most cases, the interest in buildings is not only its whole solid but also its surface-related information. For example, a building can be described as a residential house which has owner, address, it also has wall, roof, boundary, textures. In CAD/CAM, BR and CSG are often used to store 3D model, but they are not efficient in managing large amount of 3D geometry and attribute data. Layer Combined model (QQ Li, BS Yang,1998,1999) is developed to construct building model. The major improvement of this model can meet the requirements of efficient 3D geometry and attribute query and analysis, and to decrease the volume of data storage and to improve the visualization.

2.1 Layer Combined Model

With the development of modern city, the building reveals a huge variety in 3D urban model. In most case, the applications of 3D urban model are related to buildings, in many applications such as virtual reality (VR), not only the outside shape but also the inside shape requires to be represented. In order to describe geometrical structure and attribute of different layers, layer combined model is developed to construct building model. In this data model, a building layer is defined by having the same function, structure or attribute, which is a concept layer including one or many practical layers. In addition, the roof is considered as an independent layer because of its particularity. Figure .1 illustrated the LC Model.

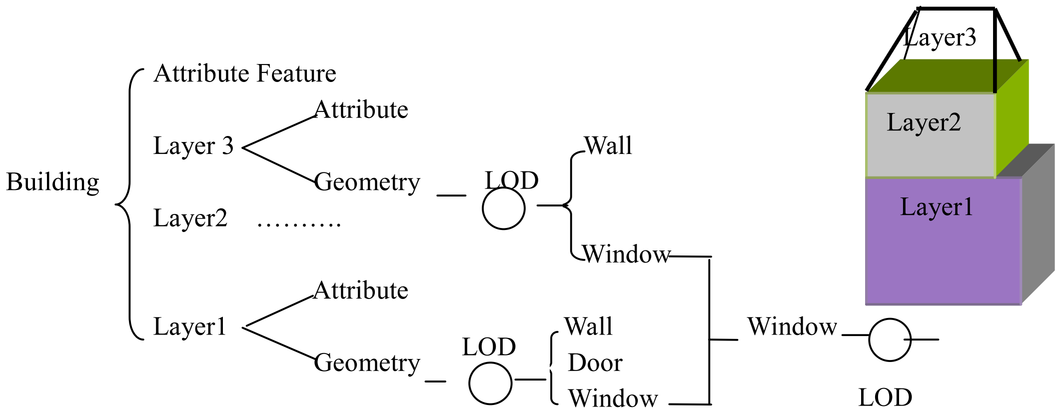

Figure 1: Layer combined model

In LC Model, the buildings can be decomposed into many basic primitives and roofs. For the reason that almost all the walls of buildings are vertical, these primitives can be constructed by a closed polygon with the assumption that every edge of polygon defines a wall, the geometry data of the primitives can be stored by the point group (x_1,y_1, x_2,y_2,…, x_n,y_n, z_1,z_2) in clockwise or counterclockwise direction, where z_1 is the height of bottom surface and z_2 is the height of top surface. At the same time, a sole symbol is assigned to the every wall surface to mark it. Because of the complexity and peculiar shape of roof, the roof can be depicted with TIN, which are created by boundary points and inner feature points.

In this model, the buildings are comprised by complex structure, containing identifiable layer (sub-object). Every layer has the property of geometry and attribute like wall, roof, color, material, texture and so on, the topology among layers is also well described. Furthermore, it can be linked with different attribute data or texture data to enhance the reality of buildings.

Compared to other data model, LC model has several advantages:

- Not only outer shape of buildings but also inner object of buildings can be depicted.
- Multiple data source can be integrated in LC model such as image data, vector data, attribute data, multimedia data and so on.
- LC model can depict LOD model of different abstract layer .

2.2 Model Creator—Creating Building Model

In 3D urban model, many applications are related with buildings. For example:

- Topology query and measure the volume, surface area of object.
- Incorporate new buildings into existing urban model(Alexander Köninger, 1998).
- Edit the properties of object such as color, textures and so on.
- Aesthetic assessment of an existing neighborhood.

It is easy to see that these applications are of vital importance in urban planning, where not only auto reconstructing building model but also creating new building model according to design or planning is required. So a editor is developed to create new building model according to design or planning of building. For the representation of building model, it must correspond to mathematical model, for instance: parametric models and generic models. The former structure is fixed and can be described by several fixed parameters, the latter structure is not fixed and requires several parameters. In order to fulfill the task of creating models, a model creator is developed, the editor not only can create parametric models such as box, cone, cubic, sphere, but also can create generic models. the shape of roof can be depicted by TIN, which are created by boundary points and inner feature points of roof surface. The models also can be moved, deleted, combined with other basic 3D models. Furthermore, complicated 3D model can be interpreted by integrating with its 2D primitive on the ground surface.

Sometimes, there is no suitable 3D data or auto-reconstruct process is not perfect to depict sufficient details, for instance, the window, balcony and a small tower in buildings can not be auto-reconstructed. Operator has to do this by himself. The 3D data can be used to create two basic categories objects:(1) point, line and surface objects coinciding with ground surface such as streets, roads etc. (2) volume objects which stick out the ground (buildings, tower, and so on). The former follows the same principle as 2D GIS, the latter can be divided into parametric models and generic models. For parametric models, the method of creating is simple, for generic models(for instance building), the basic assumption is that the wall of 3D primitives is vertical, so the wall can be obtained by projecting the every edge of top polygon to the ground, and the top closed polygon forms a planner roof surface. If the wall can not be created by the projection of the outline of roof, it can be created by projecting the ground points to roof, where the roof is an independent surface. For effective visual control of creating basic primitives, the editor permit operator to delete, move, rotate 3D primitives. Moreover, the 3D primitives can be modified by changing the shape of ground polygon, they will be reconstructed instantly. Once the basic primitive is created, the texture, height and color can be linked to it.

The roof can be depicted by TIN, which are created by skeleton points and boundary lines, however, in most cases, the skeleton points of roof are in arbitrary order and the shape of roof is rather complicated, auto-reconstruct all kinds of roofs is impossible. For instance: for special shape of roof, some corner points are invisible in image so they can not be acquired from DPW (Digital Photo-grammetry Workstation). These complicated roofs probably can not be auto-reconstructed, but they can be completed by operator add auxiliary points. When automatic reconstructing, the roofs can be represented by triangle networks. Ma,XH(1999)decompose arbitrary polygon into delaunnay triangles. But this algorithm is unable to handle inner points of polygon. In order to construct complicated roof with skeleton points and lines, this algorithm is integrated with insert algorithms(Victor J.D., 1993) to enable it to handle feature line such as skeleton line of roof. For the reason that roof is rather complicated, sometimes the results of this algorithm probably do not correspond with the shape of natural roof. So manual edit must be implemented to correct it, which can be completed later by operator construct triangle network according to the natural shape of roof. The roofs can be integrated with different primitives according to the top shape of theirs to combine complex buildings(Figure 2).

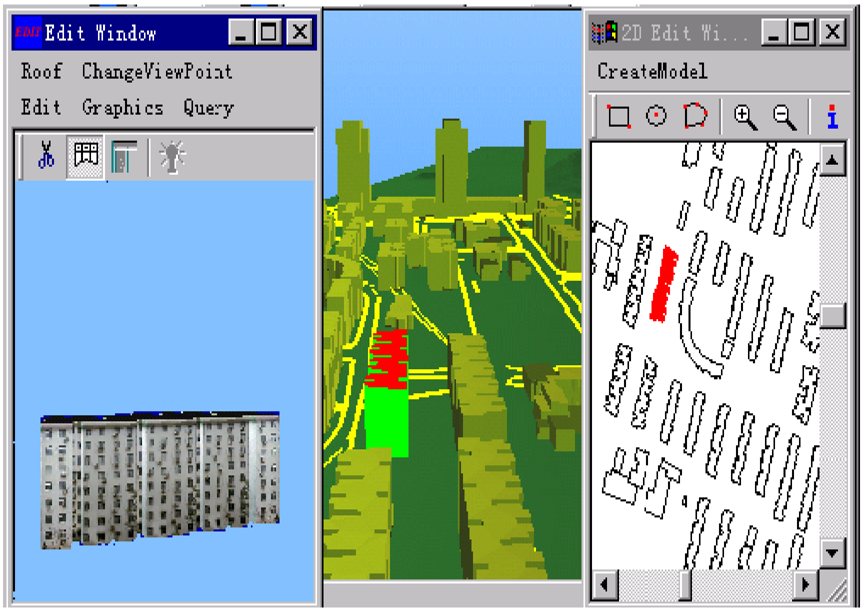

Figure 2: Creating building model

3 STORING LARGE DATA SET

The multiple and large amount of building data require the data management to be powerful and efficient. The traditional Relational Database Management (RDBMS) is the most successful database management because of its simple structure and complete theory (Chen J, 1999). The RDBMS has several weakness in managing 3D geometry and attribute data, especially in hybrid data structure. However, it provides binary large object (BLOB) type, permitting image and spatial data management. Because of large amount of building data and multiple such as image, attribute data, RDBMS is not adequate for the requirements of spatial data retrieval and visualization. Considering the entire data of all buildings such as millions of thousands buildings in a city, it is impossible to keep all the data in memory of a workstation for visualization and analysis, so a well-organized data structure and fast data retrieval mechanism have to be provided.

3.1 The Data Model—LC Model Combined LOD and R-tree Index

The RDBMS treats BLOB as an object without knowing its content so it is not convenient for analysis and query. In order to efficiently manage 3D building data in database, the BLOB can be extended to store building model. For the purpose of query and analysis, the operation of writing and reading BLOB from database must be defined, at the same time, the index of BLOB also must be provided to fasten the data retrieval. The R-tree structure is proved to be a useful index. Compared with other spatial data structure such as Quad-trees or Oct-trees, it is obvious that R-tree is much better suited for the organization of overlapping object, the rectangle bounding boxes of 2D or 3D CAD model of building, building blocks and large urban units (Gruber, 1998). According to the R-tree, the block of divide building can be a district or several buildings. Figure 3 is a R-tree index of building. For the purpose of visualization, different abstract layer of LC model data and R-tree index require to be stored in database. According to LC model, the 3D building object can be depicted as follow:

BuildingObject=(Layers, BodyObjectArray, RoofObjectArray, R-tree index).
BodyObjectArray=(Body1,Body2,...,Bodyn).
RoofObjectArray=(Roof1,Roof2,....,Roofn).

Body=(PointArray, Height, LOD), Roof=(BoundaryArray, FeaturePointArray, LOD).

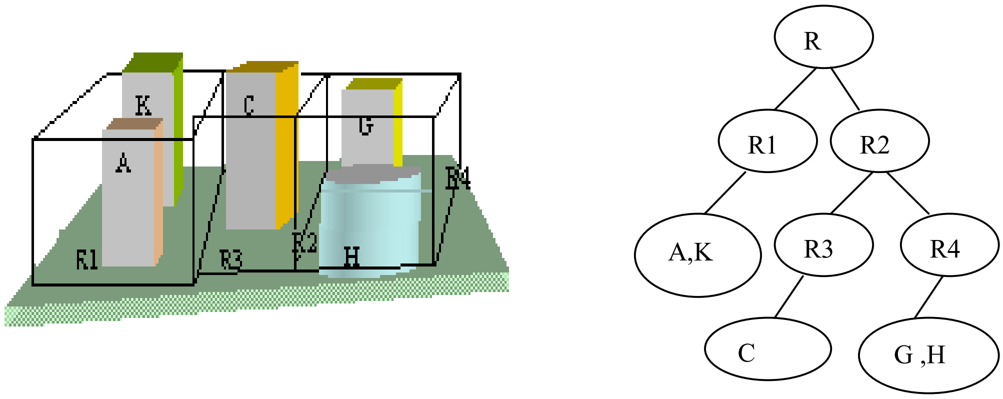

Figure 3: R-tree index

The data of building model, its index and LOD info are stored in the database. Once the query scope is determined, the knot of R-tree is traversed. The buildings are in this scope can be acquired from the database.

4 EXPERIMENT

Combined the LC model and the data structure of storing of building model, a system , joining aspects of visualization interface is implemented to visualize and analyze the 3D building models, moreover, in this system, the building model can be combined with DEM model to construct 3D city model. Similar to real world, it can visualize a existing city model or a plan about city planning or design perspective, creating new building model, analysis and query the attribute data of buildings, walk through or fly through along a defined route or navigate by mouse. The user is able to change the visualization process according to his/her viewing habits, it provide a interactive process during walking through or flying through, which allows user to input information during procedure of visualization to construct a free envision space to walk or fly in it. Moreover this tool can support different LOD which means it can display areas and objects at different LOD focusing on the detail character of single building or entire urban landscape. Several experimental results are shown as follow:

Figure 4 3D building model

5 CONCLUSIONS

The creating and data model of building models are necessary for generating 3D city model of high fidelity, at the same time, storing of large amount of spatial data and attribute data also is of vital importance. The 3D city model is very useful in many fields (landscape analysis, urban planning etc). Interactive operation about building model such as creating new buildings, editing properties of buildings, and so on, is indispensable. In this paper, some researches about creating and storing 3D building model are introduced. Lots of experiments are finished and several conclusions are drawn as follows:

- LC model is developed to construct complex buildings, which not only can be used in automatic reconstructing, but also can be integrated with semi-automatic reconstruction(interactive operation).

- A data structure for storing building model is implemented for the requirements of visualization, interactive operation such as delete, move, query, mapping textures, and so on.

- A system, joining visualization interface and model creator, is developed to create building model and visualize 3D city model.

- Interactive operation about building model, such as create, delete, move, query, mapping textures, and so on, can be fulfilled in this system.

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