From 2D to 3D GIS for CYBERCITY

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ABSTRACT
CyberCity is becoming one of the hotspots in urban information infrastructure. In order to understand the 3D landscape with many high buildings of a city the 2D GIS has to be extended to 3D GIS. The further development of CyberCity has to include various applications of 3D scenes from the outdoor scenes to the indoor ones. In this paper, some key techniques, such as data management method and dynamical visualization method for the outdoor and the indoor scenes, are discussed respectively. The indoor scene is compared with the outdoor one. The idea of integrated representation of the outdoor and the indoor scenes in CyberCity GIS is discussed.

KEY WORDS: CyberCity, Three-dimensional, The outdoor scenes, The indoor scenes, Integrated representation.

1 INTRODUCTION

Since coming into the 21st century, CyberCity is becoming one of the hotspots in urban information infrastructure. Until now, CyberCity is mainly applied for the outdoor scenes including natural and cultural objects such as DEM, rivers, roads, vegetation and building surfaces. In these applications, users can walkthrough, visit city landscape, and implement some operations such as querying, editing and analyzing in the outdoor 3D scenes except the indoor ones. Nevertheless, it is well known that in the real world, buildings, where people study, work or entertain, etc., are the most important part in a city. Therefore, the further development of CyberCity should include various applications from the outdoor scenes to the indoor ones. And, the integration of the outdoor and the indoor scenes in CyberCity GIS is increasingly impending.

2 REPRESENTATION OF 3D BUILDINGS BASED ON CAD OR GIS

At present, architectural indoor 3D scenes furnished with a great many detail objects (furniture, electrical appliances, and cables, etc.) are primarily applied in the domains such as architectural and decoration design, intelligent edifice, virtual mall, HVAC (heating ventilation and air conditioning), CAFM (computer-aided facilities management). They are generally based on CAD. Their 3D scenes are usually a community or a separate building. They emphasize the visualization of the building models without regard to the GIS functions such as interactive querying, editing and analyzing for graphics and attribute data. Furthermore, they do not include the geographical data such as digital line graph, DEM or digital orthoimage map.
On the contrary, just like the outdoor applications, which are based on 3D GIS in CyberCity, the indoor applications in CyberCity can also be considered as 3D GIS.
In CCGIS, a CyberCity GIS software, developed by the National Key Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing, China, a primary integration of the outdoor and the indoor scenes based on 3D GIS is achieved.

3 DATA MANAGEMENT

3.1 The Outdoor Scenes

As data of CyberCity consists of 3D vector models, texture images, DEMs, and multimedia attributes, CyberCity GIS is expected to support effective data access through integrated database management. CCGIS implements data handling including the spatial index (such as R^+ tree), data selection, and clipping in perspective space; the data subsection process; and dynamic loading. For the hybrid management system of files and relational database system is hardly able to manage and index large amounts of data and to control multi-user access, as an alternative to the object-oriented database system which is still used infrequently for GIS, for a large CyberCity an object relational database system (ORDBS) like Oracle8.i is the first choice in CCGIS, and for some special applications in small districts the file system is also provided. For the purpose of fast visualization of 3D city models, based on the object-oriented method, an effective data organization strategy combining the LOD concept for the integration of raster and vector data is designed.

3.2 The Indoor Scenes

Geometrical data of an indoor scene can be distinguished into two parts called architectural structure and detail objects. Architectural structure includes wall, floor, room, stairs, girders, etc. Detail objects include furniture, electrical appliances, lamps,

cables, etc. Architectural structure, which determines the room structure, is relatively stable. Detail objects may be moved, added, deleted frequently as necessary.
A large building structure is usually composed of 3 parts, namely annex, top floor and standard floor. In 3D space, the architectural model is an extending in the upright direction of the 2D floor plan. Therefore, a building may be subdivided in a 2D space according to the 2D plans of the three parts, respectively. Each floor is subdivided into 2D polygons whose boundaries coincide with major opaque surfaces (e.g., walls) using floor plans. To subdivide the floor plan, a floor plan is digitized into a cell (or room) polygon layer and a portal linear layer with softwares such as Arc/Info, Arcview GIS or Auto CAD, etc. in above subdivision principle. In the room polygon layer, a floor plan is subdivided into many polygons, which individually corresponds to a certain room or corridor. Here, a corridor is considered as a particular room.
On the basis of the coordinate positions of all portal and wall segments in the above two digitized layers, the room-portal relationship that which portals a room includes and which rooms a portal belongs to can be set up. And, according to the position relationships among the detail objects and the room polygons, the room-object relationship can be set up. Then, the hierarchical structure of building→floor→room →detail object may be formed.

4 DYNAMICAL INTERACTIVE VISUALIZATION

3D dynamic interactive visualization is a fundamental feature of a CyberCity GIS. Dynamic visualization stands for the real time loading of the necessary data subset, and interactive visualization means the manipulation in virtual modes, such as the walkthrough or flyover models.

4.1 The Outdoor Scenes

Even if the entire database of a CyberCity is available, it is no longer possible to keep all the data in the memory of the workstation.
The memory paging technique is first used for dynamical data loading and the realtime generation of virtual models, i.e., a certain amount of memory is located at first. For a DEM and orthophoto images, the volume and subdivision of the memory page coincide with the block as planned when creating the databases. For the object texture imaging and the vector models, the volume of the memory page depends only on the planned rendering times and number of triangle facets per frame. Only at the start should the full page of data be loaded and updated, so we call this the dynamical data page.
In addition, LOD technique is used to improve the performance of realtime walkthroughs. For objects near the viewpoint the higher detail level is kept and for the objects far away from the viewpoint the lower detail level is kept. In the data page, the objects in different blocks may be displayed at various levels of resolution and quality. Because it is impossible to avoid the visible loss of quality when the terrain texture

images of the same frame are at different resolutions, the resolutions of the orthoimages on all the data page blocks are identical. However, because the DEMs are at different levels of detail, another special process has to be adopted to remove the seam between DEMs when rendering. Fortunately, because the resolution difference of any two adjacent DEMs is determined beforehand, simple but fast approaches can be used to solve the seam problem.

4.2 The Indoor Scenes

As a large furnished 3D architectural model is usually made up of millions of polygons, ideal frame rates for smooth interactive walkthroughs in an indoor scene are hardly available. Visibility processing for potentially visible set of polygons (PVS) is of great importance in improving performance for interactive indoor walkthroughs.
Based on the above indoor subdivision and the room-portal relationship table, we implement a visibility algorithm of constructing room-to-room PVS and view-to-room PVS for arbitrary architectural structures that is presented in (LIU Qiang and LI Deren, 2003), namely, not only simple axis-aligned architectural structures but also non-axis-aligned ones, or even those with concave rooms. First, we precompute and construct room-to-room PVS, namely a set of all rooms potentially visible from a room through its portals. Certainly, the computing time is irrespective of the velocity of walkthrough. Hence, in the process of realtime walkthrough, on the basis of the room-to-room PVS of the room where the current viewpoint is, we further compute the view-to-object PVS of the current viewpoint, namely the set of all detail objects potentially visible from the viewpoint, and render the architectural structure and all detail objects in the view-to-object PVS. Contrarily, Detail objects that are not in the PVS will not be rendered. For the PVS is usually a rather small subset of the set of all detail objects in the indoor scene, the number of triangles needed rendering is decreased greatly. Test shows the performance of real-time interactive walkthroughs in a large building 3D model can be drastically improved.

5 THE COMPARISON BETWEEN THE OUTDOOR AND THE INDOOR SCENES

According to the above methods of data organization and management for the outdoor and the indoor scenes, we can implement not only the realtime interactive walkthrough, but also some basic 3D GIS functions such as editing, querying and analyzing for graphics and attribute data both in the outdoor and indoor scenes. The outdoor and the indoor scenes can be compared each other as follows:
Dimensions: On account of being based on DEM, strictly speaking, the outdoor scenes should be called 2.5D GIS. However, on account of being based on the architectural structure, which has different floors in upright direction, the indoor scenes can be called real 3D GIS.

Amount of data and visualization: Both of them have vast geometrical data, and they need to apply some methods, such as LOD or visibility computation, to improve the rendering performance.
Fundamental data: the fundamental data in the outdoor scenes is DEM; that in the indoor scenes is the architectural structure model.
Objects: the outdoor scenes include river, vegetation and municipal infrastructure, etc.; the indoor scenes include the detail objects such as furniture, electrical appliances, lamps and cables.
Editing function: Both of them can layout, edit or update the 3D scene.
Interactive querying function: They are similar. For example, in the outdoor scenes we can click a certain object geometry (for instance, a road) to query its attribute, and in the indoor scenes we can also click a detail object geometry (for instance, a desk) to query its attributes.
Statistics function: In the outdoor scenes we can determine the statistics area in multiple ways, for example, the number of buildings over 50 meters can be calculated with a polygon edited interactively on a 2D map, or with a block polygon; in the indoor scenes the number of detail objects can be calculated with a floor unit or a room unit.

6 AN INTEGRATED REPRESENTATION OF THE OUTDOOR AND THE INDOOR SCENES

As mentioned above, the outdoor and the indoor scenes are discussed respectively. They are considered relatively as separate parts. Nevertheless, only after achieving the integration of the outdoor and the indoor scenes, a CyberCity can be called a whole one, where we may feel that just like the real world, the outdoor and the indoor scenes form an organic whole.
In CyberCity, the construction of the indoor scene will make the vision integrated, namely, we can see the indoor scenes or look at the outdoor scene through the window from the indoor scene. And, along with the change of viewpoint from far to near, the buildings of the CyberCity will form a LOD structure from coarse to fine, as illustrated in Figure 1.
The techniques for dynamical walkthroughs applied in the outdoor and the indoor scenes individually can meet the demand of the realtime walkthrough frame rates in both the outdoor and the indoor scenes. Thus, we can produce smooth sense both in the outdoor and in the indoor scenes.
The techniques for data management applied in the outdoor and the indoor scenes can make both the outdoor and the indoor scenes have the basic GIS functions respectively. Therefore, in GIS functions they achieve an integration.
With R^+ spatial index tree, the whole area is subdivided into several rectangual subareas. A global table is applied to manage the subdivision information in the database. Each leaf node corresponds to a geometric object. Each building is a special

leaf node, which is a subtree in the meantime formed by building structure model and detail objects with the hierarchical structure of building→floor→room→detail object. Based on the R^+ spatial index tree, in the process of realtime walkthrough, while the visitor is situated at the outdoor scene, the outdoor data such as DEM, orthoimages, roads and water pipes are dynamically loaded, whereas, for buildings only corresponding building structures except indoor detail objects are loaded and rendered; while the visitor is situated at an indoor scene, on the one hand, the corresponding building structure and detail objects in the PVS are rendered, on the other hand, according to the visible range of the outdoor scene through the portals from the current viewpoint, the outdoor data such as DEM, orthoimages and roads and other building structures are dynamically loaded and rendered.

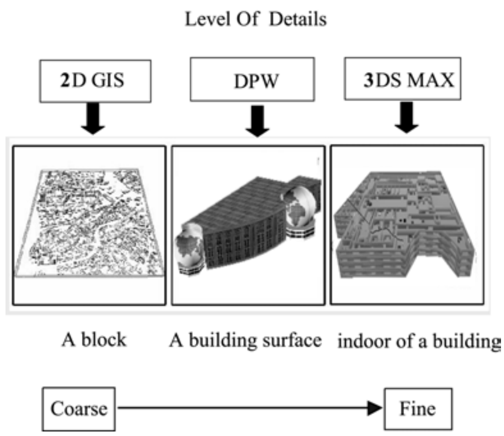

Fig. 1. LOD of buildings in a CyberCity

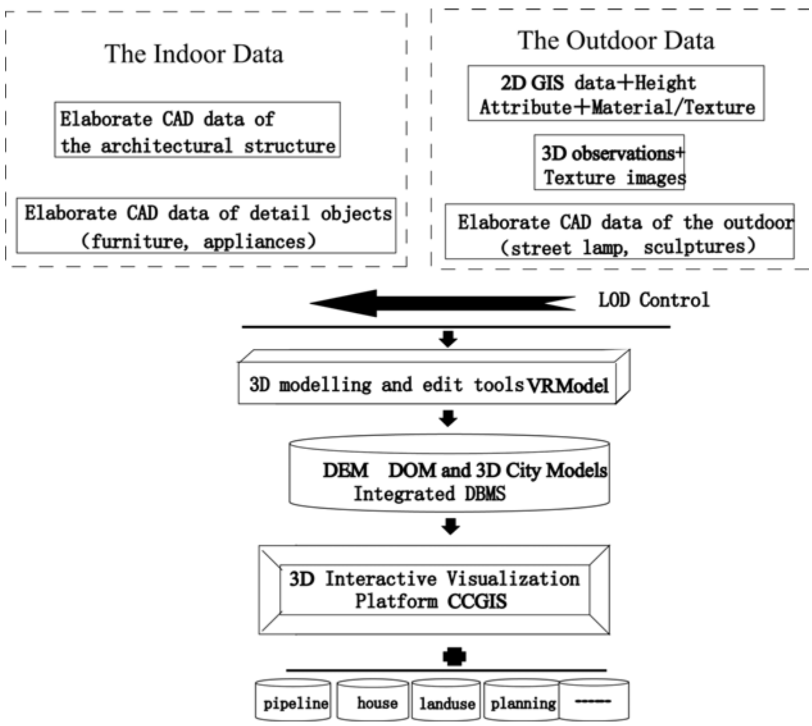

Fig. 2. The architecture of CCGIS

In data loading an organic integration can be achieved. For example, when we walkthrough in the outdoor scene, the architectural structure models but not the detail objects models within the view field need to be rendered. While, when we walkthrough into the indoor scene, the potentially visible detail objects models, and DEM, rivers and municipal infrastructure within the view field need to be rendered.

In a CyberCity with the integration of the outdoor and the indoor scenes, we may imagine as follows: for a land parcel in a certain city, an estate agent can query and evaluate its commercial value to determine if he should buy it to construct buildings or not. After buying the parcel and finishing the design of the 3D building model, he can put the building model in the CyberCity. He can evaluate the design effect in 3D CyberCity. Before construction, the amount of excavation and fill can be calculated in the CyberCity system. Then, under construction, with the help of CyberCity system, he can implement effective management of the construction. After the construction is completed and the building works as an office one, the HVAC or CAFM for the building can be implemented in the CyberCity, etc.

Figure 2 illustrates the structure of CCGIS with the integrated representation.

Figure 3 illustrates indoor and outdoor scenes of LIESMARS building in Wuhan University.

7 CONCLUSIONS

In this paper, the techniques of data management and dynamical interactive visualization for the outdoor and the indoor scenes are discussed, the outdoor and the indoor scenes are compared, and the integration of the outdoor and the indoor scenes are discussed. It can be believed, in the near future CyberCity, just like the real world, the outdoor and the indoor scenes will form an organic whole.

8 ACKNOWLEDGEMENTS

The research described in this paper was funded by '010302 Funded by Open Research Fund Program of LIESMARS' founded by National Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing, China.

(a) The outdoor scene

(b) The indoor scene

Fig. 3. The scenes from outdoor to indoor of LIESMARS

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