The Research and Development of 3D Urban Geographic Information System with Unity3D

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Abstract—3D urban geographic information system (GIS) is of great importance in urban planning, management and decision support. However, the system development is difficult from the infrastructure perspective or expensive based on the professional GIS platform. Therefore, this paper puts forward the development method of 3D urban GIS with the Unity3D game platform. The thought and technical framework are introduced firstly. 3D modeling, attribute data management and query, scene browsing and analysis methods are presented secondly. And a satisfactory result has been achieved through the development practice and proves that the method is feasible. This research also explores a new way in small 3D urban (county-level) GIS development and application.

Keywords—3D system development; urban GIS; Unity3D; 3D modeling; scene browsing

I. INTRODUCTION

3D urban GIS is a special form of GIS which represents objects of urban area with true 3D models, and provides query, browsing, management and analysis functions. With the deepening application of GIS, the rapid development of computer science and technology, the demand for improving the level and efficiency in city management and visual management, the development of 3D urban GIS has been an urgent and important direction [1-3].

At the present, the main development methods of 3D urban GIS can be divided into two kinds. One develops the system from infrastructure, which uses Visual Studio, OpenGL and DirectX and other open source software tools or technologies. However, this is difficult to achieve due to the need for large manpower, time, and strong abilities in programming. The other develops a system based on professional GIS platforms with programming languages. The primary development platforms include ArcGIS, MapInfo, MapGIS, SuperMap, etc. However, the high cost of software greatly restricts the development and application of small 3D urban GIS on the county level.

As we all know, the main object is models in the general 3D scene and 3D game scene. Therefore, it is feasible to use Unity3D to make a general 3D scene. In spite of fact that Unity3D is weak in terms of spatial analysis, it has its advantages in 3D visualization, 3D scene editing and high cost-effectiveness on development [4]. This paper puts forward the development method of 3D urban GIS based on Luanchuan 3D urban GIS with Unity3D. In this paper, the basic structure is described as follows: II introduces the development thought and technical framework, III is a study of the 3D modeling methods, IV is study of the data management and query methods, V is a study of scene browsing and analysis methods, and the conclusion is given in VI.

II. THE DEVELOPMENT THOUGHT AND TECHNICAL FRAMEWORK

The system development mainly includes three parts, e.g., the 3D modeling, attribute data management and query, and the 3D scene browsing and analysis. The development thought is using 3DMax to build the object model; using Unity3D to generate the terrain model, manage 3D model and realize visualization; using the SQLite database to manage attribute information; and using the script programming to realize attribute information query. 3D scene browsing and analysis. The framework is described in Fig. 1.

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III. THE 3D MODELING METHOD

A. Classification of 3D Modeling

The modeling objects are divided into seven categories, i.e. terrain, building, road, vegetation, water, pipeline and sketch. Specific classification and subclasses are shown in Table I.

<table>
<thead>
<tr>
<th>Category</th>
<th>Category Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrain</td>
<td>Null</td>
</tr>
<tr>
<td>Building</td>
<td>Fine, Simple model</td>
</tr>
<tr>
<td>Road</td>
<td>Null</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Tree, Spherical, Ribbon vegetation</td>
</tr>
<tr>
<td>Water</td>
<td>Null</td>
</tr>
<tr>
<td>Pipeline</td>
<td>Sewage, Storm water, Water supply, Heating, Gas, Communications, Power supply pipeline, etc.</td>
</tr>
<tr>
<td>Sketch</td>
<td>Street lighting, Litter bins, Signage, Bulletin boards, etc.</td>
</tr>
</tbody>
</table>

B. The Key Problems of 3D Modeling

1) Terrain modeling

Terrain modeling is generated with Unity3D based on digital elevation model (DEM), the methods of generating DEM based on ArcGIS and generating terrain model based on the DEM are introduced in the following steps.

a) Extract contour lines and elevation points and save as .shp data. The .shp data are described as Fig. 2(a).

b) Generate TIN data by contour lines, further modify TIN data by elevation points;

c) Convert TIN to grid, then convert grid to DEM, setting the resolution. DEM is described as Fig. 2(b).

d) Import the DEM into Unity3D and generate 3D terrain model. Terrain is described as Fig. 2(c).

2) 3D tree modeling

The methods mainly include three kinds, e.g., model-tree, plane-tree, and cross-tree. All method contain limitations [5]. The model-tree is difficult to build and the data quantity cannot conform to the requirement of real-time rendering. The plane-tree and cross-tree both have problems of distortion in lighting [6]. This paper chooses the cross-tree method for tree modeling through trial and testing, and improves the overlooking effect through increasing the cross plane. The method is described as follows:

a) Extract texture with Photoshop

Extract texture and add the Alpha channel. In order to extract rapidly, efficiently and beautifully on the texture, we try to choose representatively the single-background tree images.

b) Model based on cross-tree

According to the height of the tree and the width of the canopy, the 3D tree models which carry with texture is built in 3DMax.

c) The method of improving overlook effect
Two titled planes are putted where the planes’ heights are equal to the canopy’s height and the width is slightly smaller than canopy’s width on the plane of vertical direction.

3) Building modeling
Considering the effect and benefit of system, the building models are divided into two kinds. One is the fine model, e.g. landmarks buildings, special requirements and protective buildings, schools, etc. The other is the simple model, e.g. residential buildings, temporary buildings, etc. [7]

The collection of buildings’ texture is an important work for the building model. The collection work includes making plans, data recording, classification, and data processing. According to the classification and data condition of Luanchuan County, the outline and surface of building structure information are extracted based on the architectural design drawing (e.g. DWG data). The modeling process is described as Fig.3.

Building planning and design drawing

Contour information
Walls, Windows, etc.

3DSMax

3D model
Texture

Simulation model

Figure 3. Modeling process

IV. THE DATA MANAGEMENT AND QUERY
The query function development includes the collection of attribute information, the definition of data table and the script programming.

A. Attribute Data Definition
The database which stores building attribute information is established on SQLite. The attribute data table is defined and shown in Table II.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Field Properties</th>
<th>Empty or not</th>
</tr>
</thead>
<tbody>
<tr>
<td>encoding</td>
<td>string</td>
<td>not</td>
</tr>
<tr>
<td>Name</td>
<td>string</td>
<td>not</td>
</tr>
<tr>
<td>Rights holders</td>
<td>string</td>
<td>yes</td>
</tr>
<tr>
<td>Area</td>
<td>float</td>
<td>yes</td>
</tr>
<tr>
<td>Height</td>
<td>float</td>
<td>not</td>
</tr>
<tr>
<td>Floor</td>
<td>int</td>
<td>yes</td>
</tr>
</tbody>
</table>

B. Attribute Information Query
1) The query classification and implementation method
The query mode is divided into two kinds, one is attribute query. Get the query field and query information firstly; extract the records and the keyword which conforms to the requirement secondly; search the object model associated with the keyword in the 3D scene lastly. The other is click query. First, get the keywords which are associated with the interested objects; second, extract records from database according to the keyword.

2) The query result output:
Whether it is the attribute query or click query, the results include text and model information. The text information is shown in labels or floating windows; while the model is centered, magnified, and highlighted on the screen.

V. 3D SCENE BROWSING AND ANALYSIS
A. Model Importation and Scene Production
Scene production is the process of forming a complete 3D scene with terrain, model and environmental factors [8]. This paper uses Unity3D to realize scene production. The object model can be imported into Unity3D in .MAX or .FBX files. The 3D scene production is completed through model placement and the setting of the light angle, strength and shadow. Fig. 4 is a part of the 3D scene.

Figure 4. The part of 3D scene

B. 3D Scene browsing and Analysis
In order to browse 3D scene freely, the camera should be bound to the keyboard (e.g. WASD keys) and mouse. According to the principle of ray, the browsing path should be generated through the election and store of the ground points in the 3D scene, and automatic flight along the path should be realized through Unity3D script programming [9, 10].

Measurement analysis steps are described as follows: First, get and store the measurement points according to actual demands; then, generate geometry and select the appropriate
calculation model based on the type of measurements (e.g., distance, area, height, etc.); finally, calculate and display the results. We provided data support for the analysis and decision making of users through spatial measurement. The work of the measurement is to get the measurement points in the 3D scene, the codes and remarks of getting space point are shown as follows:

```csharp
Ray ray = Camera.main.ScreenPointToRay(Input.mousePosition); // According to the mouse in screen coordinates, launch rays in 3D space.
Physics.Raycast(ray, out hit, 1000);  // Return the collision point.
Newobj.transform.position = hit.Point;    // Set tag at the collision point
Point[i] = Newobj.transform;     // Store the collision point coordinates
```

VI. CONCLUSIONS

3D urban GIS is of great importance in urban planning, management and decision support. However, the system development is difficult from infrastructure or expensive based on the professional GIS platform. This paper proposes the development method of 3D urban GIS with Unity3D and introduces the methods of attribute data management, query, 3D modeling, scene browsing and analysis. The successful development of the Luanchuan 3D urban GIS proves that the path is feasible, and also explores a new way in small 3D urban GIS development and application. However, the spatial analysis ability of Unity3D is weak. Therefore, enhancing the spatial analysis function of the Unity3D system requires further exploration and research.

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REFERENCES
