Computer Aided 3D Information Geographical Modelling System and Simulation in Building Structure Optimization

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Abstract. This study takes the construction of the geospatial framework of the digital city as an example, and focuses on the application of the construction of a three-dimensional geographic information system in the optimization of building structures. We use the sketch master 3D modelling module to achieve 3D modelling of buildings, and use its interface with ArcGIS software to implant it in the 3D information geographic system to build a large-scale 3D digital application module for urban buildings. The system realizes 3D browsing and application.

Keywords: 3D information geographic modelling system, architectural structure optimization, sketch master, model optimization, data cache.

1. Introduction
Since the development of GIS, we already have a large amount of complete two-dimensional GIS data and keep it updated, but the real world exists in three-dimensional space. With the help of two-dimensional GIS data to express three-dimensional spatial information, the elevation of objects is often only exist as ancillary information [1]. With the development of GIS applications, the importance of elevation information has become more and more prominent, but the lack of expression of two-dimensional GIS data has made it difficult to meet the objective needs of information development for information data. The emergence of 3D GIS data has made up for the lack of spatial expression of 2D data. It can not only accurately reflect the accurate information of objects in real space, but also provides the possibility for information analysis and processing in 3D space. In contrast, the production mode of virtual 3D modelling is more conducive to the development of applications, so this article will briefly introduce the application of the virtual 3D modelling representative software 3DMAX in the 3D GIS city building data modelling process, and explain the production of virtual 3D modelling Model and data characteristics, and finally introduce some experience of 3DMAX in 3D GIS data optimization.

2. Building modelling and GIS application

2.1. Modelling platform development
The establishment of a large-scale building three-dimensional model should fully consider various factors such as the amount of data, the precision of the model, the modelling cycle, and the commonality of model data [2]. In addition to the three-dimensional models that directly reflect the
real world, the three-dimensional GIS platform must be used to process and use these three-dimensional models, and provide various geographic analysis functions. ESRI Arc GIS provides the 3D module Arc Globe. Arc Globe is suitable for large-scale data display in the whole city, the whole province, the whole country, and even the world. It is designed to display scenes with large data volumes. Based on a global perspective, the data is displayed in hierarchical and divided blocks to improve display efficiency. The new version of ArcGIS has been able to directly edit 3D elements, providing analysis functions such as 3D vector analysis and 3D dynamic tracking, providing a lot of room for expansion in future 3D applications.

2.2. Principle and process of 3D model establishment
Essentially, 3D modelling consists of geometric modelling and texture mapping. It is divided into three steps: establishment of three-dimensional geometric model, texture mapping and model optimization, as shown in Figure 1.

3. Multi-angle image 3D modelling principle of large building structure

3.1. Control network data collection and processing
Due to the use of a fully digital operating process, field data collection does not have to follow the principle of first overall and then partial, first control and then fragments, if the internal calculation adopts this principle. The plane control generally adopts the form of the corner net to arrange the net, and the internal business obtains the plane coordinates of the control point after the adjustment calculation [3]. The elevation control adopts the form of triangular elevation measurement to be deployed synchronously with the plane network. The elevation control network can be adjusted independently or with the plane .Net joint directly performs three-dimensional adjustment.

3.2. Data collection and coordinate calculation of broken parts
When the prism-free laser ranging total station performs non-contact data collection, the observation values of each fragment point are the horizontal disk, vertical disk, and slant distance readings. The three-dimensional point position calculation formula of the fragment point is as follows:

\[
\begin{align*}
    x &= x_0 + S \cos \alpha \cos (\beta_0 + \beta) \\
    y &= y_0 + S \cos \alpha \sin (\beta_0 + \beta) \\
    h &= h_0 + S \sin \alpha + i
\end{align*}
\]
Among them, the point coordinate of the measuring station is \((x_0, y_0, h_0)\), which is the azimuth angle in the backsight direction, \(\beta\) is the horizontal angle, \(\alpha\) is the vertical angle, \(S\) is the slope distance, and \(i\) is the instrument height.

### 3.3. Building structure node calculation

Current buildings are generally frame and brick-concrete structures. For houses with this structure, the nodes are the intersections between the centre lines of beams and beams or beams and columns. Therefore, it is impossible for us to directly measure through the total station. The three-dimensional coordinates of the output node. This paper derives the mathematical calculation model of the node for the special case of calculating the structure node. As shown in Figure 2, \(f\) and \(g\) are the dimensions of the cube, points A, B, and C are the measured fragment points, and N is the node. Due to the damage of the earthquake and the characteristics of the building structure itself, in the actual survey process, the three-dimensional coordinates of node N cannot be directly measured with measuring instruments, and the pillars on the wall can only be seen on one side, so it can only be measured by other the coordinates of the points indirectly derive the three-dimensional coordinates of the centre node. The coordinates of points A, B, and C can be accurately measured with a total station, respectively (\(X_A, Y_A, Z_A\), \(X_B, Y_B, Z_B\), \(X_C, Y_C, Z_C\)).

![Figure 2. Schematic diagram of the node model.](image)

If \(\Delta=+1\) (due to the measurement error, this condition will not be strictly met, use \(\Delta>0\) to judge), then it is a right-handed system, indicating that this solution is the solution of model 1; if \(\Delta=-1\) (due to measurement error, this condition will not be strictly met, use \(\Delta<0\) to judge), then it is the left-handed system, indicating that this solution is the solution of model 2. Finally, the three-dimensional coordinates of node N can be calculated as follows:

\[
\begin{bmatrix}
    x_N \\
    y_N \\
    h_N
\end{bmatrix} = \begin{bmatrix}
    x_b \\
    y_b \\
    h_b
\end{bmatrix} + \frac{f}{2} \begin{bmatrix}
    \cos \alpha_{BC} \\
    \cos \beta_{BC} \\
    \cos \gamma_{BC}
\end{bmatrix} + \frac{g}{2} \begin{bmatrix}
    \cos \alpha_{DN} \\
    \cos \beta_{DN} \\
    \cos \gamma_{DN}
\end{bmatrix}
\]

(2)

### 4. Data processing method

#### 4.1. Data reprocessing

In the early stage of 3D modelling, the first step is to process the data required for modelling. 2D vector data is the basis of 3D modelling. In the process of 3D modelling, vector data is required to have the characteristics of high accuracy, good current situation, and standard data format. High accuracy means that the vector data must meet the modelling requirements. If the accuracy is not up to the requirements, the subsequent modelling work will be used up. Good current situation means that
the two-dimensional vector data must be as consistent as possible with the collection time of field photos, the shorter the better [4]. If the time interval is too long, there may be inconsistencies between the photo and the topographic map, which will affect subsequent operations. The data format standard means that the data that meets the requirements of the project operation must be imported into the software. At the same time, it should be based on the accuracy requirements of the project operation to simplify the complex, highlight the main characteristics of the building, modify, and simplify the two-dimensional vector data, and delete some A point or line that is not a key element. It should be noted that the main corners of the building cannot be simplified.

4.2. Digital model modelling

In 3DMAX, polygon modelling, NURBS modelling and patch modelling are three common modelling methods. Since the three-dimensional GIS modelling takes regular geometric buildings as the main object, the modelling method often adopts the polygonal modelling method. According to the modelling sequence of "main body modeling→feature performance", the realization method can be simply summarized as follows: 1) Through the analysis of the appearance of the building, use as few simple geometric models as possible to construct the main body of the building. 2) Omit local details, highlight the characteristic local appearance, use editable lines to outline the outline, generate and copy by extrusion. The modelling process only completes the structure of the three-dimensional spatial information data. In order to realize the realism of the virtual building model, it is necessary to assign textures to the model [5]. With the help of the partial textures made in the pre-processing stage of real photos, we can implement them in the "Material Editor" of 3DMAX. Using the "Material Editor", we can use textures to simulate the surface gloss, texture, shading and other effects of the object, so that the performance of the model is closer to the real. It is worth noting that the texture needs to be matched with the correct texture coordinates and size on different faces of the model in order to correctly realize the real simulation effect. In 3DMAX, we use the "UVW Edit Modifier" to manage the coordinates of the texture. "UVW" refers to the texture coordinate system, which is different from the XYZ space coordinate system in the modelling scene. It splits the coordinates of each surface of the model, so that these surfaces are developed into a plane, and then each surface is attached with Accurate map of spatial orientation. Figure 4 shows the effect of combining UVW textures based on modelling.

![Figure 3. UVW mapping effect of architectural modeling.](image)

4.3. Optimization of modelling data

Since the construction scope of a 3D geographic information system is often a city, the amount of data is large, and the operation of big data will inevitably bring pressure to the system. The speed of system operation is also an important aspect of judging a system, so the optimization of 3D modelling data has become a popular research direction in the construction of 3D geographic information systems. In
order to achieve the goal of "achieving the best virtual performance with the least model data", this research optimizes the data from the following three aspects.

4.3.1. **Optimization of the number of faces.** Surface is the basic unit of 3Dmax model. Under the premise of satisfying the virtual performance of the model, the number of surfaces used in modelling should be reduced as much as possible. Usually, the optimization of the surface is mainly to delete the overlapping repeated surface, the surface that is invisible to the outside model, and the bottom surface of the building [6]. At the same time, in the case of meeting the accuracy requirements of the project, the vector data processing link should be simplified as much as possible. Lines and points are mainly used to reduce the number of faces during modelling.

4.3.2. **Number optimization.** The number of models is also an important aspect of optimization. The more models, the heavier the system load. Therefore, in order to simplify the model, under the premise of ensuring the requirements of the project, the model can be made by overall modelling for dense buildings or residential areas facing the street.

4.3.3. **Optimization of texture mapping.** Texture mapping is one of the important factors for the operation of the image 3D system. The size and quantity of textures directly determine the amount of data. Under the premise of ensuring accuracy, the number of texture maps should be controlled as much as possible. A texture map material library can be established during the construction of the project. For some textures that can be represented by the material library, use the texture library texture as much as possible, such as: doors, windows, walls, Pavement, etc. This not only reduces the workload of processing pictures, improves work efficiency, but also reduces the number of textures and improves the running speed.

5. **Experimental analysis**

The local point cloud data of the Niagara area provided by ISPRS in 2011 was selected as the experimental data, and the registered real radio image TDOM was used for contour reconstruction accuracy check. The number of laser points in the area is 146,215, and the average density of the point cloud is about 2.2 points/m². The area contains many typical multi-storey buildings with different sizes; at the same time, the shape of some buildings is extremely irregular, and the accuracy of contour regularization and consistency processing can be evaluated more objectively [7]. We use the area growth algorithm proposed in literature to extract the building data and hierarchical structure information in the area; use the regularization method based on subject orientation constraints proposed in literature to regularize the roof profile, and the results are shown in the figure 5 shown.

![Figure 4. Details of building consistency processing.](image)

In order to further evaluate the reconstruction accuracy of the three-dimensional contour model, a quantitative evaluation method is used to compare with the manual accurate drawing results of the point cloud TIN and TDOM in the combined area shown in Figure 4, and the mean error (Mean E) and
average of the contour inflection point are calculated. Root square error (RMSE) and maximum displacement (Max D), the results are shown in Table 1.

|       | Mean E | RMSE | Max D |
|-------|--------|------|-------|
| X     | 0.35   | 0.41 | -0.81 |
| Y     | 0.29   | 0.34 | 0.86  |
| Z     | 0.21   | 0.13 | 0.58  |
| Flat  | 0.46   | 0.52 | 1.18  |

It can be seen from Table 1 that the average error and the root mean square error of the automatic reconstruction results of the building contour in this method are less than the average distance between laser points (0.68m), and the maximum displacement of the contour inflection point is also less than twice the average distance between laser points. The overall reconstruction accuracy is high.

6. Conclusion
Although this article only briefly describes the application of 3DMAX in 3D GIS modelling, the characteristics of model data, and optimization settings, etc., the purpose is to show you how the 3D GIS model data is in the modelling process of virtual 3D modelling. Some commonalities. This paper uses the mature 3D graphics standard OpenGL, based on the maintainable data structure, to realize the 3D visualization of the modelling process and calculation results for the typical structural numerical analysis models such as the segmental variable stiffness unit model, the discrete unit model and the multi-spring model, and Attempt to apply to solve the problems of calculation model checking, component crack depiction, component elastoplastic deformation display, and three-dimensional animation performance of structural collapse response.

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