Research on BIM Forward Design Based on Oblique Photogrammetry Reality Model

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Abstract. With the rapid development and steady advancement of Building Information Modeling (BIM) technology in China, traditional 2D Digital Line Graphic (DLG) data cannot visually display rich 3D spatial information, and it is difficult to meet the needs of BIM forward design. Aiming at the increasing demand for 3D spatial data in municipal project design, this paper proposes a forward design method based on oblique photogrammetry reality model. Firstly, the Quadric Error Metrics (QEM) algorithm is used to lighten the reality model. Secondly, the standard model library of municipal facilities is built in CATIA, and the lightweight reality model is integrated into CATIA for fine restoration. The refined reality model can provide BIM designers with reference to features, geomorphology, etc., avoiding unreasonable spatial planning, no external reference to model monomers, and missing model space location information. It is convenient for designers to design, display, compare and modify the scheme in the same platform to improve the efficiency of BIM design. Change the delivery form of traditional surveying and mapping data results, and encourage designers to use BIM technology for forward design from surveying and mapping, and accelerate the popularization and promotion of BIM technology in the whole life cycle of the construction industry.

1. Introduction

With the growing maturity of technologies such as big data, AI, VR, mobile communication, cloud computing, Internet of Things, UAV technology and the integration of multi-technology in different fields, the construction pace of smart city has been accelerated, and the construction industry has been transformed and upgraded to the direction of informatization, intellectualization and green environmental protection. CAD technology pushes manual drawing to computer aided drawing, realizing the first information revolution in engineering design field. However, the supporting role of this information technology on the industrial chain is a breakpoint, and there is no correlation between various fields and links. From the overall point of view of the industry, the comprehensive application of information technology is obviously inadequate. Building Information Modeling (BIM) technology perfectly combines the information model of building life cycle with the model of building engineering management behavior to achieve integrated management, bringing a second revolution in the field of construction industry. BIM technology not only revolutionizes the whole life cycle from two-dimensional design to three-dimensional design, but also, more importantly, changes the...
collaboration mode of all parties involved in the project and people's work coordination concept for the whole construction industry.

BIM technology is widely used in engineering project design, construction, transportation and management. As shown in figure 1, the BIM design scheme of a tunnel under a road based on traditional two-dimensional DLG data can not effectively support the BIM design scheme by expressing spatial information in three-dimensional way in the process of scheme display, comparison and bidding. DLG is difficult to meet the needs of BIM design. The demand for spatial mapping data in BIM design is increasing. Using spatial mapping data as basic data for BIM design is an important development direction of municipal design in the future. The rapid development of Oblique image measurement technology has laid a solid foundation for rapid acquisition of spatial mapping data.

![Figure 1. BIM design based on DLG](image)

At present, the software and hardware of oblique photogrammetry are developing rapidly, but the real-world model data generated are huge and there are many kinds of distortion. The existing model repair software focuses on different aspects, which can not solve the problem of rapid and refined repair of municipal facilities. Super Map and Skyline Globe are the platforms supporting the fusion of real-world model data and BIM data. The above-mentioned software focuses more on the application of BIM schemes in comparison, display, function analysis, model singularization, data mining, etc. [1]. BIM design based on spatial mapping data mainly integrates DSM, DEM, point cloud data, TIN and image into BIM software for scheme design, comparison, analysis, display and management [2-6]. However, the real-world model data can not be directly used in BIM design. In order to speed up the popularization and application of BIM technology and strengthen the depth and breadth of application of BIM technology, according to the characteristics of Oblique photography real-world model, this paper constructs a standard component model library of municipal facilities in BIM software, which is used for fine restoration of real-world model and rapid design of BIM scheme.

### 2. Lightweight of spatial surveying and mapping data

The essence of BIM design based on spatial mapping is the integration of multi-source data in BIM design software. There are many types of spatial surveying data, various storage formats and huge amount of data. If directly integrated into BIM design software, huge amount of data will reduce the efficiency of data management and transmission, which is not convenient for designers to manage and use. Therefore, the lightweight of spatial mapping data is an urgent problem to be solved.

High density point cloud data can be obtained in various ways, which is the basis of grid construction, while scene model adds corresponding texture information on the basis of grid. Therefore, this paper chooses high density point cloud data and scene model data as the research object of lightweight processing.

#### 2.1 Lightweight point cloud data

Point cloud data lightweight follows the principle of "sparse points where the surface changes slowly and dense points where the curvature changes greatly". In CATIA, the adaptive and Homogeneous methods are used to lighten the high density point cloud data. Under the same parameters, the lightweight results are shown in figure 2 and table 1.
Figure 2. Lightweight comparison

| Filtering algorithm | Sampling parameters | Point cloud quantity | Compression result | Data volume size |
|---------------------|---------------------|----------------------|--------------------|-----------------|
| Adaptive            | Chord length (mm)   | 10                   | 3460688            | 35.73%          | 178.7M          |
|                     |                     | 100                  | 1292485            | 13.35%          | 66.8M           |
|                     |                     | 1000                 | 30252              | 0.31%           | 1.6M            |
| Homogeneous         | Sphere radius (mm)  | 10                   | 9499039            | 98.09%          | 494.5M          |
|                     |                     | 100                  | 4983089            | 51.46%          | 257.3M          |
|                     |                     | 1000                 | 133262             | 1.38%           | 6.9M            |

Under the same parameters, the effect of Adaptive is lighter than that of Homogeneous, but the details are easily filtered out. The filtered point cloud data can provide some reference for designers in a wide range, but the local performance is not good. For the accuracy of the point cloud data after processing, there is no accuracy evaluation analysis yet. BIM designers can select appropriate parameters to lighten the processing according to actual needs.

2.2 Lightweight model data

High-precision scene model can truly present virtual objects, and the complexity of the model is directly related to the amount of data and the cost of calculation. Therefore, while ensuring the accuracy of the model, reducing the amount of data and computing costs, how to automatically calculate and generate simplified models is the goal of grid simplification.

In this paper, Garland's Quadric Error Metrics (QEM) algorithm based on quadratic error as measurement cost is used to simplify the mesh. The algorithm is a folding algorithm, which takes the square of the distance between the vertex generated after edge folding and the correlation plane of the
two end points before edge folding as the error measure. The algorithm has the advantages of small calculation amount, fast simplification speed and high quality of simplification [7, 8]. This paper simplifies the scene model of the same area, and the result is shown in figure 3.

![Figure 3. Model simplification based on QEM algorithm](image)

(a) Facial reduction to 1%      (b) Facial reduction to 60%        (c) Facial reduction to 90%.

When the number of vertices decreases, the number of grids decreases. However, the number of patches in the texture data remains unchanged, and the original texture patches do not match the direction and size of the newly generated meshes, resulting in loopholes in the simplified model. Using QEM mesh reduction algorithm to lighten the scene model data, the results show that: when the number of facets is reduced to more than 60% of the original model, the visual effect of the model is not affected; when the number of facets is reduced to 50%~20% of the original model, the vulnerability area of the model increases gradually; when the number of facets is reduced to 20%~1% of the original model, the model can not be used. Therefore, without affecting the visual effect and model use, QEM algorithm can effectively reduce 40% of the patch size of the model.

3. Repair of scene model based on standard construction library

Unmanned aerial vehicle Oblique photogrammetry technology is to take multi-angle photography of ground objects with one vertical and four Oblique cameras on the same platform. The acquired images have the characteristics of high resolution, large field of view, rich side texture information, and can restore the real scene. However, due to the influence of unmanned aerial vehicle flight platform, weather conditions and software algorithms, there are many distortions, such as loopholes, deformation, uneven texture, suspended matter floating and so on. The existing model repair software, such as 3D Max, Geomagic Studio, Mesh mixer, Context Capture, mainly solves the problems of water surface vulnerabilities, uneven water surface, distortion of building walls, suspended solids in the real model. However, for the distortions of municipal facilities in urban real-world models, such as distorted suspension of traffic lights, vulnerabilities of road signs, blurred information in the figure 4, the existing model repair software and methods are difficult to achieve rapid and refined repair of such facilities.
According to the characteristics of BIM design and real model repair, in order to achieve the goal of fine model repair, this paper takes BIM design software CATIA as model repair platform, and establishes standard model database in the platform. In order to avoid missing information and enhance the expressive effect of the model, the independent model base is divided into four categories according to the mapping element system of two-dimensional DLG, as shown in figure 5.

The standard component model library of municipal facilities is constructed in CATIA. Figure 6 is part of the component model of transportation facilities, including road signs, signal lights, concession signs and high-light.

In CATIA, the standard component model is used to repair the distortions of traffic facilities in the real model quickly and finely. The process and results of the repair are shown in figure 7.
4. Application of forward design

Compared with the traditional two-dimensional DLG data, the BIM design scheme based on spatial mapping data has the characteristics of strong reality, clear expression, high degree of visualization and rich information. Figure 8 shows that the high-density point cloud data are integrated into CATIA after lightweight processing. BIM road design based on point cloud data provides external space reference for designers to avoid unreasonable spatial planning and missing spatial location information of models. Figure 9 shows the BIM elevated design scheme superimposed on the basis of fine model modification of traffic facilities after 40% lightweight of the actual model data of Qianjin Street in a city. The scheme design, display, comparison and modification are carried out directly in BIM design platform without the help of third-party software, so as to avoid the repeated comparison and modification of multiple platforms.

Figure 7. Reality model refinement

(a) Model repair                                            (b) Repair results

Figure 8. BIM design based on point cloud data

(a) Lightweight Scene Model + Independent Object Component Model  (b) Scene Model + Component Model + BIM Model

Figure 9. Design, display and comparison of BIM scheme based on reality model data
5. Summary
The data types of results provided by survey and mapping departments directly affect the working methods of subsequent designers. Based on the traditional two-dimensional DLG data, BIM design can be carried out. However, in the process of scheme display, comparison and bidding, DLG cannot express spatial information in a threedimensional way, which cannot effectively support the BIM design scheme. Therefore, the paper puts forward the BIM forward design concept based on the real-world model, integrates the light-weighted real-world model into CATIA, and establishes the standard component model library of municipal facilities for fine repair of the real-world model and rapid design of BIM. The refined scene model can provide the BIM designers with the reference of terrain and geomorphology, better control the three-dimensional space factors, and provide the basis for the display, comparison and optimization of design schemes. Integrating real-world model data into BIM design software not only meets the needs of designers for spatial data, but also helps to promote the process of BIM forward design, thus speeding up the popularization and application of BIM technology.

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