Research on the Construction of County-level Digital Pedestal Platform Based on WEBGL--Taking a County as an Example

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Abstract. With the overall promotion of the country's real-life three-dimensional, digital process, how to build a real-life three-dimensional digital base at the county level has become a hot spot in the current research. This paper proposes the use of Cesium and Threejs development engine, combined with Vue-Cli scaffolding, in the use of MQTT and Websocket IoT transmission protocol, the construction of real-life three-dimensional technology based on the construction of a county smart city digital pedestal platform methods and applications. Through the real-world 3D modeling technology, the real-world urban environment is mapped into the digital model to provide a real data base for the pedestal platform. On this basis, the key technologies for the construction of the pedestal platform and the effect of its application in smart city management are discussed. The research results show that by taking a county city as an example, it is verified that the use of lightweight real 3D technology to construct the pedestal platform can greatly reduce the size of the 3D quantity, and the actual effect in the fields of urban planning, traffic management, environmental monitoring and so on. Finally, the future development direction and challenges of the digital pedestal platform are discussed, which can provide reference and significance for building a county-level smart city digital pedestal platform construction based on real-view 3D.

Keywords: Real-scene three-dimensional; BIM; Cesium; Three-dimensional spatial analysis; Informatization systems and technologies

1 Introduction

Smart cities based on the digitalized base of Realistic 3D are attracting more and more attention, however, the expansion of the city scale and the increasingly complex urban challenges also bring great difficulties in management and decision-making. Therefore the use of Realistic 3D technology for urban planning and design, environmental resource monitoring and resource management will be a more efficient, intuitive and smarter means; Realistic 3D technology is able to present the real geographic features

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and spatial layout of the city by establishing a highly accurate 3D model, providing a more lifelike and comprehensive visualization representation. However, the large amount of 3D data can not be loaded and presented faster, how to reduce the number and faster loading applications, will be the focus of this paper's research direction.

The research of this thesis will provide new ideas and technical support for the development of smart city real 3D data lightweight, and also provide research exploration for the application of real 3D technology in urban planning and management. Through this research, we are expected to provide more comprehensive and sustainable solutions for the future construction and digital transformation of smart city live 3D. Zhou Yongshuai [1] studied the methodological research of tilt photography monolithization based on Cesium framework. Hao-Yong Jiang [2] and others introduced the construction of digital village platform based on live 3D geographic environment. Yang Cheng [3] discussed the real-life 3D technology as an effective way to promote the construction of digital cities. He Linghua [4] and others, explored the digital empowerment of urban construction by CIM platform, building a digital pedestal and the traceability of green development. On the basis of extensive reading of literature, this study is based on lightweight real-world three-dimensional data for a county application, puts forward a real-world three-dimensional digital pedestal platform based on the Cesium open source engine research and development, mainly using the front-end Vue-Cli framework, combined with the open-source mapbox, Echarts technology to build a lightweight real-world three-dimensional model based on the technical routes of the pedestal platform, so that the County management more efficient and intelligent.

2 Data Acquisition and Preprocessing

2.1 Data Acquisition and Integration

The construction of the smart city digital base platform begins with the data acquisition and integration phase. This phase involves obtaining various information from multiple data sources, such as geographic data, sensor data, satellite images, etc. These data cover various aspects of the city, including terrain, buildings, roads, traffic flow, environmental indicators, etc., to ensure the authenticity and usability of the digital model.

2.1.1 Real-Scene Three-Dimensional Modeling

Real-scene three-dimensional modeling is one of the core links of the digital base platform, including laser scanning, image capture, geographic information system (GIS) data processing, and other steps [4-6]. In laser scanning, LiDAR obtains precise geographic data from various corners of the city. Then, through image processing techniques, images are fused with geographic data to generate high-precision three-dimensional models with accurate geometric shapes, texture features, and relative positions, Model Accuracy Check.

2.1.2 Urban Underground Pipeline Survey and Three-Dimensional Modeling

The survey and three-dimensional modeling of urban underground pipelines are important tasks in urban infrastructure management, aiming to address the challenges of complex pipeline distribution and opaque information. By applying modern technologies such as laser scanning and Geographic Information Systems (GIS), we can obtain real-time accurate locations and information of underground pipelines[7-9]. Additionally, with the help of real-scene three-dimensional modeling technology, we can transform these collected data into visually realistic three-dimensional models to achieve visualized management of underground pipelines. This not only enhances the monitoring efficiency of pipelines but also provides strong support for urban planning, maintenance, emergency response, and other aspects. The application of this comprehensive approach provides a new way for the refined management and intelligent decision-making of urban underground pipelines.

2.2 BIM Model Construction

The combination of real-scene three-dimensional modeling and Building Information Modeling (BIM) contributes to precise simulation analysis of complex spatiotemporal processes coupling multiple scenarios above ground, at the surface, and underground, as well as more accurate predictive analysis. By utilizing oblique photography techniques combined with manual vector three-dimensional geometry drawing methods, a highly accurate BIM (Building Information Modeling) construction process has been achieved.

Firstly, through oblique photography techniques, we capture images of buildings from different angles, obtaining multi-angle, high-resolution image data. Then, by manually drawing vector three-dimensional geometry, we convert these images into accurate three-dimensional models. Manual drawing allows us to capture the details and dimensions of buildings more finely, ensuring the accuracy and realism of the models.

After the three-dimensional geometry drawing is completed, we further map actual texture images onto the model surface to give buildings a realistic appearance. This means that the building models not only match the actual geometry but also have a high degree of similarity in appearance. This comprehensive method not only provides accurate dimensional and shape information for BIM models of buildings but also offers visual support for design, planning, and decision-making fields.

This construction method, combining oblique photography, manual drawing, and texture mapping techniques, demonstrates powerful potential in BIM modeling.

2.3 IoT Perception Data Processing

The base platform requires real-time processing of sensor data, reflecting changes in the real world into digital models. To ensure real-time processing, an efficient data collection and transmission mechanism need to be designed to quickly respond to changes in the city. This mainly includes: Traffic Sensors: These include traffic flow sensors, vehicle recognition sensors, cameras, etc. These sensors are used for real-time monitoring of traffic conditions on roads, including vehicle numbers, speeds, congestion levels, etc. Through real-time data processing, the base platform can simulate traffic congestion scenarios and optimize traffic flow. Environmental Sensors: These sensors monitor various indicators of the urban environment, such as air pollution levels, noise levels, temperature, humidity, etc. Through real-time data processing, the base platform can predict environmental issues and formulate environmental governance strategies. Security Sensors: These sensors monitor the security situation of the city. Through real-time data processing, the base platform can provide real-time alerts for security events and support emergency response. Water Quality Sensors: These sensors monitor urban water sources, water quality, water levels, etc. Real-time data processing can help managers predict water pollution situations, take timely preventive measures, and ensure water quality safety. Real-time data processing not only maintains the timeliness of digital models but also allows smart city managers to provide decision-makers with accurate city conditions and changing trends in a timely manner through real-time data processing, thus supporting more scientific decision-making.

3 Base Platform Key Technologies

3.1 Real-Time Data Synchronization and Updates

The digital base platform needs to be able to obtain data from the real world in real-time and synchronize it with the digital model. The platform needs to consider the diversity of data sources, such as sensor data, social media data, etc., as well as the format and frequency of the data. Real-time data synchronization and update technology should ensure the accuracy and consistency of the data, thereby ensuring the real-time nature of the digital model. The digital base platform needs to be able to handle data from different sources and formats. Cross-platform data compatibility technology can achieve data format conversion and integration, allowing data to seamlessly interact within the base platform. This requires the development of adaptable data interfaces and middleware to transfer data from various sources to the digital model.

3.2 Data Visualization and Interaction Design

Data visualization is an important part of the digital base platform, allowing large amounts of data to be presented to users through charts, maps, virtual reality, etc., making it easier for them to understand and analyze. Interaction design technology can provide users with a user-friendly interface, allowing them to navigate and operate the digital model easily, conduct simulations, and make decisions.

3.3 Lightweight Technology for 3D Model

Lightweight processing technology for 3D data adopts two kinds of structural compression methods and instance lightweighting.

3.3.1 Structure Compression Technology

The purpose of lightweighting BIM geometry is to reduce the size of the model data and optimize its performance, while still ensuring that the model has a sufficient level of detail to support the design, analysis, and collaboration process. First, identification of the model's structural elements, including structural elements such as faces and lines, is performed and specific characteristic attributes are defined for these structured elements. Subsequently, the BIM is converted to a polygonal and triangular mesh structure, and the triangular mesh is utilized to characterize the individual components. Combining the shape recognition features, the Draco grid compression technique is applied to fine-tune the parametric BIM model. When performing the triangular sectioning, the triangular mesh with different levels of details is added according to the model complexity. Through the simplification technique, a selective algorithm based on triangle segments is adopted to optimize the ordering of triangle segments within the model, removing those triangle segments that are small in area and have little impact on the overall structure. Adaptive simplification of the model is achieved by measuring the density of triangular segments and applying a standardized approach to maintain the key features of the model, constructing the model with different levels of detail, and measuring the density of triangular segments. The simplification process takes into account the ratio of the number of model facets relative to the number of pixels projected orthogonally on the three dimensions of the model's axial wraparound box. That is.

$$\rho = \frac{S}{p_x + p_y + p_z} \tag{1}$$

where S is the number of model facets; , , , are the number of orthographic projection pixels of the model in its axial surround box in three dimensions, respectively; and ρ is the facet density of the model. It is as follows:

$$\rho' = \frac{\rho - \rho_{\min}}{\rho_{\max} - \rho_{\min}} \tag{2}$$

$$r = \begin{cases} C_0(\rho' - 0.25), & \rho' \geqslant 0.25 \\ 0, & \rho' < 0.25 \end{cases} \tag{3}$$

where, is the triangular facet density; is the minimum density of the triangular facet; is the maximum density of the triangular facet; is the value of the triangular facet density after normalization, ∈ [0,1]; is a constant, the value is determined according to the actual situation; r is the simplification rate of the triangular facet of the model. After calculation, it is concluded that the simplification rate is set to 0, i.e., no simplification is performed, for regions where the facet density is below a certain value.

The originally constructed multi-level detail (LoD) model not only realizes efficient lightweight processing of data, but also maintains the topological connectivity of the triangular network. The 3D solid data model utilizes high-quality, topologically closed triangular mesh surfaces to explicitly delineate a homogeneous volume space. The boundary of this space constitutes a well-defined and closed two-dimensional manifold, while its topology is represented by the half-edge data structure (HDS), which places special emphasis on the detailed construction of the boundary composition. It consists mainly of two directionally inverted half edges, each of which records an associated vertex and a neighboring triangular face. Boundary edges are recognized on the basis that one of the half-edges is at an edge; and when a surface contains no boundary half-edges, the surface is said to be completely closed. Typically, the half-edges follow a counterclockwise direction, meaning that the normals of the faces will point outward according to the right-hand rule.

3.3.2 Instantiation Technology

For the situation that the same model is placed in different positions or in different poses in BIM data, the instantiation technique is used to store similarity models with the same parameter set or graphic using the "family" model, which adopts the method of geometric model + pose/position matrix to realize that the same geometric model is stored only once and reduce the disk storage space. Instantiation technology is used when the same model is placed in different positions or in different poses in a 3D scene, or when there are objects that are shared hundreds of times, which have instantiation information, such as bolts, nuts, railroad sleepers, electric poles, insulator strings, etc. Through the joint storage of the geometric model and the pose/position matrix, it successfully realizes that the same geometric model only needs to be stored once, and it will be stored as a layer processing. In the drawing process, the instantiation technique is used to effectively reduce the rendering burden of the graphics card, and at the same time significantly improve the rendering efficiency while reducing the disk storage space, maximize the optimization of the system resource consumption, improve the loading speed of the whole city-level scene, and satisfy the performance requirements for data transmission and analysis in different end-use applications. For example, in the case of a large number of identical "door" objects in a house, by using the instantiated rendering technique, only one "door" object needs to be drawn and instantiated at the desired location, which effectively reduces the burden on the graphics card and memory, etc. This optimization method not only improves the rendering efficiency of the city 3D scene, but also improves the system resource consumption. This optimization not only improves the performance of the urban 3D scene, but also significantly reduces resource consumption.

4 Platform Applications

4.1 Comparison of lightweight processing results

Using the SuperMap platform, the UDB data of the polygonal grid is generated, and the rest of the parameters are set as default except for the compression format, and the cache file size after and before compression using the three lightweighting techniques is tested. After the lightweight processing, the amount of data of each element in the BIM is compressed, as shown in Table 1.

Table 1. Comparison of Lightweight Data Before and After

Polygonal grid	After lightweight treatment	Before compression

Terrain	3.5MB	5.5MB
Curtain wall panel	12.3KB	20.9KB
Roof	2.6MB	3.6MB
Structural Column	502KB	1.2MB
Windows and Doors	5.6MB	8.6MB
Stairs	12.3KB	50.2KB
Total	12.2MB	18.9MB

As can be seen from Table 1, the data volume before compression is 18.9MB, and after using the lightweighting technology to compress the model, the data volume is 9.7MB, and the compression rate can reach 51.3%, and the lightweighting technology used in the paper is a good solution for the data loading problem caused by the large data volume of the urban 3D model.

4.2 Urban Planning and Design

In order to better verify the application effect of the digital pedestal platform in the smart city, we selected a modern county-level city with rapid development and diverse challenges as the research object, which is facing great challenges of digital transformation and innovation and needs to adopt innovative methods to enhance the sustainable development of the city. Through the practical application in the platform, we can view more intuitively the effect of the digital pedestal platform in the management of the smart city, and provide decision makers with an intuitive data display and simulation environment to help them better understand the operational status and changing trends of the city.

4.3 Environmental Monitoring and Resource Management

In terms of environmental monitoring, the real-time data update of the pedestal platform enables city managers to respond quickly to environmental issues and safeguard the quality of life of residents. The base platform can provide city planners with comprehensive urban data and simulation environments to help them better carry out urban design and planning. By simulating the effects of different planning scenarios, city planners can predict future development trends, optimize road layouts, distribution of public facilities, and green space planning, and help planners make more informed decisions.

5 Conclusion

In this paper, the data volume of BIM data before compression through compression algorithm is 18.9MB, and the data volume of the model after compression using lightweight technology is 9.7MB, and the compression rate can reach 51.3%, and the lightweight technology adopted is a good solution for the data loading problem caused by the large data volume of the urban 3D model. Following this, the key technologies and application potentials of using lightweight live 3D technology to build smart city digital pedestal platform are discussed in depth through actual cases, and the key role of live 3D technology based on Cesium and Threejs engine in smart city digital pedestal platform is emphasized.

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