# DATABASE CONSTRUCTION AND INTEGRATED DISPLAY OF 3D CITY MODELING DATA

Z. K. Zhai [1], W. H. Zhao [1]*, J. J. Liu [1], J. W. Liu [1], Y. Gao [1], J. Che [1]

[1] National Geomatics Center of China, Beijing, China - zhaowh@ngcc.cn

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**ABSTRACT:**

With the rapid development of computer technology and geographic information system (GIS), three-dimensional (3D) data are becoming an important aspect of GIS. It can provide more information than traditional two-dimensional (2D) surveying and mapping data. It plays vital important role in city building and management. In this paper, 3D city modeling data of different type are collected, including tilt 3D data, building model data, BIM data and underground data. Then database construction is completed by using the distributed database method, which can greatly improve the efficiency of data access and display. Furthermore, these data are processed and published as standard data services. Then a system is developed to display these data integrated with digital elevation model (DEM) data and remote sensing image data. It can provide data and technology support for the management of various natural resources. In the future, there will be further optimization of this system. We will continue to promote the application of these data to serve the government and the people. We also hope more and more data can be integrated into this system.

## 1. INTRODUCTION

The geometry and appearance of the earth have typical three-dimensional (3D) characteristics. And human visual perception has also three-dimensional characteristics. 3D data and scenes can provide more and richer visual perception details than two-dimensional (2D) data (Zhu, et al., 2022; Shan, et al., 2019). Whereas, traditional surveying and mapping data are usually collected on two-dimensional plane due to the limitation of technology. These data include digital elevation model (DEM), remote sensing images and thematic survey data and so on, which have played an important role in government decision-making, environmental protection, urban planning and daily life. With the rapid development of technology and society, these data are no longer enough for the application of land resources allocation, urban planning and construction, environmental monitoring and so on.

3D city modeling data is a digital representation of 3D geometry and structure of common objects in citys. Generally, these data include roads, buildings, infrastructure, vegetation and landscape. Besides, spatial relationships and related activities between them are also important part of 3D city modeling data. (Zhu, et al., 2014; Zhu, et al., 2005; Zhu, et al., 2003) Due to the development in technique of data acquisition, the cost of 3D city modeling data acquisition is getting lower and lower. There is a huge amount of 3D city modeling data accumulated in recent years, including tilt photogrammetry data, building model data, building information model (BIM) data and so on. With rapid development of computer technology and geographic information system (GIS), 3D city modeling data are becoming an important aspect of GIS. It plays an important role in digital twin model, which can help us better understand the earth we live on. At the same time, with the rapid development and widely use of database technology, data management becomes more and more efficient, which leads to more and more application of 3D city modeling data (Zhou, et al., 2006; Zhang, et al., 2021; Chen, et al., 2021).

3D city modeling data have characteristics of various types, complex structure and large amount, which is different from traditional surveying and mapping data. Therefore, traditional database construction method is no longer applicable, which leads to many difficulties in database construction. After the database construction is completed, how to use these data efficiently is also a problem. Besides, traditional surveying and mapping data also needs to be integrated with 3D city modeling data, which can browse, query and statistical analysis together. In order to realize the efficient display of these data, data scheduling strategy needs to be considered (Zhu, et al., 2018).

Ministry of Natural Resources released the overall plan for informatization construction of the Ministry of Natural Resources, which proposed to promote the construction of 3D real scene database. It can realize the 3D dynamic visual management of large scenes in the real world. Besides, in the overall plan for the construction of natural resources investigation and monitoring system, 3D space-time database construction of natural resources is also proposed. It can directly reflect the spatial distribution and change characteristics of natural resources, which can realize the comprehensive management of various natural resources. Therefore, 3D city modeling data can provide important data support for government decision (Liu, et al., 2022; Liu, et al., 2021).

At present, most 3D city modeling data are displayed and applied through specific client software. Different data are displayed using different display systems. All data cannot be used in a same display system. Moreover, most of the software uses their own data formats and is not open to the public. The 3D city modeling data of public format needs to be converted into its own format before it can be imported into their specific software. Although data browsing speed is fast. But it is not

* Corresponding author

conducive to display and apply of these heterogeneous data (Li, 2010; Zhu, 2004; Yang, et al. 2004; Gu, et al. 2020).

In this paper, 3D city modeling database construction is completed by using the distributed database construction method, which can greatly improve the efficiency of data display. And these 3D city modeling data are processed into standard online service, which can be integrated display in a system together with DEM data and remote sensing image data. It can realize the management of various natural resources. This method can truly reflect the real situation of the earth, which can help the government to better manage various natural resources.

## 2. GENERAL DESIGN

In this paper, distributed database method is used to build 3D city modeling database, which can manage these data efficiently. These data are stored and managed in different databases according to different types. This can reduce the pressure of database construction and data scheduling, which can greatly improve the efficiency of data access. Meanwhile, 3D city modeling data are processed and published as standard online data services. These data are then displayed integrated with DEM data and remote sensing image data. It can perform 3D visual browsing, query, statistical analysis and other functions. It can realize quick browsing and online application of natural resources in 3D space, which plays an important role in natural resources management. (Figure 1).

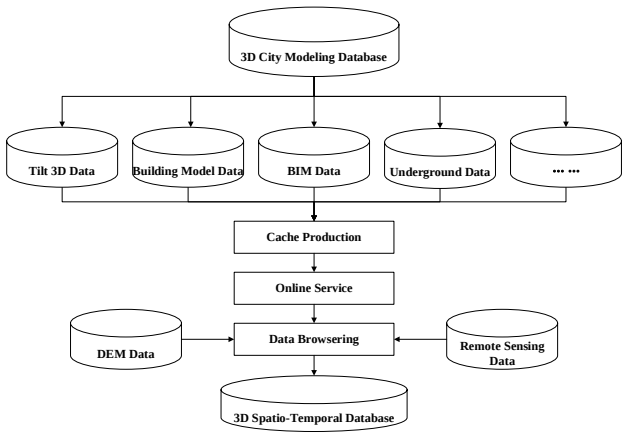


**Figure 1**. General Design of 3D City Modeling Database Construction and Display

## 3. TECHNICAL METHOD

### 3.1 Comparison of Different Data for 3D City Modeling

With the development of technology, data acquisition costs are getting lower and lower. In recent years, many cities have accumulated a large amount of 2D and 3D city data, including DEM data, remote sensing image data, tilt 3D data, building model data, BIM data and underground data. Each type of data has its specific purpose.

DEM data and remote sensing data can be used to construct large scale 3D real scene. Topographic relief and current state of the earth can be visually displayed directly. Tilt 3D data are more refined, which can directly reflect the current situation of city buildings in 3D scence. It is convenient for rapid construction of 3D city modeling. Therefore, these data can be used to achieve more sophisticated city management. Furthermore, in order to realize the management of single building, building model data are produced based on the real building. Relevant attribute information can be attached to each building. Birth and vanish of each building can be tracked based on its attribute information. To achieve more refined management of each building, BIM data are produced, which can record design, construction and operation of each building throughout the entire lifecycle. Moreover, BIM data can provide component-level information of each building, which means each part of the building is available as a separate object. Besides, underground data also plays an important role in city planning. For example, underground pipeline data plays an important role in the rational development and utilization of city underground space. Advantage and application of different type of 3D city modeling data are shown in the Table 1.

| Data type | Advantage | Application |
|---|---|---|
| DEM Data | Elevation Information | Large Scale 3D Real Scene Modeling |
| Remote Sensing Data | Visual Information | Large Scale 3D Real Scene Modeling |
| Tilt 3D Data | Texture Information | Rapid Construction for 3D City Modeling |
| Building Model Data | Building Information | Building Management |
| BIM Data | Component Information | Project Management |
| Underground Data | Planning Information | City Planning |

**Table 1**. Comparison of Different Type of Data for 3D City Modeling

These data are important components of 3D city model database, which play an important role in comprehensive management, city digitalization and smart city construction. 3D city modeling data usually refers to tilt 3D data, building model data, BIM data, and underground data.

### 3.2 Database Construction of 3D City Modeling Data

In general, the database is mainly composed of three parts: infrastructure resources, database, management and application service system (Figure 2). Firstly, Infrastructure is the hardware, software and network equipment that supports the management and application of the entire database. It mainly includes computer infrastructure resources such as computing resources, storage resources, network resources and security equipment. Secondly, the database is the data resource of the entire database system, providing data storage and management capabilities. Thirdly, the database management and application service system realize functions of data management, integrated display, query and retrieval, service application, data maintenance, and system security management.

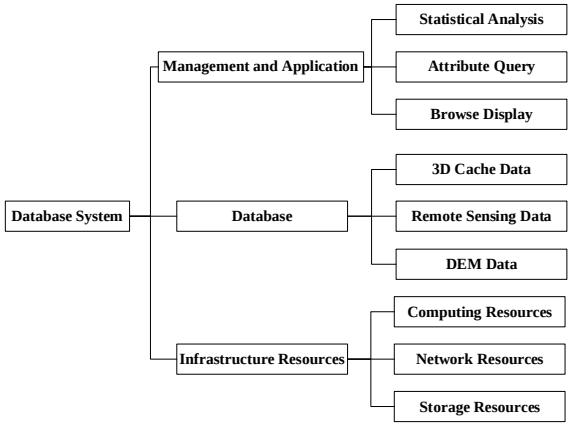


**Figure 2**. The Composition of Database System

In this paper, distributed database method is used to build 3D city modeling database. According to the characteristics of different types of data, different storge service are used to build database (Figure 3). Due to the large number of data formats, a file-based database is used to build the database. Meanwhile, metadata of these data are stored in the relational database in order to query relevant information of these data, including data range, production information and so on.

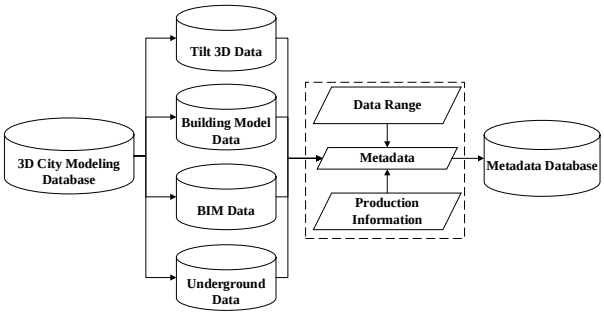


**Figure 3**. 3D City Modeling Database and Metadata Database Construction

These data are stored in different storge servers according to different type. After database construction is finished, these data are ready for cache production.

### 3.3 Cache Data Production of 3D City Modeling Data

Due to the complex structure and large amount of 3D city modeling data, data processing needs to be done after database construction is finished, which can speed up data browsing. This makes sure that 3D city modeling data can display, query and apply quickly. Cache technology is a graphic display technology commonly used in mainstream GIS systems. It can make data browsing speed become more smoothly. Therefore, in order to improve the overall performance of the 3D city modeling data application, it is necessary to create a multi-level cache for these data, which can improve the display efficiency when zooming and viewing data. Meanwhile, spatial index data are created based on these cache data, which can also speed up data loading (Figure 4).

Moreover, when browsing a 3D scene, the amount of data transmitted from the server to the client is larger. In this paper, dynamic caching mechanism is also required to improve the speed of the access efficiency of the client. After data service is published, when user accesses the service to browse data for the first time, the server will generate the cache of the corresponding data dynamically. And the user does not need to generate the cache next time. This improves the response speed of the server when users access these services again.

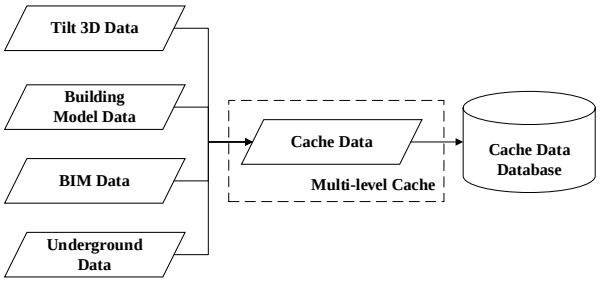


**Figure 4**. Cache Data Production and Database Construction of 3D City Modeling Cache Data

The process of data cache is very important. Besides, cache database is constructed to manage these data better. Then these cache data are ready to be published to online service.

### 3.4 Integrated Display of 3D City Modeling Data

After cache data production is finished, these data need to published as standard online data services to display. In order to facilitate service integration management and application, browsers are usually used to load and display these cache data. In this case, users can only use browser to access these data easily, which means that it is not necessary to install other client software. Developers can centralize the core system function on the server, which can simplify development, maintenance and use of the system. The browser interacts with the database through the data server. Most importantly, it can work on different platforms, which is very convenient. The servers generally use high-performance computer. This can speed up data browsing. This structure's advantage is simple and easy to maintain and upgrade data and application function. All the operation of data update and function upgrade can be done on the server. It can provide more rich and vivid interaction with users. It will be easier for users to use.

In this paper, a system is developed to display these 3D city modeling data (Figure 5). These data can be displayed in the display system intuitively. These data can be loaded, browsed and queried through a browser arbitrarily. All data in database can be accessed through a standard data service.

At the same time, DEM data and remote sensing data are also integrated into this system, which plays an important role in large scale 3D real scene modeling. As it should be, all data are integrated into this system through standard data service. Other systems can also access these data services directly, which can save a lot of work and avoid repeated data processing and service publishing. This is also the trend of future system integration.

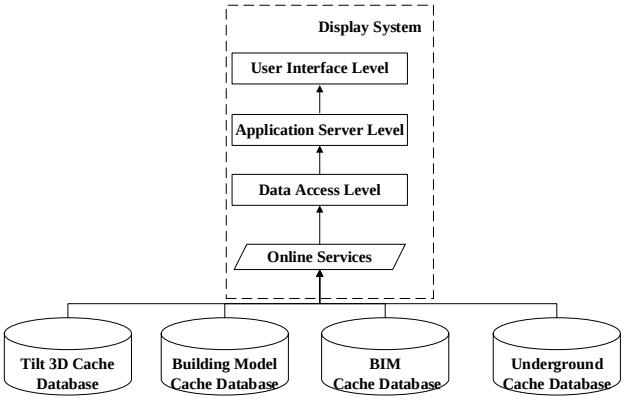


**Figure 5**. Integrated Display of 3D City Modeling Data

Meanwhile, a proxy server is used to manage these data services uniformly. If an exception occurs to an individual data service, this data service can be switched to another data server in a timely manner, thus avoiding a large number of changes to the system, especially in providing data services to other units or system. The other unit or system has no feelings when switching these data services. We have also developed a service supervision system to monitor whether these data services operate normally or not. If the data service is abnormal, it will alarm in time. And it will make sure that data service is always working normally.

## 4. RESULTS

In this paper, 3D city modeling data of different type are collected, including tilt 3D data, building model data, BIM data and underground data. However, these data have characteristics of different standards, different formats, different types, different coordinate systems and large amount of data. Therefore, these data need to be analysed and processed in order to ensure data consistency (Figure 6).

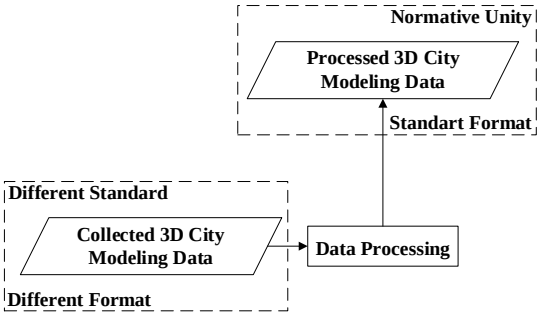


**Figure 6**. Processed of 3D City Modeling Data

In view of characteristics of different standards, different formats, different types, inconsistent coordinate systems of data, data transform and integrate need to be done to achieve the standard and unified data. The workload of data processing is very large. But this part of work is also very important. Otherwise, there will be problems in display system when integrating and displaying these data.

Moreover, database construction is completed by distributed database method, which can manage and use these data efficiently. These data are stored in different database according different types, which is more flexible and convenient.

Furthermore, these data are processed and published into standard data services, which can easily access these data through the network. Moreover, a display system is developed to display these data. It is more suitable to meet needs of current application and work. It can realize quick browsing and online application of natural resources in 3D space, which plays an important role in natural resources management.

## 5. CONCLUSIONS AND DISCUSSION

In the past, traditional surveying and mapping data are mainly 2D data. For example, we are familiar with traditional 4D products. It consists of DEM, digital orthophoto map (DOM), digital raster graphic (DRG) and digital line graphic (DLG) (Figure 7). These products constitute the basic data framework of GIS data. And these products are space information carrier of other data. Users can choose their own data products and develop various thematic GIS software system according to their own requirements. Most of these data can be displayed and used in desktop software. And these data have played an important role in economic and social development.

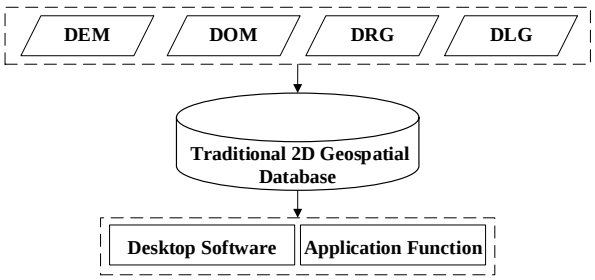


**Figure 7**. Traditional 2D Geospatial Data and Application

However, with the rapid development of data acquisition and computer technology, the traditional 2D data have certain limitations. Nowadays, traditional 2D data and scenes can no longer meet current needs of application and work. Due to reduction in data acquisition costs, 3D aspects attract a lot of attention. Many companies are also continuing technological innovation. Meanwhile, large amount of 3D city modeling data is accumulated in many projects. How to manage and use these data is also a big challenge. However, the rapid development of computer and database technology makes it possible to manage these data (Xie, et al., 2022; Sun, et al., 2014; Liu, et al.,2011).

According to human cognition, it is very abstract to know and use geospatial data with a 2D graphical interface, which only professionals with experience and relevant professional knowledge can understand and know how to use these data. However, compared with 2D data, 3D data can provide a richer and more realistic view for display of spatial information, which enables people to visualize abstract and difficult spatial information. People can understand it by combining their own relevant experience. Furthermore, they can make accurate and rapid judgments. There is no doubt that 3D data has unique advantages in visualization (Zhu, et al., 2017; Wang, 2017; Zhu, et al., 2004). However, the interactive visualization function of 3D data also puts forward special requirements for computer hardware and computer graphics technology. It is a trend for 2D and 3D data to provide services through the network in the future. The data service can be accessed online in real time, so users can use it without any feeling. On the premise of ensuring data security, we can easily access these data with our computers or mobile phones through the browser. More importantly, the efficiency of data access and browsing will be significantly improved.

The spatial analysis function of 2D data has some limitations. Whereas, spatial analysis function and application of 3D data will be more powerful, which 2D data cannot be realized. In 3D scene, 3D data can visualize the abstract and difficult spatial information (Wang, et al., 2004; Bao, et al., 2021), and people can make accurate and fast judgments according to their own experience. This means that we can all use these data directly without too much relevant professional knowledge. It is vital important for GIS application of our daily life. The powerful multi-dimensional spatial analysis function of 3D data is not only a leap of GIS spatial analysis function, but also fully reflects the characteristics and advantages of GIS in a greater extent. At present, the existing 3D spatial analysis function is relatively simple, including inundation analysis, geological analysis, sunshine analysis, spatial diffusion analysis, intervisibility analysis. In the future, we need more 3D analysis functions for business work. However, the browser has limited load ability. Complex 3D analysis function needs to interact between the browser and server (Zheng et al., 2022; Wang et al., 2015). The data is processed on the server, and the results are returned to the browser in the form of data services (Figure 8).

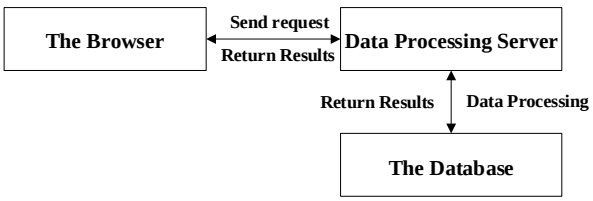


**Figure 8**. Flow Chart of Complex 3D Analysis Function

So far, many companies focus on their 3D platform product development. With the development of computer technology, there are many products, which can manage and display these 3D data. But there are relatively few applications for 3D data and 3D scenes. Most of the application is mainly display of the data instead of data application. How to make better use of these data to meet the need of our work is also very important, which can realize the value of data. Besides, how to further improve the efficiency of data process is also our further work, which can greatly reduce the workload of our work.

In general, this method has great advantages in manage 3D city modeling data. It can greatly improve the efficiency. This also allows us to manage and use these data better. It can provide data support for the basic land and space information platform and provide technical support for the comprehensive management of natural resources. In the future, we will also integrate more data of different type. Moreover, there will be further optimization of this method. We will continue to promote the application of these data to serve the government and the people.

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