Research on Modeling Precision and Standard of 3D Digital City

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Abstract

Researches and practices on 3D digital city have been widely performed in many cities, since most of them were used in specialized fields, and cannot share resources and inter-operator with other systems completely, it is urgent to develop related standard and criterion as the basic guideline for the construction of the digital city, thus to satisfy varies demands for 3D data. Based on project “Wuhan 3D digital map”, this article discussed and gave good reference on the modeling precision and standard of digital city.

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1. Introduction

Considered as the center of regional economy, politics and culture, city is the high concentration of modern industry and the carrier of the sustainable development of national economy. It creates and gathers a great deal of national material wealth, and also plays a dominant and leading role in the economic development. The digital city is the binary reappearance and reflection of the material city in the computer, and it is a management and service system of urban information, which takes the information technology (especially the GIS technology) and network technology as the essential factors. The main task of digital city is to build a information platform, meanwhile a application system and a security system of policies and regulations for the government-enterprise and community, using the modern technology for data collection, integration and mining in a variety of urban information resources. With the maturity of 2-D GIS technology and rapid development of spatial information technology, 3D display is becoming the main way for the online services of geo-spatial information.
Breaking through the limitations of traditional planimetric map, the 3DCM is the 3D digital display of the real cities, which could provide the user with a virtual urban environment similar with the real one through the 3D simulation of topography and features. Through the digital management of 3D virtual city, it could provide information services for the sustainable development of the urban planning, construction and operation. Furthermore, it is to enhance the sharing and using level of the urban spatial information, and also the urban overall information-based management will be improved.

Currently, there has been a lot of research and practice concerning with the 3D digital city, which is now playing a more and more important role in urban planning, land resources management and traffic administration. However, because most of the achievements are based on specific field, and the resource sharing and interoperation between different systems is still not available, it is very urgent to set relevant standards and norms as guidelines for construction of digital city and authoritative, scientific data support for decision-making in city planning.

The project “Wuhan 3D digital map” aims to construct a 3D digital model database of Wuhan and also a system for 3D data update and maintenance, based on which the spatial information services platform for designation and approval of urban planning, urban construction and operation management will be built. In this paper, based on the project “Wuhan 3D digital map”, the modeling precision and standards of digital city construction are discussed.

2. Modeling precision of 3D digital city

The 3D model is what the construction of 3D digital city is based on. The precision of 3D model could affect directly how the visualization would be performed, and the higher the precision is, the more realistic the performance of scene will be. Nevertheless, the 3D data with high precision has great impact on the system’s running speed, meanwhile it increases the cost of model construction and delays the progress of model production. So the modeling precision of 3D model is the first thing that should be taken into account at the beginning of the project.

Firstly, the precision of 3D model should meet the system’s functional requirements. For instance, if the model is used for the research on pollutant diffusion, city’s space layout and so on, a simple model without texture will be qualified. But for the assisted urban planning or the virtual tour, the more realistic scene and preciser model will be needed. That is exactly why the construction of model should be based on the corresponding application. Meanwhile, taking the following functional expansion and the development’s trend into account, the room for upgrades should be left. Considering a variety of factors, the following principles of model construction in the project “Wuhan 3D digital map” are established.

2.1. Constructing different levels of LOD model according to the system’s requirements

The 3D urban model should be constructed at different levels according to the different simplification levels and different fields of application. Generally speaking, the more important the features are, the higher precision the model should be with to ensure the good performance of 3D viewing. Meanwhile, as a result of different fields of application, the features should be simplified at different levels. For instance, only the contour and the height of the features are needed to display for macro-analysis and statistics (such as the skyline analysis), while models with higher precision are required for modeling of windowsill and balcony in micro-analysis (such as solar analysis). By all accounts, the 3D LOD model should be constructed taking all the needs of different business departments, so that the final production could serve for different applications.

In the project “Wuhan 3D digital map”, the modeling precision of buildings is divided into four levels, which are block level, basic level, standardized level and premium level. Models in the four above-
mentioned levels are used in the following corresponding fields: urban spatial morphology and distribution, virtual tour, assisted urban planning and approval, elaborate management of buildings and so on.

2.2. Using different levels of LOD model in different areas

Because of the disparities between the needed functions in different urban areas, it is not impossible to model using a unified precision. Different levels of LOD model are needed for different areas. Furthermore, due to the complexity of the actual situation, even in the same area with the same precision, a minor distinction has to be made between the levels of precision according to the disparities under regional conditions. In the practice, models in basic level are further divided into basic ones and preciser basic ones, while the standardized ones are divided into standardized ones and preciser standardized ones.

In the project “Wuhan 3D digital map”, for the main streets in the central urban area, the landmark buildings, scenic construction and protected buildings, standardized models and preciser standardized ones are adopted in the modeling progress, while standardized models for the newly built communities, preciser basic ones for the general areas, block ones and basic ones for lowrise buildings or urban villages, and block ones for areas to be constructed.

2.3. Making fine distinctions between the numbers of triangular patches at different levels of LOD model

It is needed to divide the models into different levels not only for the implementation of the system’s functions, but also for enhancing the system’s efficiency. Real-time viewing of 3D large-scale scene with high precision has always been one of the bottlenecks in 3D systems. The most commonly used method is to build multi-level LOD models for complex models to achieve the refresh rate of the animation frames. And the LOD models are loaded in real time due to the current perspective in the running time of the software. So fine distinctions should be made between the quantities of data at different levels of LOD model to switch LOD models to increase the system’s efficiency.

In the project “Wuhan 3D digital map”, there are six levels of LOD model (Table 1). The quantity of data in certain level is 3 to 4 times more or less than its adjacent ones. The different levels of LOD model is displayed in figure 1.

2.4. Matching the model’s geometric accuracy with the texture’s resolution

The 3D model includes geometry part and texture part. The geometric accuracy should be matched with the texture accuracy. The higher the geometric accuracy is, the higher the texture’s accuracy should be. At present, there aren’t relevant norms concerning with texture’s resolution yet, which is currently judged by the experience of the modeling staff. For example, the pixels for wall within windows is 256*128, the barrier is 128*256, the windows is 128*128, the proof is 64*64.

| Level | Name          | Instructions                                                      |
|-------|---------------|-------------------------------------------------------------------|
| LOD1  | Block         | Extruded from the outline of buildings’ bottom(without texture)   |
| LOD2  | Basic         | LOD1 with general texture                                          |
| LOD3  | High Basic    | Modeling precision lower than 2 m with real texture(with occlusions) |
| LOD4  | Standard      | Modeling precision lower than 1 m with real texture(without occlusions) |
| LOD5  | High standard | Modeling precision lower than 0.5 m with real texture(without occlusions, with high resolution) |
2.5. Leaving room for post-upgrades

The construction progress of models should not only meet the system’s current functional requirements, but also fully take the possible needs newly generated during its application into account. In the post-upgrade progress, we should make full use of the original results to speed up the modeling progress at the same time to reduce the production costs, such as the grouping of static models, the level setting of dynamic models and so on.

3. Modeling standards of 3D digital city

“Digital city” is a huge systematic project, in whose constructing progress the modeling standard always plays an important role. With the growing demand of 3D spatial data, researches on the standardization of geographic information and development of relevant standards are accelerated. Through years of study, experts in geoscience, information technology and law come to the consensus that information standard is the prerequisite, while information sharing is the purpose and related legislation is the guarantee. Including the technical supporting system, the standard supporting system and the policy supporting system, three main systems must be constructed to meet the requirements of information sharing to make it operational in practice. The standard supporting system consists of five parts of standards concerning respectively with data collection, data processing and producing, data management and maintenance, data distribution and data service and application. In this section, based on the project “3D digital map”, the former two parts of the standards are mainly discussed.

3.1. Zoning the modeling region into units

Because it is a long-term progress to construct the digital city, the work should be done step by step, focus by focus and region by region. Before the work of construction, the region to be modeled should be zoned into basic units for modeling. During the construction progress, at first, we should conduct tests at the typical regions, then come to the other ones gradually.
In the project “Wuhan 3D digital map”, according to the zoning of planning units and the current road network, the whole urban area is zoned into 519 regions, 194 ones of which are in the main urban district.

3.2. Standards of data collection

In the project “Wuhan 3D digital map”, the original data consists of DEM, DOM (satellite images and aerial images), DLG (maps with scale of 1:2000 and 1:500), laser scanning data, data of the buildings’ bottom outline, planning drawings, on-site images and video, and so on. These different kinds of data are on what the 3D modeling is based. The original data must be ensured to be normative to ensure the correctness of the model construction. Therefore, relevant standards should be developed.

The standards that the basic geographic data should satisfy are summed up as follows:

- All the geographical data should use the same coordinate system and be able to be matched accurately.
- There are no cracks between adjacent DEM map sheets or DOM map sheets.
- The corresponding grid points in the DEM edgematching region should have consistent elevation.
- The DOM images should contain the positioning information.
- The buildings’ bottom outlines should be closed. And they should be assigned with properties such as name, the number of floors, height of each floor, usage and so on.

For the texture acquisition, the zoned modeling units should be further divided. In a single unit for texture collection, the number of the buildings should be controlled between 20~30. Because the scene’s performance and fidelity depend on the collected texture, it is necessary to set relevant norms of texture collection. The major themes are listed as follows:

- The shooting date, the weather conditions and requirements of the perspective.
- The photographic techniques for different features (buildings, bridges, virescence, urban facilities and so on).
- The resolution and clarity of the images.
- The naming rules for the images.

3.3. Standards of data processing and producing

The 3D model data processing includes two parts of graphical data processing and raster processing, of which the former one includes 2-D vector graphics processing and 3D modeling processing and the latter one includes image processing and image rectification.

Right now, because there have been perfect tools and processes of DLG and DOM processing and also relevant standards and norms, it is not necessary to discuss those again. In the following section, the 3D modeling processing is mainly discussed.

The nine main parts of 3D modeling standards are summed up as follows:

- The coordinate system of models
  The unified 3D coordinate system is what the construction of 3D large-scale scene system is based on. In the construction progress of “Wuhan 3D digital map” system, the maps with the scale of 1:2000 and 1:500 are used as basis to enable the system to be compatible with other GIS or surveying systems. In order to import the 3D models into the database smoothly and correctly, all the coordinates should be unified.

- Basic unit of models
  Because the planar coordinate system in meters is usually adopted in urban large-scale maps, the basic unit of model construction should also be in meters. We should model according to the features’ actual size and the precision of size should be set according to the model’s LOD level.

- Modeling
  The 3D digital map is used mainly to display the urban appearance. During the modeling progress, taking the quantities of data into account, we should model only the visible parts outside and
minimize the number of patches on condition that the basic shapes and characteristics of features are maintained. For this part, specified norms should be set and experiential indicators such as the number of cylinders’ edges or the spheres’ sections should be offered.

- Reference point for model positioning
  For each model, there must be a reference point for positioning. The reference point is the origin of each model’s local coordinate system and is used for the precise spatial positioning of the model. It is very useful for importing the same or similar features in the 3D scene, such as poles, street lamps, traffic lights and so on. In the modeling progress of the project “Wuhan 3D digital map”, it is prescribed that the center point of the feature’s minimum bounding rectangle is considered as the reference point of the model.

- Models’ height
  There are three methods to get the models’ height, especially the buildings’, according to the requirements of models’ performance at different LOD levels.
  - For the block models and the basic models, the height of the buildings and other features could be calculated according to the current GIS data (such as the number of floors). For instance, we can calculate the building’s height by multiplying the number of floors by each layer’s height.
  - For the models with higher quality requirements, we can get the height using aerial stereo-pair, laser altimeter or LIDAR.
  - For the premium models, we can get the height from architectural plans or working drawings.

- The use of spline curves or surfaces
  Although the spline curves or surfaces could display the surfaces delicately with just a few of parameters, the data will be massive when transformed into general formats, such as “3DS”. So in the modeling process, the spline curves or surfaces should be used as little as possible or be transformed into polygonal lines for further optimization.

- Image processing
  For the on-site images, we must first conduct the perspective correction, and then the hue adjustment. If the images are used for models at the LOD levels higher than the standard level, the occlusions should be eliminated to get a better visual performance. At last, the texture images are named normatively according to the feature’s zoning code (Figure 2) and building code.

- Texture mapping
  In the progress of texture mapping, only the diffuse maps and the opacity maps are used. Generally, a lot of methods of texture mapping are offered by 3D modeling softwares. However, for the common exchange file format, only a few are supported. So in the project, we use the most common way of texture mapping.

- Tools for modeling and forms of submitting products
  The models constructed by tools for modeling are submitted in two forms, of which one is the default format of modeling tools (such as the format of MAX) and the other is the transformed format of 3DS. And the texture is submitted in the form of folder with the same name as that of the model file.

  The above-mentioned principles are those the modeling progress should follow. During the implementation of the project, concerning with how to do it specifically, the detailed modeling process should be designed and relevant norms of texture mapping should also be developed according to the modeling software. Besides, the coordinate system, the basic unit and the reference point could be recorded as metadata for the convenience of further maintenance.

4. Conclusion

The construction of “3D digital city” is a huge systematic project. During the designation progress, according to needs of application and information sharing, the precision of 3D modeling should be set and the relevant standards should be developed to make the products meet the relevant requirements. For
the construction of “3D digital city”, it should be recognized that there is still not a unified mathematical model aiming at the 3D modeling of the urban multi-scale and complex objects. And the modeling still depends on personal experience and skills. At the same time, the LOD models at the middle levels still can’t be generated automatically by the block ones and the premium ones. The need for generating discrete and multi-level models manually makes a great impact on the modeling efficiency and models’ universality. There are still a lot of work in need of further research.

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