Research on Rapid Parameterized Modeling of CityEngine in the Application of Smart Campus Platform

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Abstract: Currently, government departments in various regions are vigorously promoting the construction of smart cities. As a part of smart cities, quickly obtaining or creating three-dimensional spatial models of campuses is an important part of the basic framework of smart campus construction. Existing modeling methods have problems such as low modeling efficiency and difficult maintenance in the later stage. This article proposes a CGA (Computer Generated Architecture) parameterized 3D modeling method based on CityEngine, exploring the parameterized modeling rules of important modeling entities such as roads and buildings in university campuses. By expanding and customizing the modeling rules, campus road and building modeling rule templates are created. The results showed that the proposed method and texture mapping rules were used to achieve fast and accurate 3D scene modeling of the campus, avoiding a lot of repetitive modeling work and improving the efficiency of modeling work.

1. Introduction

Smart campuses build a digital space on the basis of traditional campuses by digitizing everything from environment, resources, to applications, in order to expand the time and space dimensions of real campuses, improve the operational efficiency of traditional campuses, and ultimately achieve comprehensive informatization of the education process, thereby improving management level and efficiency. The construction of a smart campus includes the construction of an information-based basic environment and the construction of campus application systems. The former focuses on the construction of network security, campus information management, unified information portal, identity authentication, and campus one card from the perspective of informatization[1]. The latter combines 3D visualization technology and virtual reality technology to reproduce the real situation of the geographical environment, mainly including view operation, roaming and other functions. It can view the campus landscape from multiple perspectives to achieve a comprehensive understanding of the campus, with the characteristics of dynamism, real-time and interactivity[2]. Smart cities can provide some reference for digital campuses.

"Smart City=Smart City+Internet of Things+Cloud Computing". Drawing inspiration from smart cities, smart campuses can be defined as applications that achieve thorough perception, ubiquitous connectivity, and intelligent integration through the use of Internet of Things technology[3]. As a fundamental component of smart campuses, 3D visualization is of great research significance in achieving fast and accurate 3D modeling[4].

This article adopts CityEngine based parametric modeling ideas and CGA modeling rules. By compiling and improving the modeling parameters and rules of some buildings, and taking the Daxing Campus of Beijing University of Civil Engineering and Architecture as a scene example, three-dimensional intelligent modeling and visualization research is conducted on buildings, roads, and other ancillary facilities in the campus. The model is applied to the Beijing University of Civil Engineering and Architecture Smart Campus Platform, implement spatial analysis and other operations on the model. The research and implementation of methods have certain practical significance for future smart campus construction and even research on smart cities.

2. Research methodology

2.1. Parametric modeling

Parametric modeling is the process of establishing and analyzing a model through parameters (variables) rather than numbers, and new models can be established and analyzed by simply changing the parameter values in the model. The advantage of doing so is that the parameter values can be flexibly modified, allowing for different analyses and optimizations of the model[5]. Through parameterized modeling, the key features of a problem can be abstracted into parameters, transforming the problem into a function of parameters. In this way, in different situations, by changing the values of the parameters,
corresponding models and results can be obtained. This model can be used to analyze different situations of problems, optimize parameter selection, explore the relationship between parameters, etc[6].

CityEngine parametric design is divided into two parts: parametric elements and parametric modifications. The elements in CityEngine appear in the form of components, and the differences between these components are reflected through parameter adjustments. The parameters save all information about the elements as digital building components. The parameterized modification engine provides parameter modification techniques, allowing users to automatically reflect any changes made to architectural design or document sections in other related sections. The parameter changes caused by the movement, deletion, and size changes of components can cause correlated changes in the parameters of related components. Any changes that occur in any view can be parameterized and bi-directional propagated to all views to ensure consistency of all elements, without the need to modify all views one by one, improving work efficiency and quality. The essence of parametric design is that the system can automatically maintain all invariant parameters under the influence of variable parameters[7].

2.2. Campus Building Parameter Design

Parametric modeling is the process of abstracting the geometric features of a 3D model in a reasonable way, mapping them to variable parameters, and controlling the values of each parameter to achieve changes in model size and shape. Therefore, when conducting three-dimensional parametric modeling of campus buildings models, its basic and combination parameters should be set in advance.

2.2.1. Basic parameters

The basic parameters of the campus building model can reflect the basic performance and characteristics of buildings and roads, as shown in the figure. The calculated parameters include building specifications, building types, coordinate parameters, and road specifications. The building specifications are mainly divided into building area (above ground and underground parts) and building height. The types of buildings are further subdivided into texture materials (brick, wood, glass, concrete, etc.), building functions (classrooms, laboratories, dormitories, etc.), and building layouts. The coordinate parameters for model positioning include X, Y, Z coordinates, and UV coordinates during model mapping. The specifications of the road model include width, material, and orientation. The design of basic parameters plays a crucial role in the subsequent changes and maintenance of the model, as shown in Figure 1.

2.2.2. Combination parameters

Combination parameters usually refer to the combination of multiple parameters to achieve specific design goals or meet specific requirements. As shown in Figure 2, the relationships between campus buildings can be divided into the relationships between buildings, buildings and roads, and roads and roads. The combination of these different relationships requires Boolean operations and the construction of elements. The characteristic parameters of the building are the cross-sectional parameters and centerline parameters of the road. The cross-sectional information of various pipelines is obtained from CAD drawings or field data collection, and the centerline of the road is used as the layout path to perform feature operations on the pipelines - cross-sectional layout[8]. Considering the large and complex number of campus buildings, additional connection methods have been added to improve the connection between buildings.

2.3. Construction of a Smart Campus Model Based on CityEngine

2.3.1. CGA rules

CGA rules are modeling rules customized by the CityEngine platform, which define a series of rules that determine how the model is generated[9]. All modeling in CityEntine software is created through CGA rule driven creation. CGA rules are divided into standard rules, parameter rules, conditional rules, and random rules. When existing rules cannot meet user needs, users can create their own rules. And custom rules can be used to update already built models, reducing workload and improving modeling efficiency.
2.3.2. Building Modeling

(1) To define the properties of a building for modeling regular individual buildings, it is necessary to first establish the properties of the building, select or create appropriate CGA rules, define relevant parameters and variables, mainly including texture settings, window parameters, floor height, etc.

(2) After the property definition of the building is completed, the plot can be stretched, and the building frame can be established from the ground according to the overall height of the building, splitting the roof and facade. For modeling needs, adjusting the variable values of the corresponding parameters can obtain real-time results after adjustment.

(3) Applying texture and texture to building models can be done using existing images on the platform or using self-collected texture images. Simply change the texture rules in the CGA rules. Figure 3 shows the CGA rules and Figure 4 shows the corresponding renderings used for modeling the teaching building.

2.3.3. Road modeling

The method of road parametric modeling is to classify the road as a whole, use different parameter settings for different parts, and create and modify the road model by adjusting parameter values.

CityEngine provides basic modeling rules for common urban roads, and compared to urban public roads, campus roads have their own characteristics. Based on the actual situation of the roads, existing road modeling rules can be modified and expanded. The specific expansion methods are as follows:

(1) Due to differences in road width and function, there are varying degrees of differences in the form of road sections when dividing roads of different types. This requires road modeling rules to have sufficient flexibility so that they can adapt to multiple sections. Based on the characteristics of campus roads, divide them into three levels: four lane, two lane, and single lane.

(2) Based on the general knowledge of road design and the actual situation of campus roads, determine the default section element values for different levels of roads by setting road parameters. Each default parameter of the road can be adjusted through interactive means, such as adjusting the distance between street lights.

(3) The extension of road modeling rules adapts to the existing CGA rules based on the actual situation of campus roads, mainly including changing the road paving effect, intersection status, etc. Figure 5 shows the CGA rules and Figure 6 shows the renderings used for campus dual lane modeling.

2.4. Spatial overlap

The overlapping detection process queries for the cross overlap between models. The easiest query can detect whether there is any overlap between the current model and any other model, and the result may be no ("none"), partial ("part"), or complete ("full") overlap.

Tile: Shape. oc ("sideface") == "full" → node

This statement detects whether there is a cross in the side section, and if it is completely overlapping, the shape of the door will not be created. Configure a subset of shapes for each detection result:

(1) The previous detection results will detect the intersection of all models, including replaced or invalid model rules. Overlap detection only applies to the currently applied model, while using the keyword "active" to query.

(2) Retrieval can use specific identifiers to limit the search scope of a subset of models, such as Shape. oc
3. **Experiment**

3.1. Preparation of experimental data

The experimental data in this article includes vector data, building height data, digital elevation model, and appearance texture data information from Beijing University of Civil Engineering and Architecture. The 3D model of the building is roughly divided into two parts, namely the three-dimensional model of the exterior facade of the building and the establishment of its internal model. The three-dimensional model of the exterior facade usually requires the preparation of digital elevation models (DEMs) and their terrain base projection maps, while the three-dimensional internal model requires the preparation of information data such as distribution maps of each room on each floor of the building. In addition, it is necessary to prepare texture image information and orthophoto image DOM for the texture mapping section. Due to the large amount of data, scene areas are divided based on the distribution of campus topography and land features. Create scene models gradually in order of scene hierarchy from high to low and from coarse to fine in each divided area.

3.2. Modeling process

Firstly, convert the foundation bottom data of the building into ArcGIS Shapefile or File Geo database format. As CityEngine can only set projection coordinate systems, it is necessary to perform projection conversion on the modeled data. As the foundation of parametric modeling, it is also necessary to enrich the attribute information of objects. Assign design parameters based on building requirements to building model components and import the model into the CityEngine scene. According to the modeling approach, combined with the characteristics of campus architecture, write parameter rules (CGA), and then select the two-dimensional planes of each component, assign corresponding rules, and generate relevant models in large quantities and quickly. After completing the building model creation, another important project is texture mapping. There are a total of six texture layers in the CityEngine system module, which have a one-to-one correspondence with UV sets (texture coordinate system sets). The specific process is shown in Figure 7.

3.3. Parameterized models in smart campus platforms

This article applies the constructed campus road and building model to a smart campus platform based on WebGIS. By associating attribute information with model information, spatial analysis operations such as measurement and information query can be performed on the model, achieving unified information management of buildings, enhancing the semantic expression of the model, and fully realizing the value of the model. The effect of the smart campus platform is shown in Figure 8.

4. **Summary**

This article mainly adopts the CGA parameterized modeling method. Compared with current 3D modeling methods, this method can reduce a lot of repetitive manual operations. By compiling, creating, managing, and updating 3D models through shape syntax, it can quickly build 3D models of buildings and roads, and also conveniently modify and maintain model data. In addition, CityEngine and ArcGIS can be seamlessly linked, making the output, storage, management, and visualization of model data very convenient. The 3D model of the campus scene created in this experiment can be applied to the smart campus platform, playing an important role in campus planning, resource allocation, intelligent management, and environmental maintenance.

As a parameterized modeling platform, CityEngine still has significant research space in complex modeling. Due to my lack of experience and limited programming abilities, my research on CGA is still limited to a relatively ordinary level of architecture. And future research directions can be extended to levels such as irregular buildings and internal structures of buildings. The application of CGA modeling technology is still in its
early stages in China. Through this research, it can be expected that this technology will become the mainstream of urban modeling in the future, and its application prospects will be very broad.

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