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Research on Urban Building Parametric Modelling Method Based on CityEngine

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Abstract: With the advancement of technology and the development of cities, urban planning and management methods are also constantly improving. From paper-based assignments to modern digitization, new technologies have enabled more efficient design and management for cities. 3D modeling can used to simulate the urban environment, which can assist in urban planning and management. However, large-scale modeling cannot be achieved through existing modeling methods, and there are still some shortcomings in the maintenance of the model. Therefore, this article proposes a Computer Generated Architecture (CGA) parametric 3D modeling method based on CityEngine. Research on expanding and customizing modeling rules to create indoor and outdoor modeling rule templates for buildings and methods for generating urban 3D models have been carried out. The results have shown that the completed model can be displayed on different platforms thanks to parameterized modeling. The model can be modified easily and directly applied to the analysis and decision-making of urban planning schemes.

Keywords: CGA rules; Urban planning; Texture mapping; Parametric modeling

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1. Introduction

With the digitalization of urban information, related technologies are constantly maturing and developing, and the methods of urban planning and management are gradually shifting towards digitization and intelligence [1]. Urban Geographic Information System (UGIS) is an important part of the digitization of urban information. Its principle involves collecting, storing, managing, querying, and analyzing various spatial and non-spatial data using computer hardware, software, and network technology. UGIS will also serve as an advanced tool for modern urban management, planning, and scientific decision-making, making it a part of urban infrastructures. 3D GIS technology is developed from 2D GIS technology, which can intuitively reflect the formal situation of the relevant area through 3D data and increase the detailed representation of the model. Compared with traditional 2D GIS, 3D GIS provides a more realistic representation of the city as it is built upon more information, which facilitates the portrayal of spatial relationships [2].

With the rapid advancement of urban construction and the modernization of urban management, the

demand for multi-temporal, high-resolution, and 3D simulation that can express relevant geographic spatial data is also increasing in building construction and urban planning. An accurate 3D simulation of the terrain, landforms, and urban conditions can facilitate planning approval, construction, and other works of the government [3]. The use of 3D GIS in urban planning and design will grow in popularity in the future. 3D GIS is currently widely used in urban planning and design, including land use planning, urban building planning, and transportation planning [4].

This article adopts the parameterized modeling concept based on CityEngine and CGA modeling rules. By compiling and improving the modeling parameters and rules of indoor and outdoor buildings, a "modeling analysis compilation" is created, which can act as a guide for urban building designs.

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 modified easily, 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, corresponding models and results can be obtained after changing the relevant parameters. This model can be used to analyze different problems, optimize parameter selection, and deduce the relationships between parameters [6].

2.2. Urban building parameter design

Parametric modeling is the process of abstracting the geometric features of a 3D model, mapping them to variable parameters, and controlling the values of each parameter to achieve changes in model size and shape.

The basic parameters of urban building models can reflect the basic performance and characteristics of buildings, as shown in **Figure 1**. The parameters calculated include building specifications, building types, coordinate parameters, and indoor 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 parameters of the indoor model include indoor area, window area, and indoor layout. The design of basic parameters plays a crucial role in the subsequent changes and maintenance of the model, as shown in Figure 1.

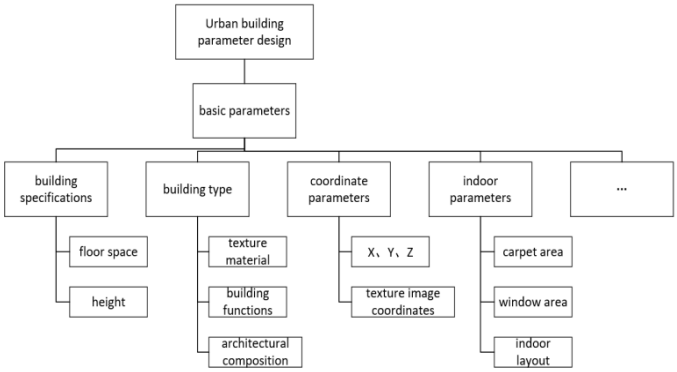

Figure 1. Basic parameters of urban buildings

2.3. Construction of urban building 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. All modeling in CityEngine 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. 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, and 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.

(3) Applying 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 2** shows the CGA rules used in building modeling and their corresponding renderings.

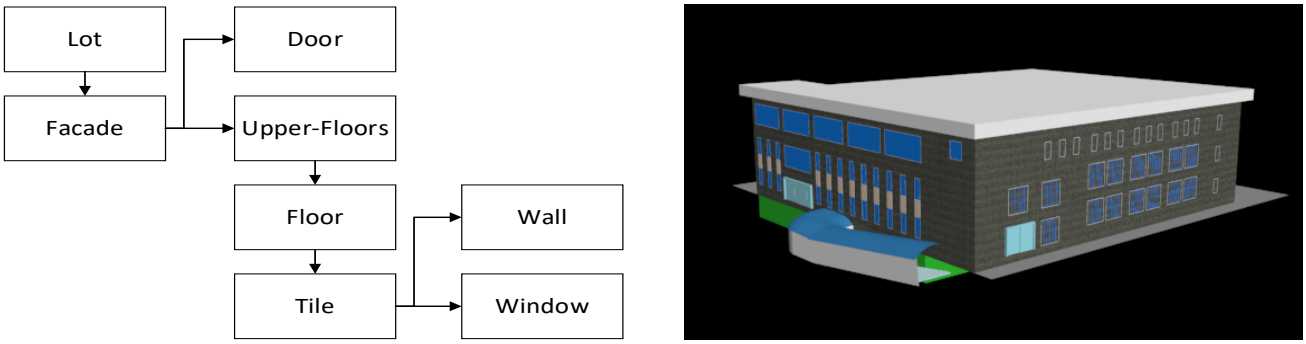

Figure 2. CGA rules and modeling effects used in the modeling of teaching buildings

2.3.3. Indoor modeling of buildings

When using CityEngine for internal 3D modeling of buildings, the first step is to assign a base map to each floor of the building based on the internal plan of each floor. These base maps include the internal and external contour lines of the building. The internal contour lines are the basis for generating the internal structure of the building model, and the external contour lines are used to generate the outer shell that surrounds the internal structure of the building. These base maps were added with a type attribute when edited in ArcMap, and the value of this type attribute can be read during rule writing. Based on this type attribute value, the internal type of the building can be determined, and different rules can be written for different types to create 3D models of the interior of each floor of the building. At the same time, in the data preparation stage, the number of floors corresponding to each building was recorded. After importing the building base map from ArcMap into CityEngine, different floors are identified through a loop, and the contour and wall of each floor of the building are generated using the CGA rule's stretch and translation functions based on the internal and external characteristics of the floors. **Figure 3** shows the CGA rules used in indoor building modeling and their corresponding renderings.

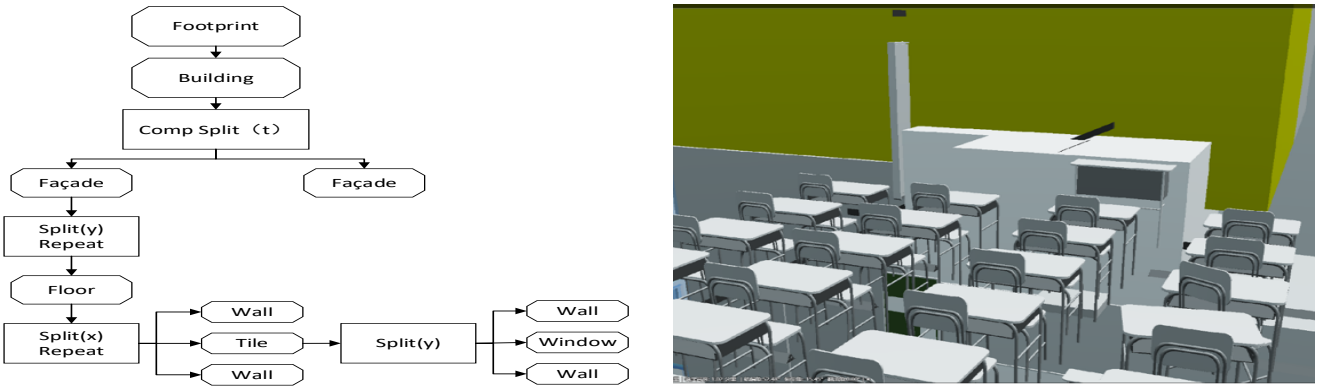

Figure 3. CGA rules and modeling effects used in the modeling of indoor buildings

3. Experiment

3.1. Preparation of experimental data

The experimental data of this article includes building vectors, building height, digital elevation models, and texture. The 3D model of the building was 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 3D 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 data such as distribution maps of each room on each floor of the building. In addition, a Document Object Model (DOM) of texture and orthophoto images was created for texture mapping. Due to the large amount of data, scene areas were divided based on the distribution of urban landforms and features. Scene models were created according to the scene hierarchy (high to low) and from coarse to fine in each area.

3.2. Modeling process

Data regarding the foundation of the building was converted into the 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. Design parameters were assigned based on building requirements to building model components and the model was imported into the CityEngine scene. The parameter rules were written according to the modeling approach and the characteristics of campus architecture. 2D planes of each component were selected and corresponding rules were assigned. Subsequently, numerous models were generated. The next process after generating the building models was 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 process of texture mapping is shown in **Figure 4**. **Figure 5** shows the modeling effect of urban architecture.

4. Summary

The CGA parameterized modeling method was tested in this study. 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 linked seamlessly,

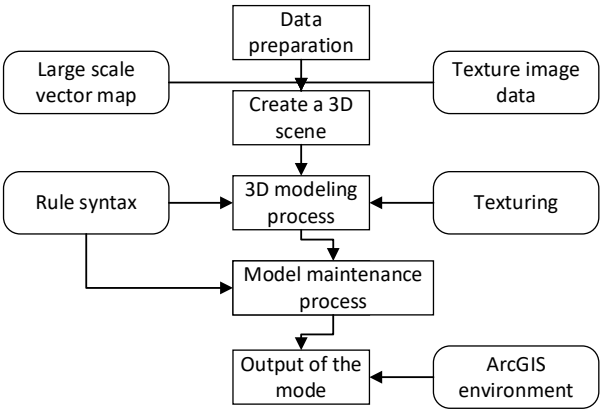

Figure 4. Urban building modeling process

Figure 5. Modeling effect of urban architecture

making the output, storage, management, and visualization of model data extremely convenient. The 3D model of urban scenes created in this experiment can be applied in digital city platforms, playing an important role in urban planning, resource allocation, and environmental maintenance.

Disclosure statement

The author declares no conflict of interest.

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