Rapid Modelling Method and Application using CGA

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Abstract. Creating 3D model Using CGA shaper grammar rules is widely used in the field of rapid building modelling. To create 3D model of Xiangnan University, a set of CGA rules is proposed. These CGA grammar rules include building rules, floor division rules, tile division rule, street rules, roof rules. Finally, in order to test the effect of the model created, the 3D model constructed is imported into Unity3D engine. The final model can be published on multiple platforms such as Web, mobile devices and PC, providing user a free 3D navigation experience.

Keywords: Rapid Modelling, Procedural Modelling, CGA, Building Modelling

1. Introduction

In recent decades, with the rapid development of digital cities, the demand for 3D modelling is growing rapidly. Fast and efficient modelling is being widely studied by industry and academia, especially in many excellent GIS (Geographic Information System) software companies, which have already developed and released a series of famous 3D GIS software. Generally, the commercial software of 3D modelling are used to create model for game animation or other commercial purposes. These kind of software include Skyline, 3ds Max, SketchUp, Autodesk Maya, CityMaker, LightWave 3D, etc. The process of 3D modelling is to use modelling tools or other means to create a spatial data model in 3D space, which requires large-scale teamwork, investing a lot of labor cost, not to mention the post-modification and maintenance. Here we list some commonly used modelling software and their disadvantages:

- 3d Max (3D Studio Max) is a modelling software for 3D modelling and animation, which is favored by advanced modelers. However, it is difficult for beginners to control accurately because it requires a long period of training to master. Moreover, The quality of the model depends entirely on the ability of the modeler.

- Skyline, a 3D digital earth platform researched by Skyline, is an extremely user-friendly tool for developers. It uses remote sensing image data of the earth satellite, elevation map data, user-controllable 2D data and 3D data to simulate the terrain and bump texture of the building. The software uses data that can be converted directly from the real building, so it has good simulation ability, which gives the user a good sense of use. However, the model built with it is highly encapsulated, so the developers don’t have too much space to play. Moreover, the price of using the software and its after-sales service is extremely high, which is not suitable for beginners and small entrepreneurial companies to use.
• SketchUp is a modelling software that allows user to create model directly, object-oriented from line to surface, and then extrude the surface of the scene. This is the most common idea and method used in modelling. Its operation is very simple, suitable for beginners modelling. However, it requires investing a lot of labor cost, so it is not suitable for building a large number of models.

• CityMaker is a modelling and 3D GIS system software independent research and development in China by Weijingxing Company. The platform has a very mature commercial solution system from the architectural topography, 2D data, 3D data, material integration, editing and modification as well as the display and release of the final model, which is convenient for customizing the needs of customers. However, the platform is highly developed and requires high levels of knowledge and technology for developers.

• CityEngine is a modelling software for urban buildings. The biggest innovation is that it uses CGA [1] rules to describe 2D and 3D data, which is a major advance in data processing and data conversion. Moreover, this software uses codes to build and control models, and various parameters of buildings are controllable and have a range value, which is convenient for developers to randomly build a large number of buildings in batches, shorten the period of building models and greatly reduce the cost of modelling.

In this paper, we use shape grammar [2, 3] based modeling method to build a campus model. Such modelling method is widely used for urban buildings modeling [4, 5]. Later people developed many other grammars to create buildings, such as wall grammar [6], tiling grammar [7], Bayesian grammar [8], etc. Improved rule based modelling method can be used to modelling ancient buildings [9, 10]. Rule based modelling method do not need the user have artistic skills. All we need is to design enough rules to describe our buildings and other components.

2. Procedural Modelling and CGA

CGA is the abbreviation of Computer Generated Architecture. CGA Shape Grammar is a rule-based shape grammar for 3D modelling. The modelling idea of CGA is to define rules, and then create detailed modelling through continuous refinement and design, which is successfully applied in CityEngine.

2.1. CGA Rule

The core idea of CGA rule is to start from a base surface, and create 3D modelling mainly through a series of operations, including translation, extrude, split, replacement, add texture. Next up is the topic of the modelling rules we designed.

2.1.1. Building rules

The basic building rule is shown in formula 1:

\[
\text{comp}(f)\{\text{front} : \text{Frontfacade}\mid \text{side} : \text{Sidefacade}\mid \text{top} : \text{Roof}\}
\] (1)

This rule is used to split the shape \(f\) into three different parts. The first part is the \(\text{Frontfacade}\) (the front of the building), the second part is the \(\text{side}\) (the multiple sides of the building), and the third part is the \(\text{Root}\) (the roof part). The facade of the building can be further constructed. A typical facade modelling process is as follows: first, the facade will be decomposed into multiple floors, then the floors will be further decomposed into tiles of multiple elements. Typical tiles include elements of walls and windows. The process of segmentation is shown in figure 1:
The floor division rule
The floor division rule is shown in formula 2:

\[
\text{split}(y) \{ \text{groundfloor \_height : Groundfloor} \mid \{ \text{~ floor \_height : Floor} \}^* \}
\]

(2)

This rule can be used to divide the shape of the Floor into multiple floors, the first floor being the Ground floor, and the floors above the first floor being floors with the same size. Figure 2(a) shows the result of segmentation.

The level division rule
The level division rule is shown in Formula 3:

\[
\text{split}(x) \{ 1 : \text{Wall} \mid \{ \text{~ tile \_width : Tile} \}^* \mid \text{~ tilewidth : EntranceTile} \mid 1 : \text{Wall} \}
\]

(3)

Using this rule, the floor can be further divided into a wall on the left, tiles, entrance, and another wall on the right. Figure 2(b) shows the result of segmentation.

The tile division rule
The tile division rule is shown in Formula 4:

\[
\text{split}(x) \{ \text{~1 : Wall} \mid 2 : \text{split}(y) \{ \text{~1 : Wall} \mid \text{1.5 : Window} \mid \text{~1 : Wall} \} \mid \text{~1 : Wall} \}
\]

(4)

This rule can be used to divide the block x in the X axis into three parts. The left and right part of the block is divided into a wall with size of 1 unit, and the middle is divided into a part with the size of 2 unit. The middle part is further divided into three parts in the Y axis, the upper and lower parts are divided into a wall with the size of 1 unit, while the middle part is divided into a window of the size of 1.5 unit. Figure 2(c) shows the effect of segmentation.

The street rule
The street rule is shown in Formula 5:

\[
\text{split}(v, \text{unitSpace}, 0) \{ \text{SidewalkHeight : Curbs} \mid \text{~1 : Pavement} \}
\]

(5)
Use this rule to divide streets into sidewalks and lanes that can be textured independently. Figure 3 shows the result of segmentation:

![Figure 3. Street Segmentation](image)

2.1.6. Roof rule
The roof rule is shown in Formula 6:

$$\text{comp}(f)\{\text{top} : \text{TopFacade} | \text{side} : \text{SideFacade} | \text{all} : \text{NIL}\}$$

(6)

Using this rule, we can split the roof into roof, side, and other faces. The roof and side have corresponding syntax rules, while the other side syntax rules are empty, so different types of roofs can be built depending on the slope of the roof and the number of faces. Figure 6 and 7 show renderings of half-slope and double-slope roofs.

(a) The half-slope roof  
(b) The double-slope roof

![Figure 4. Roof grammar](image)

3. Experiments and Results

3.1. Overview
We build the main area of Xiangnan University with the above rules with CGA grammar. An overview of the campus model in CityEngine is shown in figure 5:
Figure 5. An overview of the overall model

3.2. Street

The street is divided into five different types of shape blocks, each with different initial rules: streets, sidewalks, crossings, and junctions. According to the road width map, the height of the sidewalk is 0.2 meters. In order to improve the realism, we create street light every 15 meters along the street, with a height of 5 meters. The overall model and local area of the street are shown in figure 6:

Figure 6. The result of the street

3.3. Greenbelt

The greenbelt is important decorative component for campus model. We created greenbelt between the road and the building. The final modelling result with greenbelt is shown in figure 7(a). The plant models used for greenbelt are shown in figure 7 (b),(c).
Figure 7. The result of campus model with greenbelt

3.4. Rendering and Interactive
The model is rendered with Unity 3D engine. The user can control a player to walk around in the virtual 3D world. The final result is shown in figure 8:
4. Discussion
We designed a set of CGA rules to create a 3D model of Xiangnan university, and finally import the models into Unity 3D, providing users a free 3D navigation experience. Since the model does not obtain from the actual terrain data, building data and planning data of the university, we needs to design the map to simulate the layout of the campus independently, which will cause a series of problems. For example, after the construction of the layout of the building, it is found that the greenbelt and street data do not match well enough, which means the buildings’ position needs to be further modified.

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