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A CASE STUDY: 3D CITY GENERATION USING PROCEDURAL MODELING FRAMEWORK AND EVALUATION STRATEGIES

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ABSTRACT

This case study reviews the procedural modeling methodology to reconstruct 3D buildings when given a single facade 2D image view and their corresponding footprint. This is an algorithmic approach when compared with existing software tools that are used for mass 3D building model generation like CityEngine. Procedural modeling framework accepts the best production rule given a particular alignment of footprint. We have evaluated the framework using modeling experiments by taking real building footprint data and 2D photographs. We have proved the reliability of procedural modeling framework from the results of user satisfaction survey. The Cronbach's alpha value of 0.86 suggests that the results are statistically significant.

Key words: Procedural Modeling, 3D City Generation, Image based Reconstruction.

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1. INTRODUCTION

3D City generation[1,2] for different applications like video games, advertising, movies, urban planning and navigation is a great challenge for graphics designers and modelers. In our study, we have considered the approach of 3D building modeling which includes data acquisition from a single photograph taken from a single view of the building. Single view reconstruction can also be used to reconstruct buildings that are non-existent today and are available only from single photographs. The key idea of this approach is to reduce the infinite number of solutions that might otherwise arise when recovering a 3D geometry from 2D photographs by estimating the abstract geometric shape features of the components, followed by capturing detailed structural information and component filling. Hence, the 3D modeling is a reverse problem which involves recovering the initial 3D scene which have undergone digitalization stages like discretization, quantification that involves important loss of information. In order to effectively reconstruct a full building modeling pipelines involves time consuming and laborious manual processing to rectify the ill-reconstructed building models and to achieve high quality mass modeling. To address this problem, previous works[3,4,5] utilize procedural modeling to help generate complex and repetitive structures. However, expressing the designer’s intent by manually writing the grammar is virtually impossible and that is why many interactive, or user assisted approaches have been used.

Procedural modelling[6,7,8], can be considered as a generic approach and can be executed in a number of ways. Hence, it is not possible to associate a single definition for the process. In the seminal work[9], procedural methodology, is described as multiple steps of shape grammar associated with a particular structure. In our paper we consider the evaluation of procedural modelling technique to correspond to the design of shape grammars. In our evaluation process, we compare the component extraction methodology of the framework under study and traditional CityEngine software. Also, we have evaluated the framework using modeling experiments taking into consideration the data acquired from real building footprint data and 2D photographs. Then, we further validated the framework using the results of user satisfaction survey.

2. COMPONENT EXTRACTION TOOL STUDY

This section presents the case study conducted on constrained procedural modeling framework by quantitative experiments. Firstly, the structural information capturing module was compared with Facade Wizard of CityEngine software. Our experiments were conducted on a variety of images (mostly online photos). Each image was cropped. In the experiments, cropping is done using general interactive cropping tools. It is also possible to conceive an automatic method by selecting boundary edges from the recognized components in the image. Facades vary greatly in structural irregularity and footprint complexity. The experiments were based on the number of operations and the total time taken in extracting the components. The results are shown in Table 1. The CityEngine Fazard Wizard tool used 50 operations to extract 72 components from the given image whereas our component extraction tool used only 13 operations. The time taken for extracting the components is over one minute. This is a clear indicator that real time reconstruction using our framework is not feasible at this stage. Also, our implementation involves several pre-processing stages. The Figure 1 shows the components extracted from two different tools; (left) CityEngine fazard wizard tool , (right) component extraction tool developed for component extraction in our work..

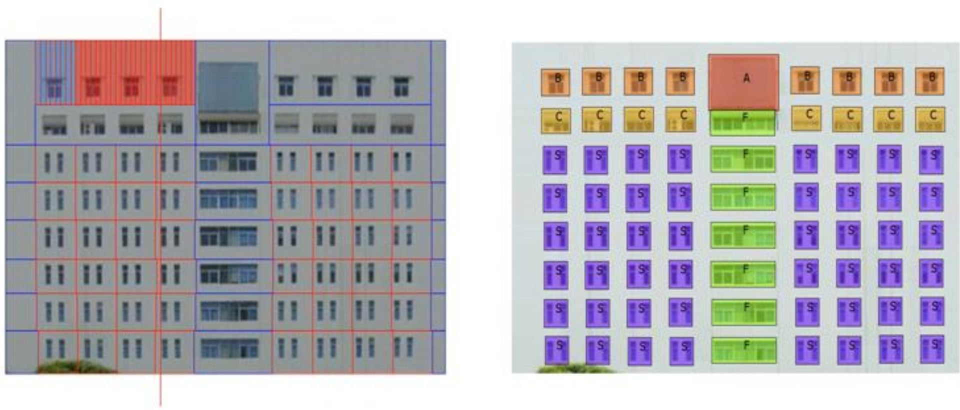

Figure 1 Comparison. (left) CityEngine Fazard Wizard tool , (right) Component Extraction Tool developed for component extraction in our work.

3. FOOTPRINT GUIDELINES FOR GENERATING 3D CITY

We have evaluated the proposed system based on user experience and satisfaction. We divided the participants into various categories based on their expertise in 3D modeling. Each user was given a single view photograph of the building to be reconstructed and a city footprint as shown in Figure 2. The generated results are shown in Figure 3. The participants actively modeled the city with ease by the procedural framework developed and the results are shown in Figure 4.

Table 1 Comparing interactive component extraction tool to CityEngine Wizard

	No. of Operations			**Total Operations**	**Total Time (min)**
Fazard Wizard (CityEngine)	Horizontal Split	Vertical Split	Repeat	50	1.45
	8	26	16		
Interactive Component Extraction Tool (Our Approach)	Select	Repeat	Clone	13	1.15
	6	6	1		

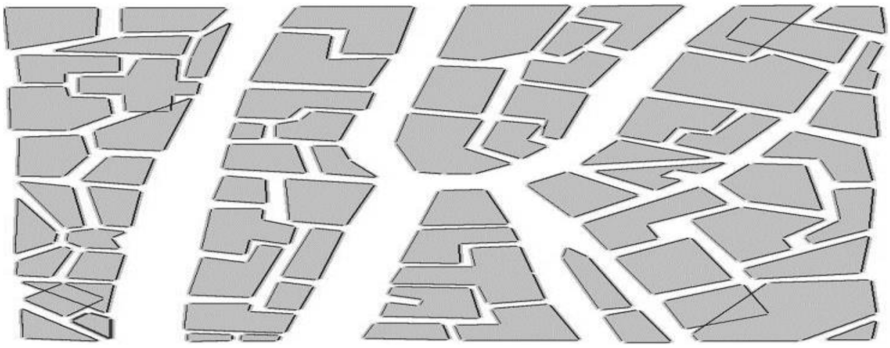

Figure 2 Footprint guidelines for generating a virtual city

Figure 3 Sample virtual city (different views) generated from the footprints shown in Figure 2

Figure 4 Progress of 3D modeling among the participants of the user study

4. USE CASE SATISFACTION

Next, user survey was conducted using direct questionnaire as indicated in Table 1. The participants varied from novice users to expert users. The results of the survey were calculated using Cronbach's alpha value. The Cronbach's alpha value is a classical theory test used to estimate the reliability of psychometric test. The value of 0.86 > 0.7, suggests that the results are statistically significant. The graphical representation of the user satisfaction survey based on the expertise of user and their satisfaction level is indicated by the Figure 5.

Table 2 Result of Questionnaire Number of Participants (n=15) (%)

1. The building generated was similar to the given 2D image.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 1(6.6) 10(66.6) (26.6)
2. It was easy to generate the building	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 3(20.0) 9(60.0) 3(20.0)
3. It was easy to align building to its footprint.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 1(6.6) 9(60.0) 5(33.3)
4. It was easy to vary the building component depth.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 1(6.6) 2(13.3) 9(60.0) 3(20.0)
5. It was easy to vary the size(height, width, depth) of the building.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 1(6.6) 2(13.3) 12(80.0)
6. It was easy to create variations of the same building.	Strongly Disagree Disagree Normal	0 0 2(13.3)

	Agree Strongly Agree	11(73.3) 2(13.3)
7. It was easy to generate a virtual city.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 1(6.6) 2(13.3) 10(66.6) 2(13.3)
8.The results of virtual building generation was satisfactory.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 1(6.6) 11(73.3) 3(20.0)
9. The results of virtual city generation was satisfactory.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 0 12(80.0) 3(20.0)
10. The test bed was convenient to use.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 3(20.0) 2(13.3) 10(66.6)
11. Recommendation of the proposed scheme for city generation and urban design.	Strongly Disagree Disagree Normal Agree Strongly Agree	0 0 0 4(26.6) 11(73.3)

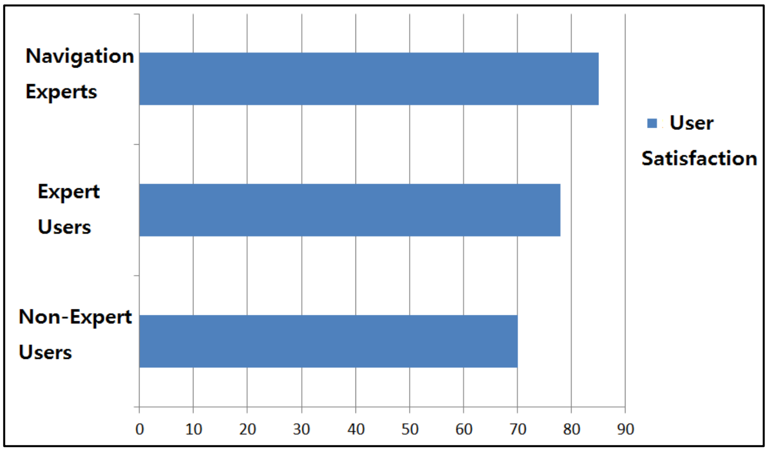

Figure 5 User satisfaction

5. CONCLUSIONS

In our work, we have presented various evaluation strategies for procedural modeling framework in order to generate and update real world 3D building given as input a single facade layout and real footprint data. The main challenge of the rule dependent Procedural Modelling technique is that they are less intuitive due to lengthy description of grammars. In the context of smart city and its digital reconstruction, a huge amount of rules are to be formulated and hence would be unmanageable for large urban cities. This paper suggests that performance is improved by adopting procedural modelling technique for city generation given such complex volumes of data.

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