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A model synthesis method based on single building facade

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ABSTRACT

In this paper we present a convenient building model synthesis method. It aims at obtaining new user-defined building models through seamless stitching after synthesis of each single building facade. During the optimization process of synthesis of each single building facade, we utilize model structure analysis method to obtain the smallest structural units and the constraint graph among them, transforming complicated three-dimension (3D) synthesis problem into two-dimension (2D) constraint graph synthesis problem. Then we construct a global energy function and minimize it through iterative optimization with expectation maximization algorithm, in order to obtain new objective constraint graph. During stitching process, in order to get complete model synthesis result, we replace objective constraint graph with structural unit to transform synthesis back into 3D space, and achieve automatic stitching between neighboring construction units and neighboring facades by using the connection point sets of structural units in original samples. The experiment results demonstrate our method can generate building models of absolutely different styles quickly and efficiently based on single or multiple samples, while maintaining the continuity and visual integrity of result models well.

1. Introduction

Since plenty of 3D building models are needed in the fields like 3D games, movies, and virtual reality, so how to generate these 3D models quickly and efficiently has become one of the most challenging problems in the field of computer graphics. Among the methods of generating 3D models, the most commonly used method is procedural modeling [1–3], which manually design the heuristic rules or parameters for creating models by experiences; however, this method is time-consuming and inconvenient to directly modify and edit the models. As the increasing appearance of plentiful sharable 3D models, constructing user-defined models based on the existing models has become a new direction in the modeling field, which has obtained a series of research achievements [4–9]. Such method can not only directly determine the pattern of models, but also simplify and accelerate the modeling process.

We propose a new modeling method for existing mesh building, which enables users to reuse already known building styles to create new contents very easily. Making use of the characteristic that most of building models are constructed from the stitching and combination of each separate facade, we transform the synthesis of building models into the seamless stitching of each single building facade after respective synthesis.

Aiming at key single building facade synthesis, we transform 3D synthesis into 2D synthesis of the 2D constraints between structural units (the constraints between structural units is defined as our constraint graph) by making use of the similarity between the structural unit repeatability (for example, a model includes multiple structural units like windows or doors, etc. of similar structure) and texture

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structure repeatability of building models, and by referring to the texture synthesis thought based on global optimization [10], constructing global energy function and solved it with optimization method, in order to obtain the objective constraint graph.

Aiming at seamless stitching, we solve the problem in two aspects: one is that the seamless stitching of the structural units included in each single facade after synthesis; and the other is that the seamless stitching of each neighboring facade. In this paper, an uniform framework is adopted to solve the above problems. Namely, the minimum distance between the connection point set in original examples of each structural unit and that of neighboring structural unit is used to achieve the automatic seamless stitching between neighboring structural units and neighboring facades.

The method proposed in this paper can achieve model synthesis based on both single example and multiple examples.

The main contributions of this paper are:

- According to the structural characteristics of building models, we have presented a new building model synthesis method. which aims at obtaining new user-defined building models through seamless stitching after synthesis of each single building facade. During single building facade synthesis, we have transformed complicated 3D model synthesis into simple 2D constraints synthesis and solved the problem based on the 2D constraints relationship between structural units of example model. During seamless stitching, we achieve automatic stitching of structural units based on the original connection point set of structural units and calculation of the minimum distance between point sets.
- Our method provides a new way for building modeling synthesis, which significantly shorten the modeling time and avoid the creation process from scratch. Starting from single or multiple examples, users could create new building models with various styles based on existing building models. Our method not only enriches the means of modeling for professionals, but also enables non-professionals to enjoy the fun of modeling.

2. Related work

Example-based synthesis [7,10–15] has always been a hot-spot in computer graphics. In recent years, research on the reuse of existing model resources has also become an important topic of researches in 3D modeling field. Our method belongs to the above technology as well, so we will briefly narrate the methods for reusing existing models related to this paper.

In procedural modeling, researchers have achieved reuse of existing models by means of inverse procedural modeling, model synthesis, and inference-based procedural modeling, etc.

The inverse procedural modeling method proposed by Bokeloh et al. [4] uses symmetry analysis to detect regular patterns of the input model, and establishes the corresponding grammar system for every symmetric element; then the symmetric elements can then be used to infer a generative model. The model synthesis method proposed by Merrell and Manocha [9] later takes an existing model as input and generates many complex variations while following a local constraint, namely every point in the output is locally identical to some points in the input. Inference-based procedural modeling proposed by Biggers and Keyser [16] introduces user interactive mechanism in the phase of model analysis and generation, they sample and extract surface patches from input models, and develop a Petri net structure that describes the relationship between patches along an imposed parameterization, then they use the Petri net to generate a new model for a new parameterized line or curve given by user. An algebraic model is adopted by Bokeloh et al. [5] to express shape structure and develop a robust interactive system where user can rapidly obtain plausible shape variations by intuitively placing and moving a set of sparse handles. The modeling system established by Barroso et al. [17] introduces the concept of visual copy and paste, rewrites the rules for the existing models of procedural modeling by adding copy and paste operations during modeling, thus building new models.

All above methods generate new models by analyzing existing examples, but they describe models with abstract rules and parameters, so model builders have to be familiar with the rule system of models or parameter setting method, which is not easy for most common users.

In the research of reusing mesh models, researchers have achieved the reuse of pre-existing resources partially through component assembly technology.

Funkhouser et al. [18] have taken the lead in providing the example modeling method based on components assembly. It allows compositing of different parts from different input models to obtain a desired output. Later, Lee and Funkhouser [19] extends this method to support sketch-based search and synthesis. Kraevoy et al. [20] and Jain et al. [21] introduce component matching in synthesis process to improve the effectiveness of the component structure.

However, the result of modeling based on components assembly depends on the establishment of model database as well as the modularized splitting and matching results of models; meanwhile, this method considers the simple structural attribute of component connectivity, so the modeling result cannot maintain the structural characteristics of original models. In addition, its very difficult to obtain complete component information from building modeling, so such method cannot be applied to the construction of building models.

In the research of reusing mesh models in recent years, a modeling method based on structure preservation has been proposed. This method generally divides the example-based modeling process into two steps – model analysis and generation, and it is mostly applied to the reuse of building models.

Merrell [7] has taken the lead in utilizing the idea of example-based texture synthesis to propose a model synthesis method, which uses the self-similarity of a discrete example to generate large models that resemble the input model with the idea of enumeration. However, the method

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