GENERALIZATION OF FUNDAMENTAL CITY SPATIAL MODEL
FOR THE DATA GENERATION SATISFIED WITH USER'S REQUIREMENTS

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ICWG II/IV

KEY WORDS: Generalization, City Spatial Model, Fundamental Model, Tailored Model, User's Requirements

ABSTRACT:

As the Geospatial Technology (GT) grows, the generation and utilization of 3D city spatial model are actively studied. In some applications, the fundamental model is too detail comparing with the level of detail (LOD) actually needed by users, which make it difficult for users to process, analyze and visualize the model efficiently. In this study, the goal is to develop a generalization procedure to generate a tailored city spatial model tailored to user's specific requirements from an existing fundamental model of higher resolution. This study consists of two stages; one is the generation of the fundamental city spatial model and the other is the generation of a tailored city spatial model through the generalization of the fundamental model. Here, the model generated in the first stage is the model of the best quality in aspects of accuracy, resolution, and detail that can be derived from the original sensory data, such as the aerial and terrestrial images. The model in the second stage is the model that is tailored to user's requirements for a specific application.

1. INTRODUCTION

As the Geospatial Technology (GT) grows, the generation and utilization of city spatial model have been actively studied (Kim, 2002; Araby, 2004; Lerma, 2004; Sidiropoulosa, 2006b). A city spatial model is a digital model abstractly representing the real world. It contains sophisticated 3D models of all the objects on the terrain, such as buildings, roads, and other facilities. Each object is represented as a model retaining its geometric, radiometric and attributive information. For example, regarding a building, its geometric information such as its shape and location is provided with a polyhedral model containing corners, edges, and facets. Texture draped on each facet provides the radiometric information. The attributes such as the usage, owner, value, and completion date of the building are also linked to the model.

Such city spatial models can be effectively utilized or sometimes inevitably required for the services offering to users in many applications. For example, when traffic congestion due to any unexpected incident occurs, the traffic management teams require a city spatial model to find the solutions more correctly and quickly. In addition, when a disaster such as a fire and earthquake happens, one can derive a clearway for the safety of the peoples in such a situation based on the city spatial model.

Many studies have been focused on generating a sophisticated 3D city spatial model covering a wider range with the geometry of higher resolution and more realistic texture, which is so-called a *fundamental city spatial model* in this paper. However, in some applications, the fundamental model is too detail comparing to the specific goals of the application and thus retains a huge data size. This may cause a significant time lag to transmit and visualize the model for the users even if it should be done in near real-time in many applications. In such cases, the details of the fundamental model have to be reduced at most to the minimum level that still satisfying the user's requirements derived from a specific application. This reduced model is called a *tailored city spatial model*, being produced the generalization of the fundamental model. Hence, the goal of this study is to develop a novel method to generate the tailored city spatial model based on the specific requirements of the users by generalizing the fundamental city spatial model.

The previous studies on the generalization of 3D models (or features) have been usually performed with the processes such as *exaggeration*, *simplification*, *typification* and other processes. Bai and Chen (2001) have defined exaggeration as the enlargement of the small but important objects in the models so that they are still recognizable in a model of smaller scale. Such objects can be a small part of a building and road facilities such as lamp posts along streets. Conversely, simplification has been used to eliminate minor parts of a building and small features (Li, 2006b).

In this study, we created a fundamental city spatial model at first. After analyzing the user's requirements, we defined the constraints for the visualization's environment and derived the generalization process under the defined constraints. Finally, we generated a tailored city spatial model through the derived generalization processes.

2. MEHODOLOGY

2.1 Overview

The creation of the city spatial models consists of two stages. In the first stage, we create the fundamental city spatial model

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retaining the best quality in terms of its accuracy, resolution and detail. It can be usually created by using aerial photographs, LIDAR data, digital map and other large scale data. We aim to display this model in an immersive virtual reality environment using a high performance computer system, that is, a cluster of PCs with high fidelity CPUs and GPUs.

In the second stage, we generate a tailored city spatial model by generalizing the fundamental city spatial model created at first stage. The fundamental model is generalized to a tailored model so that this model can satisfying the constraints on the data transmission rate, time and cost derived from user requirements to a specific application. This tailored model will be used to visualize in a web or desktop environment using a standard PC.

2.2 Creation of the fundamental city spatial model

The fundamental city spatial model is created by eight steps a shown in Figure 1, being briefly described in the following paragraphs.
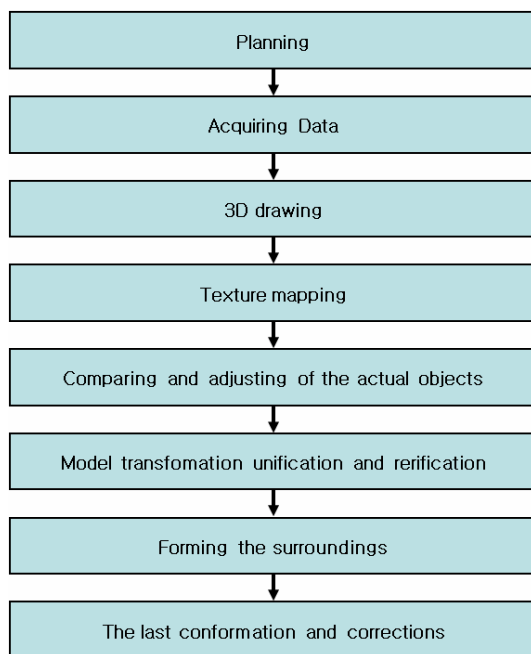

Figure 1. The generation process of the fundamental model

2.2.1   Planning: We will firstly attempt to understand the purposes, services, circumstances and requests for the fundamental model. After establishing the outline and definition about the model, we will determine the priority order of the work and derive a generation plan of the model.

2.2.2   Acquiring Data: We will acquire raw sensory data required for the creation of the fundamental model. These raw sensory data can be aerial photographs, close-range photographs and moving pictures. The aerial photographs are used to extract the external forms of buildings and earth's surfaces. The close-range photographs are used for the extraction of the texture on structure's outer walls. The moving pictures taken by a camcorder are used for one to understand the real world that the model being created represents.

2.2.3   3D Drawing: We will generate the 3D geometric model with the sensory data. After establishing the interior and exterior orientation of the aerial photographs sufficiently overlapped, we will digitize the outlines of objects such as buildings, bridges, and terrain in a stereo-view and then generate their 3D polyhederal models.

2.2.4   Texture Mapping: We will drape the textures on each facet of the polyhedral 3D-models. The textures are extracted from the close-range photographs taken in front of each facet.

2.2.5   Comparing and Adjusting: We will refine the 3D textured models by comparing them with their corresponding actual objects. We will attempt to generate more realistic model by correcting the wrong parts of the models through their comparison with the close range photographs and moving pictures.

2.2.6   Unification and Rectification: We will transform the individual 3D models in an integrated model (or a file). The EON studio software is used for the integration and visualization of the models of the entire project area. From this step, we will generate an EON file.

2.2.7   Forming the surroundings: The integrated models generated in the previous steps include mainly the buildings and terrain. In this step, we will add their surroundings such as trees, sky, flows in the stream, traffic and the persons' movements. These surroundings are generated through the manual interpretation on the moving pictures taking the environment not from the digitization of the 3D view of the scene. Hence, they do not retain the same geometric and radiometric accuracy as the 3D models of the buildings and terrains but improve the reality of the entire model.

2.2.8   Conformation and Corrections: This step is the final correction process based on the comparison of the integrated model with the real data such as moving picture acquired by the field survey.

2.3 Creation of a tailored city spatial model

The tailored city spatial model is created by defining the constraints, selecting the generalization methods and applying the generalization methods, as shown in Figure 2.
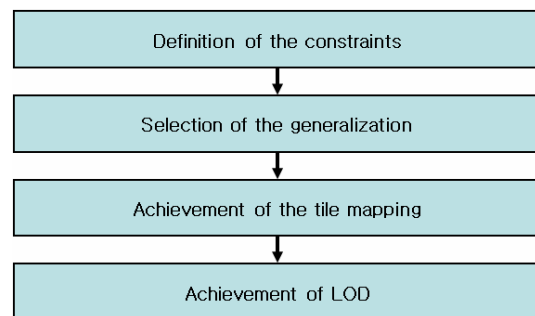

Figure 2. The generation process of the tailored model

2.3.1   Definition of the constraints
The constraints can be derived from the user's requirements in a specific application. The application is assumed as a web-based decision support system. In this system, a user is assumed to bring the 3D models of the target area and the analysis results based on the models and visualize them in a web interface

operating in a standard personal computer to support any decision based on the analysis results. For example, imagine a noise management system of an urban area. As the noises haven been recognized as an important problem in urban life, the noise management to reduce the noise level in a specific area can be more systematic and effectively implemented in a web-based decision support system. To realize such a system, we derive the standard users' requirements (or constraints) in terms of the specification of a standard person computer and the visualization performance of the spatial information and the analysis results.

The first requirement is that the visualization can be performed on a web-based interface running on a standard personal computer. The constraints derived from the user requirement can be summarized in Table 1.

Items	Specification
CPU	Pentium D 3.00GHz
RAM	2.00GB
Operating System	Window XP
Software	EON Viewer

Table 1. The constraints of computer

The second requirement is that a user can freely navigate the city spatial model with the analysis results on the web-interface. For example, the zooming in/out and panning of the model should be done in real-time. The core constraint is the minimum rendering time that a user does not feel any inconvenience abut.

2.3.2   Selection of the generalization
In general, generalization is based on five conceptual schemes, that is, classification, simplification, exaggeration, symbolization, induction. Classification is to compare the features and group the similar features into an integrated one. Simplification is to retain only the important feature by removing the unnecessary details.

By considering such general schemes, in this study, we have proposed two generalization methods to meet the users' requirements. First, the tile mapping is proposed. The tile mapping is a method to expresses the texture of a facet in a polyhedral model of an object with textures of small area, so called *tiles* instead of a texture covering the entire area of the facet. Since most areas of a facet usually retain repeated patterns of the texture of small area, the texture size is significantly reduced if a tile mapping scheme is employed. This can be categorized into a typification scheme. Second, a pyramid of spatial models with different LOD (Level Of Details) is generated. This can accelerate the rendering time when we visualize the entire model by using the the most coarse model

2.3.3   Tile mapping
In this process, we aim to accomplish the two things, the simplification of the geometry of the objects and the typification of the texture draped on the facets of the objects.

For the simplification, we first simplify the roof surface of objects into a polygon and generated the wall surface of objects with the edges of the simplified polygon. In the following typification proess, we analyzed the texture of the individual simplified surface and segment each surface into a sub-region with the similar texture. We then generate a texture tile

representing each sub-region in a repeated pattern. Instead of using the texture covering the entire region, we will use a repeated pattern of the texture tile to express the texture of the region.

2.3.4   Pyramid of different LODs
The models of more coarse LODs are generated by two processes, the simplification of the geometric structures of each object model and the texture on each facet of the model. The geometric simplification can be performed by repeatedly merging the adjacent facets with similar plane parameters. Since two adjacent facets share at least an edge, if the angle between their normal vectors to each facet is less than a certain threshold determined at each LOD, the facets are merged into a facet approximated to two facets. This process is repeatedly performed until no more two adjacent facets retain the similar normal vectors.

Regarding the texture simplification, we generated three different set of textures by compressing the original texture of the best quality included in the fundamental model.

3.   EXPERIMENTAL RESULTS

3.1   The experimental region

The Cheonggye restoration project had been performed by Seoul metropolitan city, from July 2003 to September 2005. The goal of this project were is to restore the region of Cheonggye stream by demolishing the roads and overpasses covering the stream so that the area can be converted into a historical and cultural space with more ecological environment. This project restored the region from the Cheonggye road to the Sam-il road including their peripheral regions with a budget of 380 million dollars (Seoul Metropolitan City, 2006).

This study attempted to create the detailed 3D models of the region along the Cheonggye stream before and after its restoration. These areas are shown in Figure 3.

Figure 3. Target region for the generation of city spatial model

The length of this region along the the Cheonggye stream is about 5.3 Km and its size is about 40 Km^2. After generating the individual models of 22 sub-regions expressed in Figure 3, we integrated them into an entire model.

3.2   Generalization Results

After the fundamental city spatial model of the target area being generated, it was generalized to a tailored model by simplifying the geometry and texture of the fundamental model. Figure 4 shows the results of the geometric simplification of a building. Figure 5 shows those of the texture simplification based on tile mapping. Even though the size of the texture file is reduced through tile mapping, the quality of textures is improved. Figure 6 shows some examples of a pyramid of the models with three different LODs.
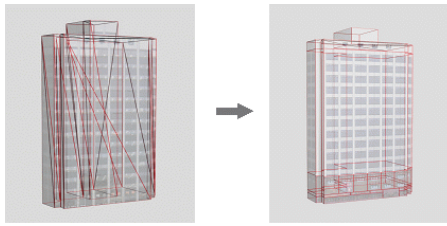
Figure 4. Result of the simplification

Figure 5. Result of the tile mapping

Figure 6. The object model with LOD

3.3 Tailored Model

The components of the tailored city spatial model finally generated are summarized in Table 2. The file size of this complicated model including the 30 bridges, 3 thousands buildings and other many objects is about 309 Mbytes. Figure 7 shows a starting portion of this model. As can be seen, the delicate geometric model with realistic texture was achieved.

Objects	Number of objects
Bridges	30
Structures	3,039
Surfaces	234
Trees	788
Streetlights	257
Ralls	32
Mapping manage	20
Mapping Source	554

Table 2. Components of a tailored model of the Chunggye stream region

Figure 7. The tailored city spatial model

4. CONCLUSIONS

We proposed the methods to create a fundamental city spatial model and generalize it to a tailored model customized to users' requirement for a specific application. The method has been successfully applied to generating the 3D models of the Cheonggye stream area. The proposed generalization methods can be an effective to generate a model of suitable file size and resolution in a computer environment of a limited capacity and performance.

ACKNOWLEDGEMENTS

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