

DEVELOPMENT OF DIGITAL CITY USING 3D GIS AND ITS APPLICATION TO VISUALIZATION OF EARTHQUAKE DISASTERS

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ABSTRACT: “Digital city” is a copy of an actual city in the virtual space. It is expected to play an important role in urban planning, disaster simulation etc. Recent advanced remote sensing technologies, which are capable to quickly provide detailed information of city areas, ease the construction of 3D city models. In this study, a virtual 3D city model is constructed using MapCube data, consisting of configuration of buildings obtained from airborne laser scanner surveying flights. First, GIS data including MapCube building data, roads, vegetation, and ground elevation from various sources are compiled. Then, all the data are imported into VTP (Virtual Terrain Project), an environment to easily construct the reality in an interactive 3D digital form. Subsequently, the textual information of actual buildings captured from aerial and ground photographs is added on the 3D model in VTP. Using these 3D models, it is able to illustrate various scenarios of an earthquake disaster through damaged buildings, road cracks and fires. The created models can be used in information dissemination and education of disaster mitigation.

1. INTRODUCTION

The needs for 3D city models are growing in numerous fields. It has been used in urban planning and design, car navigation, virtual tourism, etc. The difficulties in construction of 3D city models such as hardware, software, and detailed geospatial data have been overcome by the advances of computer and remote sensing technologies. For example, airborne laser scanner surveying flight can quickly provide very detailed information of 3D urban structures. A 3D virtual city model can represent more information and be more easily understood than a traditional 2D map. Moreover, it is not only valuable to present the current status of a city but also to simulate various scenarios of changes in the city.

3D city models have recently raised great attention from disaster mitigation field. Schwelier et al (2003) simulated building damages caused by earthquakes for the development of fast reconnaissance techniques. They generated post-event 3D CAD models. Nardi et al (2002) proposed a real-time 3D model used for monitoring in search and rescue operations in large-scale disasters. Their main goal is to construct a rescue system using 3D graphic representation. Maki et al. (2005) carried out a project on recovery process from the 1995 Kobe earthquake using 3D-GIS. It shows the changes of the city by 3D visualization. In a 3D space, the scenes of 1) before the event, 2) soon after, and 3) ten years after of the Flower Road, a landmark of Kobe, are visualized. As we can see, 3D visualization is very useful to figure out what happened, is

happening and will happen. Usually, making 3D visualization is time consuming and complicated. A simpler and faster approach should be developed.

In this study, we employ the VTP (Virtual Terrain Project), an environment to easily construct the reality in an interactive 3D digital form. The 3D structure information is derived from MapCube data, which consists of the buildings obtained by airborne laser scanner. Textural information is captured from both aerial photographs and ground-based photographs. Additionally, roads, trees, etc. are acquired from existing 2D-GIS databases. The constructed 3D model is subsequently used to illustrate a disaster scenario. Created virtual earthquake disaster scenes look very realistic and easy for understanding.

2. DATA AND TOOLS FOR CONSTRUCTION OF 3D MODEL

(1) MapCube

MapCube is high quality digital data (Takase, 2003). It represents an actual urban space by 3D polygons. It is constructed by data acquired by airborne laser scanner surveying flights. Building configuration is modeled with high precision, and detailed shape data are available (Fig.1). The height accuracy is about 15 cm. Therefore, MapCube can be exploited in various applications. In this study, we use it to construct a detailed 3D model of Nishi-Chiba campus of Chiba University, Japan (Fig. 2).

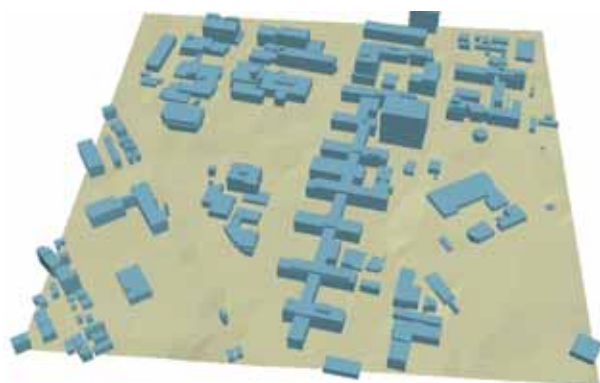


Figure 1. 3D building model in MapCube (Nishi-Chiba campus of Chiba University)



Figure 2. Bird view of Chiba University (extracted from GoogleEarth)

(2) Virtual Terrain Project (VTP)

VTP is an open-source software development effort whose goal is to foster the creation of tools for constructing easily any part of the real world in an interactive 3D digital form (<http://vterrain.org>). The tools and the source code are freely shared and modified. VTP is an ideal platform. VTP software can run on various platforms, and requires no specific hardware other than a good graphics card. In addition, VTP can import data from an enormous variety of CAD and GIS data formats, even converting between multiple spatial coordinate systems. VTP consists of several modules, including the following major ones.

a) VTBuilder

VTBuilder is a tool for viewing and processing many kinds of geospatial data. VTBuilder can accept GIS format data such as DEM (Digital Elevation Model), TIF, and SHP file. In this

module, we can input and edit coordinate systems, elevation, object sizes and colors or texture of building walls and roofs.

b) Enviro

Enviro is the VTP runtime environment. It provides an interactive, real time 3D navigation of your virtual terrain. There are two primary view modes: Earth and Terrain. At startup, you chose which view you want to start with, and you can switch to the other at any time.

3. METHOD OF CONSTRUCTION OF 3D URBAN MODELS

(1) Flowchart of construction

Figure 3 shows the flowchart of constructing 3D urban models using GIS software and VTP. First, we extract the data of ground surface, buildings, trees, roads, and the other data from MapCube, aerial photographs, and digital maps in any GIS package like ArcGIS. Next, editing and matching all the data in VTBuilder. Finally, the all data are imported into Enviro.

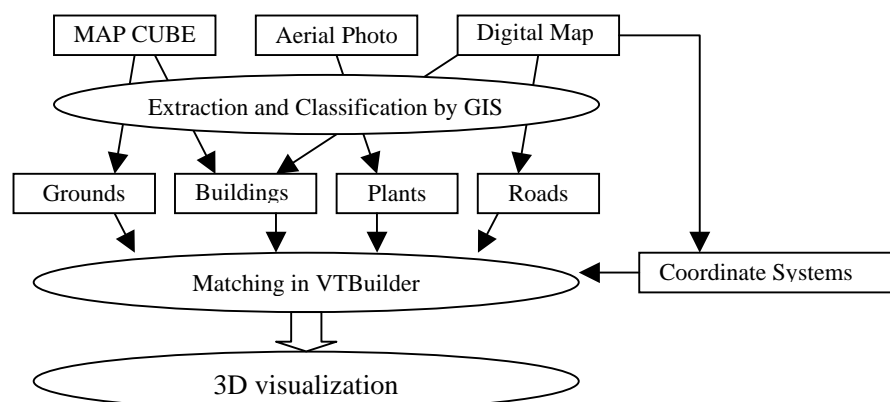


Figure 3. Flowchart of construction of 3D urban model

(2) Ground surface

Ground surface data is obtained from the ground data in MapCube. In VTBuilder, the water level is set at 0 meter as default, however, it can be modified. In addition, texture information draped on the ground surface can be edited. Aerial photographs or satellite images can also be used to wrap the ground surface.

(3) Roads

Road data is constructed from the digital map 1:2500. As the roads are stored as simple polylines, we import them into VTBuilder to input more attributes. In detail, we register names, widths, number of lanes, pedestrians, parking lots etc. Furthermore, we can register each intersection type such as the number of traffic lights and pedestrian crossings. The road surface types such as concrete, asphalt, etc. can be assigned. Ground elevation along the roads can also be changed to extrude the roads.

(4) Buildings

Building data is constructed from building polygon data in MapCube. In VTBuilder, we can input the material types, shapes of roofs, number of stairs etc. New buildings, which do not exist in MapCube, are also created. The texture information of building walls, e.g. windows, doors, columns, is obtained from the ground photographs. Figure 4 show two examples of 3D building models that were constructed in this study.



Figure 4. Building models created by VTP

(5) Vegetation

Since Japanese plant data is not included in the existing VTP plant library, 3D Japanese plant models were created using the ground photos for some species. Figure 5 shows some examples.

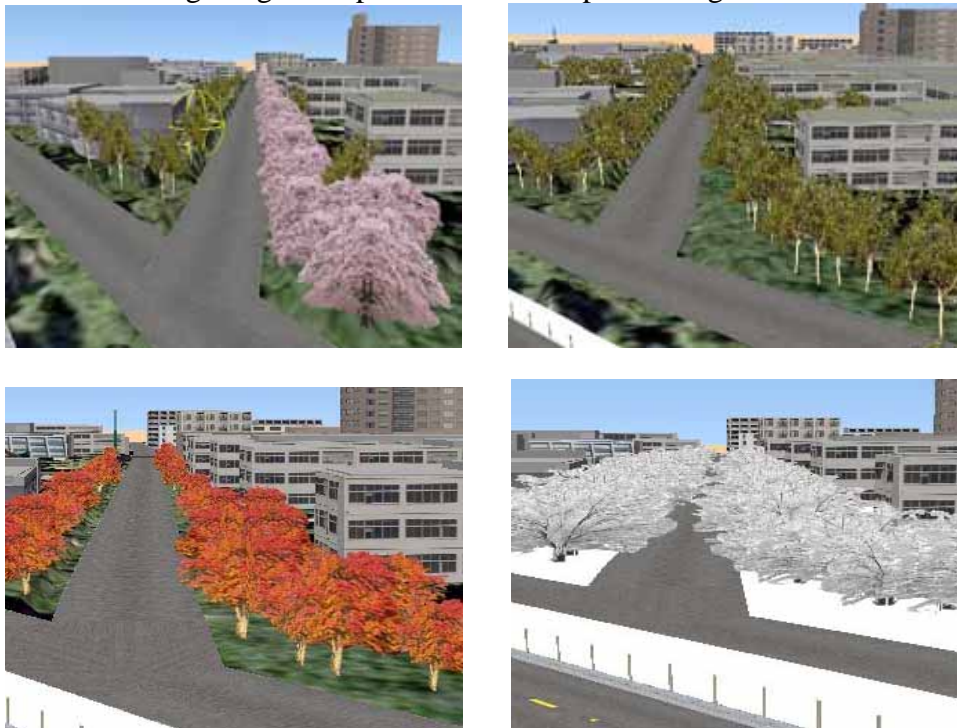


Figure 5. Changes of plants in four seasons in Nishichiba Campus, Chiba University

(6) Others

Other objects are imported directly as 3D objects such as fences, electric poles, chairs, etc. Figures 6 and 7 show such examples.



Figure 6. Model of Fence and polls



Figure 7. Model of Chairs in the forest

Following the flowchart, the detailed virtual Nishi-Chiba campus of Chiba University is constructed as shown in Fig. 8 .



Figure 8. Created 3D model of Nishichiba Campus, viewed from different directions

4. VISUALIZATION OF EARTHQUAKE DISASTER

Let assume an earthquake caused several damages in Nishi-Chiba Campus of Chiba University. The newly constructed 3D model was employed to illustrate a scenario of this disaster through damaged buildings, road cracks and fires. Such a 3D visualization is useful to enhance the images of disasters for disaster responders and ordinary citizens.

Figure 9 shows building models with damages to walls, columns, windows etc. These damage models are represented by processing the texture. Figure 10 illustrates a first-floor-collapsed building, and Figure 11 shows middle-floor-collapsed one, which was seen in the 1995 Kobe Earthquake. For these models, the height of the building and the texture information were modified. Figure 12 is an inclined building model. This building model is constructed by modifying the 3D structure and stored as a 3D object.



Figure 9. Cracked walls and windows



Figure 10. First-floor-collapsed building



Figure 11. Middle-floor-collapsed building



Figure 12. Model of inclined building

Furthermore, a flood disaster scenario (Fig. 13) and a fire disaster scenario (Fig. 14) are illustrated. Flood was generated by raising the water level. The fire scene was represented by introducing smoke and fired objects. As the flood height and the fire scale can be changed easily, we can visualize various stages of a disaster scenario.



Figure 13. Flood disaster model



Figure 14. Fire disaster model

5. CONCLUSION

A 3D urban model was constructed in VTP, based on digital map and MapCube data. Building models damaged by an earthquake were further developed. Scenes of disasters were visualized by the 3D models realistically. The experience of using VTP in this study shows that VTP is easy to use and fast to construct a 3D scene. More importantly, VTP shows its powerfulness in its applications to disaster simulation. Based on the constructed 3D scene, it is easy to modify either structure or texture information to demonstrate various disaster scenarios in various disasters. However, it is still time-consuming to collect texture information of buildings. In a further study, we will try to develop an automated approach to register a huge ground photo collection to 3D building models. In addition, construction of a 3D scene for a wider area should be tried. We believe that the 3D model has a high potential to be used widely in information dissemination and education purposes.

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