Simulation of 3D urban landscape with textures and trees by remote sensing

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Abstract: Recently 3D digital city models are required as a platform for many simulation analyses such as urban microclimate and pollution control analysis, traffic navigation and landscape planning. Most of the existing 3D digital city models, however, include only the building shapes or buildings with textures although vegetation plays an important role in the urban environment. Previous research (Yamagishi, 2004) achieved the 3D city model with trees using aerial image with high spatial resolution and Airborne Laser Scanning (ALS) data. But, building surfaces have no texture in this model. In most cases, texture is mapped from images taken from over the buildings like aerial image with high spatial resolution. One aerial image with high spatial resolution, however, often does not cover enough side surfaces of buildings. Moreover some of these images do not represent the lower parts of a building in detail, although an image from the view point of human eyes is important especially in case of 3D urban landscape simulation. It is, however, difficult to take a photograph of surface of a building from its side, for space in front of a building is usually not enough to take a photograph. Moreover, there are street trees and utility poles in the edge of street in urban city, and these obstacles make the space small. Then, in this study we present a methodology of texture mapping to the 3D model by using ground measurements under the limitation of space. Textures are mapped from the images taken from the limited open space around the building in manual way. Firstly, the building surface area was so large that images were taken in parts by a digital camera. Secondly, a mosaicing was carried out to construct composite image for each side of the building image. Finally, the texture of composite image was mapped to the 3D model using both 2D information about the building edge position extracted in previous research (Guo, 2002) and the height information of the highest part of the building from ALS data. The result indicates that 3D urban model with a detailed texture of the low part of the building might be quite useful for urban landscape simulation and planning.
Keywords: DEM/3D Generation, Data Fusion, Data Processing.

1. Introduction

Environmental issue is one of most essential factors for realization of sustainable development and economic prosperity. Many studies have been conducted about environment, especially natural environment such as forestry, agriculture. But, as the most concentrated region of human intensive activities, urban area and its environment influence much on people’s daily life directly. So, recently, 3D city models are required for many applications such as urban microclimate and transportation navigation, landscape planning and visualization.

Several studies about 3D city model have been conducted. For example, Haala and Brenner (1999) combined multi spectral imagery and laser altimeter data. In this research, classification was carried out for the extraction of buildings, trees and grass-covered areas, and buildings was reconstructed using both laser data and 2D ground plan information. Guo Tao (2002) generated 3D city model from IKONS image and ALS data. These 3D models mostly target on modeling of buildings and the detailed 3D models by remote sensing data have been achieved.

Vegetation, however, plays an important role in the urban environment. Yamagishi (2004) achieved the 3D simulation of trees using NDVI derived from an aerial image with high spatial resolution and height information from ALS data. 3D city models with not only buildings but also trees might be applied widely especially for landscape simulation. But building surfaces have no texture in this model. It is necessary to map the texture to the surface of the building in order to apply it to real applications.

In most cases of 3D city models, textures are mapped to the 3D models using aerial images with high spatial resolution. But, all wall area of a building does not often be covered with an aerial image with high spatial resolution. So a lot of flight course is needed to measure all wall area of a building. Moreover some of images taken from over the building does not represent the lower parts of the building in detail, although the image from the view point of human eyes is important especially in case of landscape simulation. On the other hand, it is difficult to take a photograph of surface of a building being beside it, for space in front of a building is usually not enough to take photographs. Moreover, there are street trees and utility poles in the edge of street in urban city, and these obstacles make the space small.

Aim of this study is to investigate a methodology of mapping texture of image taken from the limited open space around a building to the 3D model derived from remote sensing data.

2. Test Site and Data Description

1) Test Site

One side of the building surface of the Institute of Industrial Science (IIS) in Komaba campus of the University of Tokyo was selected as the test site in this study. Fig.1 shows overview around the IIS building. The building is very wide and high. The width is about 220m and the height of the highest part is about 40m above the ground. The width of the street in front of the building is about 5m and trees are planted in the edge of the street.

Fig.1 Overview around the IIS building.

2) Input Data

Three kinds of data were used for this study. The first one is digital photographs of the building surface, the second one is 2D shape information of the building and the last one is ALS data.

Digital photographs of the building surface were taken from the ground using single-lens reflex digital camera with 24mm lens on 23rd September 2005, which was a fine day. Position of the camera was moved along the building and the distance from the building to the position of camera was from 3m to 5m. Size of each photograph was 2240×1488 pixels. 2D shape information of the building was extracted from both IKONOS image and ALS data (Guo, 2002). ALS data provided by JSI was originally captured from ALTMS system (manufacture is Terra Point, built by HARC with NASA support). The average sampling space of laser points was about 1.5m and the size of foot point of laser beam on the ground was 90cm, vertical and horizontal accuracy were 15cm and about 1m, respectively.

3. Methodology

1) Photography

First step is to prepare the photographs for texture mapping. It is impossible to take photographs of the surface of the building far from it, although the building is very wide and high and moreover the surface has uneven parts like balcony. So how to take photographs is important. Surface of the building is divided into several parts based on the characteristics of the surface. This surface has a pattern in its lower part and same pattern is repeated 36 times. So the surface, firstly, is divided into 36 parts in the direction of width and the position of the camera is changed 36 times along the building. The distance from the building to the position of camera was changed within 3 to 5m because a tree canopy hides the high part of the building. Fig.2 shows the change of camera position. Secondly, target surface taken from same camera position is divided into 4 parts considering the standard points for making composite image, because target surface of 1 of 36 parts can not be covered with one image. Moreover, an angle of elevation is changed 4 times at same position. Fig.3 shows the view areas of a different angle of elevation at same camera position. And then 144 images are measured for texture mapping.

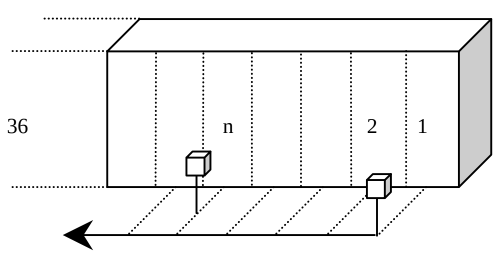


Fig.2 the Change of camera position.

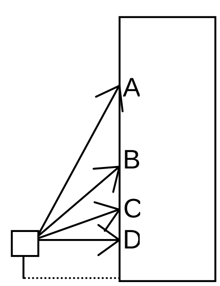


Fig.3 the view areas of a different angle of elevation at same camera position.

2) Composition of the Images

144 images taken for the texture mapping are applied by using a planar projective transformation and merge to 1 image. First step is to compound 4 images taken from same position to 1 image. Second step is to compound the 36 images made in the first step to 1 image.

3) Texture Mapping to the 3D Model

The composite image of the texture is mapped to the 3D model. Fig.4 shows the conversion model from 2D image to 3D shape. The 2D positions (x, y) of the edges of the building are got from 2D shape information of the building, and the height (z) of the highest part of the building is got from ALS data. From these (x, y, z) information and the information of the positions (u, v) of the edges of the building in a composite image, 3D information of the edges of the building is calculated using Eq.(1). And then, the composite image is divided into some parts by the difference of the height and mapped to the 3D model using the information(x, y, z) and the developed vrml program.

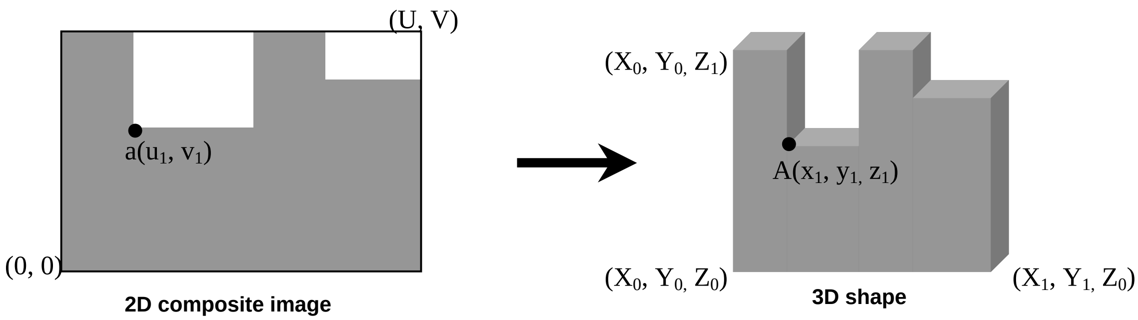


Fig.4 the conversion model from 2D image to 3D shape.

$$
\begin{aligned}
x_1 &= X_0 + \frac{u_1}{U}\left(X_1 - X_0\right) \\
y_1 &= Y_0 + \frac{u_1}{U}\left(Y_1 - Y_0\right) \\
z_1 &= Z_0 + \frac{v_1}{V}\left(Z_1 - Z_0\right)
\end{aligned}
\qquad (1)
$$

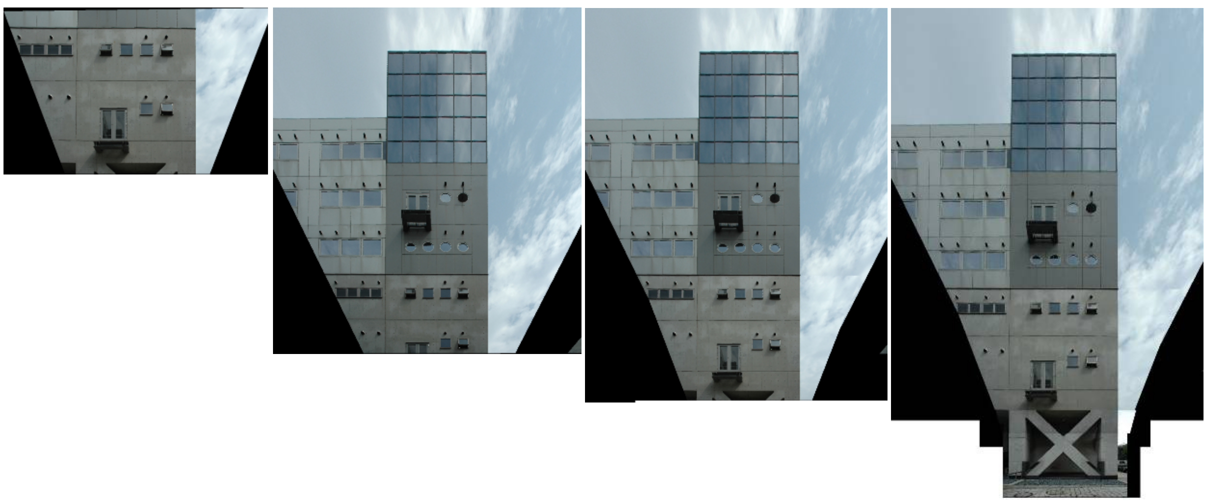
4. Results

Fig.5 shows the examples of the photographs taken from same position. And Fig.6 shows images converted by a planar projective transformation and a composite process.

Firstly, Fig.5 (b) was changed by a planar projective transformation with 4 standard points which make up a rectangle in the actual surface to another image. Fig.6 (b') shows the output image converted from (b), where 4 standard points make a rectangle. Then, Fig.5 (a) was converted by a planar projective transformation so as to fit (b'). Fig.6 (a') shows the output image converted from (a). (a') was compounded together (b') and Fig.6 (ab) shows the composite image of (a') and (b'). (c) and (d) were fitted in the same way and then 1 image was completed from 4 photographs taken from same position., and Fig.5 (abcd) shows the output image. Characteristics of 4 standard points of the image was common in 36 patterns and the size of rectangle was fixed, so this composition of 4 images was repeated 36 times and then 36 output images could be compounded as 1 surface image with size of 9066 x 1410 pixels. Fig.7 shows one part of 1 surface image. In case of composition of 4 images taken from same position, maximum error of building width was 6 pixels and also in case of 36 images, maximum error of building height was12 pixels. And then this 1 surface image was converted to 3D shape. Fig.8 shows the 3D model with the detailed texture derived from our study.

(a) (b) (c) (d)

Fig.5 4 photographs taken from one camera setting position: (a) highest part ;(b) second highest part; (c) second lowest part;(d)lowest part.



(b’) (a’) (ab) (abcd)

Fig.6 Output images by a planar projective transformation and a composite process: (b’) image changed from Fig.6(b); (a’) image changed from Fig.6 (a) so as to fit to (b); (ab);composite image from Fig.6(a) and Fig.6 (b); (abcd) composite image from 4 photographs taken from one position.

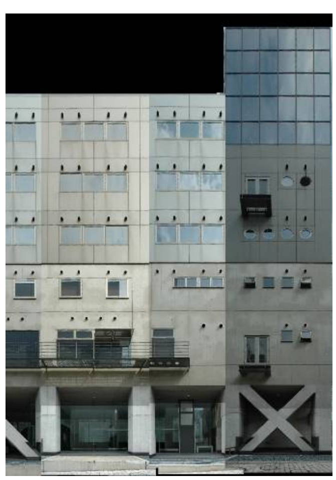


Fig.7 one part of 1 surface image.

Fig.8 the 3Dmodel with the detailed texture.

5. Conclusions

This result shows possibility of texture mapping to 3D model from digital images that is taken from limited space and has no information of the real positions(x, y, z). Fig.9 shows the 3D model with textures, and Fig.10 shows the 3D model with trees (result from Yamagishi, 2004), respectively. Fig.11 is not real fusion of 3D model with the detailed texture and 3D model with trees but image of fusion.

By comparing of these images, the importance of texture and trees in 3D model becomes clear. 3D city models with the detailed texture and trees might be practically applied to urban landscape simulation and planning.

And finally, as future work, it is necessary to add the adjustment of brightness or color balance and make the process automatic.

Fig.9 3D model with the detailed textures.

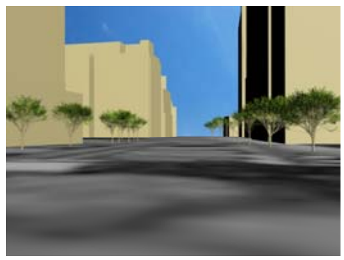


Fig.10 3D model with trees (Yamagishi, 2004).

Fig.11 image of 3D model with the detailed textures and trees.

References

[1] Haala, N. and Brenner C., 1999. Extraction of buildings and trees in urban environments, *ISPRS Journal of Photography & Remote Sensing 54:.130-137*.

[2] Guo Tao and Yoshifumi Yasuoka, 2002. Data fusion of high-resolution satellite images and airborn laser scanning data for building detection in urban environment, *proc. of SPIE Conference on Image Processing and Pattern Recognition in Remote Sensing, Vol.4898,pp.120-130*.

[3] Yosuke Yamagishi, and Yoshifumi Yasuoka, 2004. Modeling of 3D tree structure with physical parameters derivrd from remote sensing data, *Proc. ACRS'2004, Thailand, pp.1557-1561*.