3D MODELING AND LANDSCAPE SIMULATION OF A HISTORICAL ROW OF HOUSES IN TSUMAGO

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ABSTRACT:

In order to reconstruct missing city including houses, roads and other objects using historical maps, an efficient city modeling is still issue which resolved. In particular, 3D modeling of houses is important issue since houses are important component of historical city model. With this motive, an efficient method for reconstruction of historical city using historical map is proposed by the authors. In this method, five kinds of 3D models for representative houses are created previously. Spatial data such as kind of houses, positions, directions and so on are obtained by image processing procedure. Historical city modeling is performed automatically importing data which was exported to 3DCG software.

This paper reports on efficient modeling method for visualization of a historical row of houses in Tumago, and shows the landscape simulation.

1. INTRODUCTION

Existing old maps and pictorial maps were mostly produced at the Edo period in Japan, and these maps which show situation of land use and streets in those days often give important information for studying history of city planning, civil engineering, architecture and so on. As one of utilization of these maps, virtual reality has recently received more attention from possibility so that people can appreciate or experience the archeological objects or historical spaces and arts through the computer at any time and without going to the museum.

Although VR and digital archive share a common content from the view point of preservation of structures and items of cultural heritage, which will be decrepit, deteriorated, disappeared and lost, an efficient method for city modeling is still issue since reliable descriptions in VR or digital archives required huge labor, time, and expense.

An efficient modeling method for Tumago is investigated. Tsumago shows a historical row of houses and preservation activities have been performed positively as a preservation area for the traditional house groups under the ordinance by local government based on the Cultural Properties Protection Law.

2. TUMAGO

Tsumago is one of the post stations established in Nakasendo, which is one of the important roads of the traffic connects Edo with Kyoto, and located in present Nagiso-town, Nagano prefecture. While the posting station system was established by the Tokugawa shogunate at the Edo period and Nakasendo progressed rapidly, Tsumago became a major post town where there was a large crowded with people, horses, cart and so on. A row of houses of those days continued about 270m around the center part of Tsumago and further to Terashita about 80m[1)].

Preservation movement at Nagiso-town started from 1965 with cooperation of the whole community as a pioneer of preservation activities for a historical row of houses. Nagiso-town was designated as the historic preservation area including the traditional house groups in 1976[2)]. For this reason, the houses which show inns style stand in row along with Nakasendo and keep the circumstances of those days.

3. EFFICIENT CITY MODELING

3D models for representative houses were recreated previously under the historical evidence. Geometric data, such as the center

combined reserved accommodations of Honjin with wholesale store in the Edo period [1)]. Although 31 inns were located in Tsumago (Kamimachi and Nakamachi, Simomachi) from the historical material[1)], only 29 houses except Honjin and Wakihonjin are countable in Fig. 1[3)]. However, it can be judged that all these houses except Honjin and Wakihonjin were inns under the assumptions that the blank at upper part for Wakihonjin belong to Wakihonjin, and there were two inns in the blank at upper to the left for Wakihonjin in Fig.1. It can be found 4 houses in Masugata and 12 houses in Terasita from Fig.1. Similarly, it is estimated that all of these houses were inns.

Five kinds of 3D house models were recreated under the historical material[1)]. Fig.2 shows recreated 3D models. Model 1, of gravity, areas, inclinations, and aspect ratios for the house sites, were acquired using the old map (Fig. 1). Attribute data such as the kind of houses was decided automatically using the aspect ratios. As a result, a historical row of houses in Tumago is efficiently reconstructed since the houses are modified and arranged automatically based on geometric data. The detail procedures for the modeling method are as follows.

3.1 Recreating Representative House Models

Honjin combined the official accommodations for the daimyos with residence for village headman. Wakihonjin 2 show inns for samurai, Model 3, 4 show inns for the masses and Model 5 shows storehouse.

3D models for Honjin and Wakihonjin which located near the center of the town were recreated separately since these houses are representative structures for the area. Regarding 3D modeling for these structures will be mentioned later. In addition, 3D Studio MAX was used in this paper as 3DCG software.

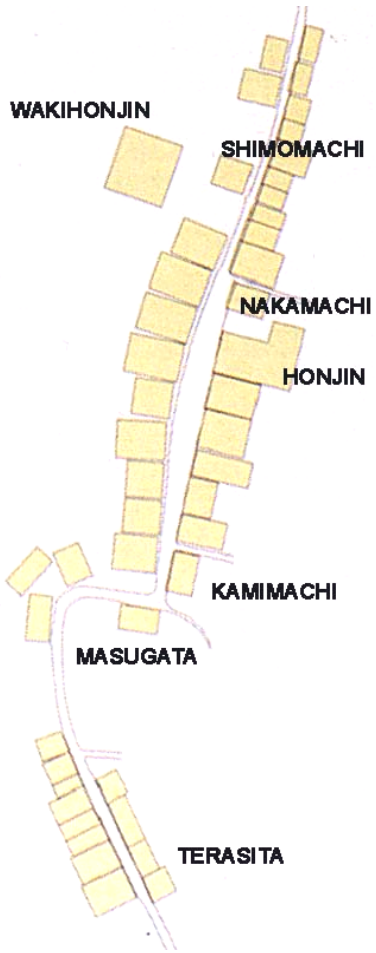


Fig.1 Map of Tumago in 1686

Fig2.1 Model 1 for samurai

Fig2.2 Model 2 for samurai

Fig2.3 Model 3 for the

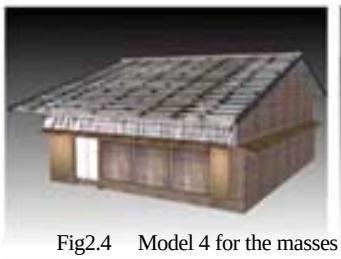


Fig2.4 Model 4 for the masses

Fig2.5 Model 5 for Storehouse

3.2 Acquisition of Spatial Data

3.2.1 Extraction of Edge Image: After digitizing the map, line extraction was performed using Gauss-Laplacian (GL) filter and edge image was obtained via image processing pocedures such as binarization, noise reduction and thinning procedures. In addition, in order to determine the front of houses automatically, road in the map was colored. Fig.3 shows the edge image for the house sites.

3.2.2 Acquisition of Geometric Data: In order to acquire geometric data such as the center of gravity, area, and inclination for each house site which required for automatic arrangement of house models, the templates for corner detection were created and the image coordinates of the four corners of each house site was calculated by following equations. Fig. 4 shows the templates for corner detection, and corner detection was performed for each pixel on the edge image.

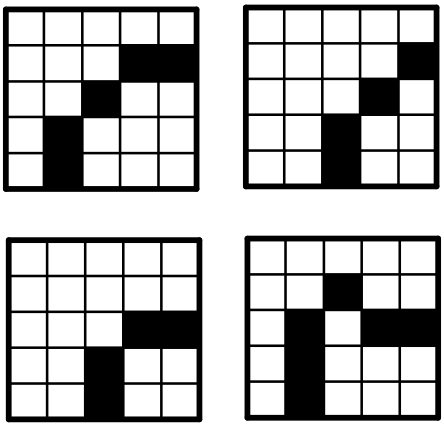


Fig.4 Template for corner detection

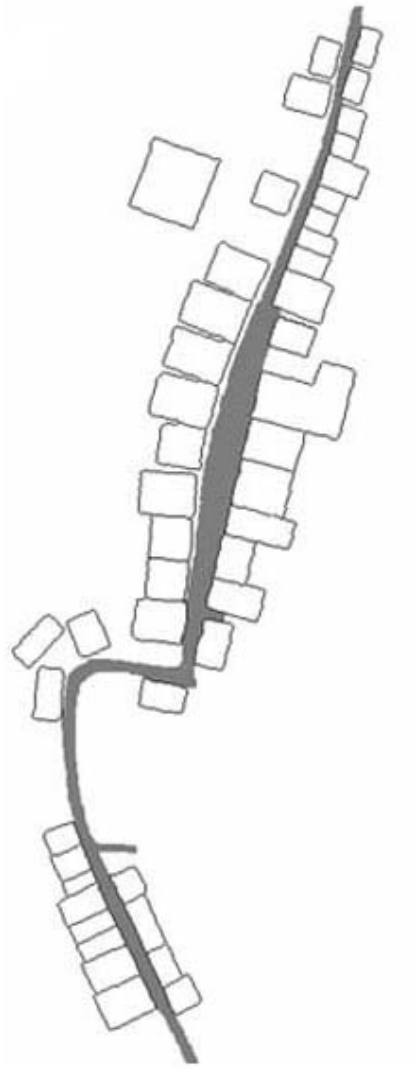


Fig.3 Edge image for the house sites

Where, (x_1, y_1) is the coordinate at the upper left corner point for the house sites. Similarly, (x_2, y_2) is the upper right corner point and (x_3, y_3) is the lower right corner point.

The Center of Gravity: $$(G_x, G_y) = \left(\frac{x_2 + x_3}{2}, \frac{y_2 + y_3}{2}\right) \quad (1)$$

Depth: $$H = \sqrt{(y_3 - y_1)^2 + (x_3 - x_1)^2} \quad (2)$$

Width: $$B = \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2} \quad (3)$$

Area: $$A = B \cdot H \quad (4)$$

Aspect Ratio: $$BH = H / B \quad (5)$$

Inclination: $$\theta = \tan^{-1}\left(\frac{y_2 - y_1}{x_2 - x_1}\right) \quad (6)$$

3.2.3 Direction of House: Direction of each house was divided roughly into the north, south, east and west automatically so that front of a house faces toward the colored road in Fig.3. The direction M is 0 degree in the case of a house toward the south. Each direction M which set up clockwise from the south is follows:

SOUTH: M=0° WEST: M=90°

NORTH: M=180° EAST: M=270°

The direction M for the house 1 in Fig. 5, for example, become 180° since the house 1 towards the north. Similarly, M for the house 2 become 0°. Precise direction is obtained by following equation so that direction of the house models coincident with the direction of the house sites on the map.

Direction of the house: $R = M + \theta$ (7)

Where, θ is the calculated value by equation (6).

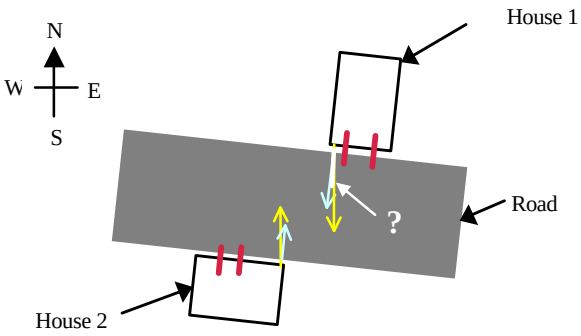


Fig.5 Determination of house direction

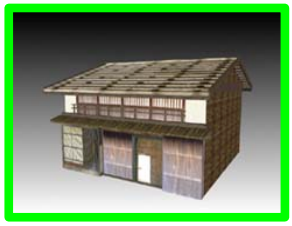
3.2.4 Acquisition of Altitude Data: In order to aquire altitude data for each house site, 50m numerical mesh map published by the Geographical Survey Institute was overlaid with the map. After scaling and rotating the historical map, the altitude data for each house site was acquired. And then, as a result of this procedure, the outline about the historical map of Tsumago was become clear as shown in Table 1.

Table 1 Outline for the map

Latitude	North latitude 35?34′10″ ~ 35?34′45″
Longitude	East longitude 137?35′45″ ~ 137?35′56″
Scale	Map of Scale $\frac{1}{3300}$ The edge picture of Scale 1m=2pixels
Direction	North : Direction which rotated 100 degrees in clockwise

3.2.5 Acquisition of Attribute Data: Attribute data is the kind of house models for each house site in this paper. The attribute data was acquired using area and aspect ratio which is calculated by equation (4) and (5). At the first, the house models were classified roughly into two kinds by the area size. Model 1, 2 are arranged at big area as the inns for samurai. Model 3, 4 are arranged at small area as the cheap lodging inns for the masses, and Model 5 is arranged at small area as the storehouses. Sub-classification for the models is performed using aspect ratio. Table 2 shows the conditions for the above rough classification and sub-classification.

Table 2 Classification of the models

	BH< 1.1	1.1? BH< 1.5	1.5? BH
Large Area	 Model 1 for samurai	 Model 2 for samurai	
Small Area	 Model 5 for Storehouse	 Model 3 for the masses	 Model 4 for the masses

3.3 Reconstruction of a Row of Houses

In order to automatic reconstruction of a row of houses, software was developed in this paper so that automatic classification, modification and arrangement can be performed automatically. 3D modeling for a historical row of hoses is performed automatically exporting spatial data on 3DCG. Fig. 6 shows overhead view for reconstructed model. It can be recognized that the inns were arranged with forwarding the road, and the inns for samurai (Model 1, 2) were located around Honjin which are the center of the town.

Fig.6 Overhead view for a row of houses

4. RECREATING HONJIN AND WAKIHONJIN

Models for Honjin and Wakihonjin were recreated and arranged manually under historical material[4], so that these structures were representative and characteristic structures in the area which reconstructed in this paper. Fig. 8 shows the recreated model for Honjin and Wakihonjin.

5. LANDSCAPE SIMULATION

Circumference environments, such as models of Honjin and Wakihonjin and a geographical feature model, were integrated into reconstructed a row of houses, and the environment which be able to walk-through and fly-through were constructed.

Fig. 8 shows the photograph for the present Tsumago, and Fig. 9 shows a landscape for the front of Honjin. Moreover, Fig. 10 shows the maps for the present Tsumago and the Edo period. The width for Nakasendo in the present Tsumago is about 4.5m, however, the width arround the front of Honjin in the Edo period was about 10m[2], because the meeting place for changing horses was established in Honjin and there was a large crowded with people, horses, cart and so on. The difference in the width of these roads can be found from these figures.

Fig. 7.1 Recreated Honjin

Fig. 7.2 Recreated Wakihonjin

Fig.8 Present Tsumago

Fig.9 Landscape simulation

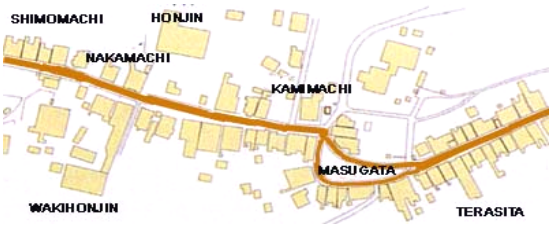


Fig.10.1 Present map for Tsumago

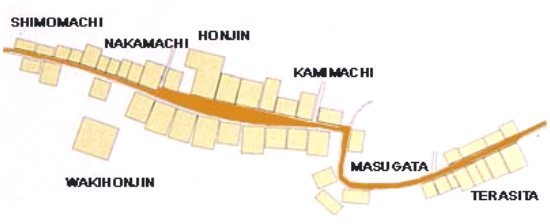


Fig.10.2 Map of Tsumago in 1686

6. CONCLUSION

In generally, huge labor, time and expense are needed for reconstruction a row of houses using 3DCG since the models should be recreated and arranged one by one manually. However, these issues are drastically reduced by the method which developed in this paper.

In order to show the efficiency of the method, time was compared manual case with the proposed method using the same map for Tumago. Obviously, time depend on CPU of Personal computer. CPU used in this paper was Intel Pentium3 processor 700MHz, it took about 3 hours for recreating each house model, and it took about 8 hours for recreating Honjin and Wakihonjin respectively. Then, 31 hours were spent for house modeling.

On the contrary, 151 hours are estimated for house modeling in case of manual case since there are 47 houses including Honjin and Wakihonjin. Furthermore, 25 hours are estimated for arranging 47 houses in case of manual since it took about 30 minutes for arranging a house model manually.

Although 34 hours were spent for reconstruction of a row of houses in this paper including data acquisition (3 hours), 176 hours are estimated in case of manual. This means that time consuming for the method will become less than 1/5 compare with manual case.

In addition, reliable landscape simulation was achieved even 5 house models. In particular, the method has ability for applying other area under customizing representative structures for the area. Therefore, it can be said that the method is the efficient city modeling method. Moreover, the method is broadly available not only the landscape simulation of a row of houses but local disaster prevention and a city redevelopment project by taking into consideration attribute data such as wooden and an apartment, the number of floors, years after construction and etc..

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