Reconstruction of the Ancient Pagodas

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Abstract— The reconstruction of the damaged historical building, pagoda and temple is a critical task in disaster recovering process. In Myanmar, many pagodas are destroyed due to the earthquake. In this research, 3D reconstruction approach is proposed for estimating the structure of the pagoda before earthquake from the 3D stricture of the damaged pagoda after earthquake. It will provide to renovate the pagoda with original structure. The post-earthquake images are acquired using the Unnamed Aerial Vehicle (UAV) and generate the point cloud data. To estimate the 3D vertices of the top and boundary of pagoda, the intersection vertices of line and curve are computed based on Hough transform. Furthermore, the proposed system can detect the complete structure of the whole pagoda.

Keywords— Unnamed aerial vehicle(UAV); 3D reconstruction; 3D cloud points; damaged area; Hough transform; ancient pagodas;

I. INTRODUCTION

. The study area is located at Bagan, the ancient capital of Myanmar, where the magnitude 6.8 earthquake is occurred in August 24, 2016. More than 400 pagodas, temple and historic building are damaged by the earthquake. Renovation work is in fact of the disaster management process after disaster. Some pagodas and temples haven't exist the record of the structure and historical data before disaster.

In many 3D reconstruction works [1-4], the result of 3D object is obtained as the structure of input images. This means that the reconstructed structure is different from the structure before earthquake. A 3D reconstruction approach is proposed for reconstructing original structure of a damaged historic pagoda in this research. The original structure is reformed from the 3D image of damaged pagoda taken by an Unnamed Aerial Vehicle (UAV). The damaged portion of the pagoda is estimated by the volume data of cloud points.

The 3D points cloud generating from multiple images [1-3]. The depth measurement of an object is determined from multiple stereo image pairs [2]. C.Jaynes, et. al [4], proposed a model-based approach to the automatic detection and reconstruction of building from aerial images using the corresponding digital elevation map (DEM).Brunner D., et al.[6] described the earthquake damage assessment of buildings by using the VHR optical and SAR imagery.

H. Shusong, et. al [7], proposed the earthquake induced building damage detection method. They searched the nearest points based on 2D projection plane of 3D point cloud data. Their characteristic-based method needs the large computing time for the geometric calculation.

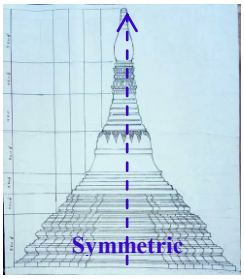
In this research, the 3D reconstruction approach is proposed. It is not like the other existing 3D reconstruction work. The structure in pre-earthquake is recovered by using the images of pagoda taken by UAV after earthquake. The 3D cloud points are generated from successive images [5]. The intersection vertices of the lines and curves are computed based on Hough Transform for estimating the 3D vertices of the top and boundary of the pagoda. It will provide to gauss the original structure of the pagoda.

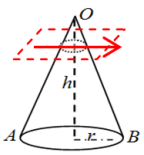
II. TYPES OF PAGODA AND DATA ACQUISITION

There are several well known words for a pagoda according to their shape and structures such as Zedi, Pahto and Phaya. The image of Buddha is known as Phaya. Pahto is a hollow square or rectangular buildings build to resemble caves. Zedi is a bell-shaped and typically solid. Fig. 1 shows the sample images of Phaya, Pahto and Zedi.

(a) Phaya (b) Pahto (c) Zedi

Fig. 1 Three kinds of Pagoda





Volume of a cone = 1/3 ($\pi r^2 h$)

Fig. 2 Illustration of the Top Portion of Zedi

Especially, Zedi is considered in this study. The structure of Zedi is symmetric and the shape of top potion is liked as a cone. Fig. 2 illustrates the structure and top portion of Zedi pagoda.

III. Estimation the Top Insection Point

The top point of the Zedi is needed to compute for reforming the original shape. Now consider the top intersection point x and y can be computed as;

$$y = m_1x + b_1 \text{ and } y = m_2x + b_2 \quad \text{..... (1)}$$

$$x = \frac{b_2 - b_1}{m_1 - m_2} \quad \text{..... (2)}$$

And, let us consider the two planes P_1 and P_2 with their normal n_1 and n_2. Assume that they are not parallel, $t = n_1 \times n_2$ is the direction vector of intersection line L of planes P_1 and P_2. The equations of the planes can be described as

$$P_1 : a_1X_1+b_1Y_1+c_1Z_1+d_1 = 0 \quad \text{..... (3)}$$
$$P_2 : a_2X_2+b_2Y_2+c_2Z_2+d_2 = 0$$

Then, $n_1 = (a_1, b_1, c_1)$, $n_2 = (a_2, b_2, c_2)$ and

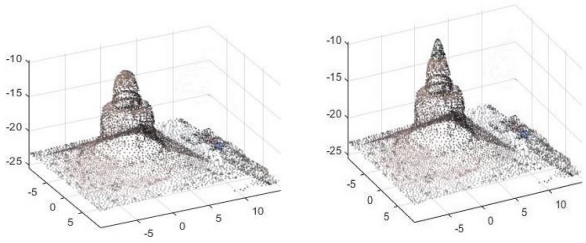
$$t = (b_1c_2-b_2c_1, a_2c_1-a_1c_2, a_1b_2-a_2b_1) \quad \text{..... (4)}$$

The point P on line L can be obtained by solving the equation of plane when Z=0. To detect the parametric curves of a Zedi, Hough transform is very useful. It can handle the missing and occluding of feature data.

IV. Experimental Results

The historic building and pagodas have been damaged by attacking the disaster earthquake. Many pagodas are destroyed their top part. To reconstruct the destroyed part of the pagoda, the point on building roof or top of the pagoda is computed by the projective transformation and intersection point approach. For each damaged pagoda, about 300 aerial photos are acquired by a UAV drone. An image has 72 dpi horizontal and vertical resolutions. Figure 3 illustrated the image of damaged Zedi. Point cloud computing is performed from the corresponding feature points after foreground extraction process. The cloud points of a Zedi is illustrated in Fig. 4(a) and reformed the original structure is shown in Fig. 4(b), respectively.

Fig. 3. Some images of AnoutBatLate Zedi



(a) (b)

Fig. 4. Point Clouds of AnoutBatLate Zedi After Earthquake

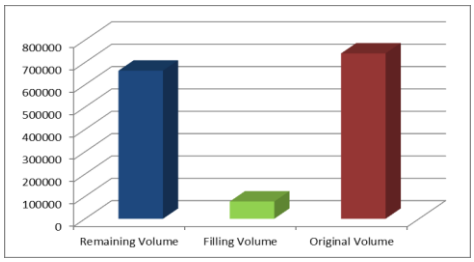


Fig.5 Experimental Results of AnoutBatLate Zedi After Earthquake

V. Conclusion

For preserving the cultural heritage, the elderly structure of a building and pagodas are needed to reform them. In this research, the 3D reconstruction approach is proposed for recovering the former structure of a pagoda by using the UAV images of a damaged pagoda. Based on the intersection vertices of curves and Hough transform, the 3D cloud points of the whole structure of a pagoda are estimated. Thought the experimental results, it can be confirmed the proposed approach work adequately.

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