ANALYSIS OF KOREAN MEGALITHIC BUDDHA USING PHOTOGRAMMETRIC AND LASER SCANNING SYSTEM

Yeu, Bock-Mo*, Kim, Gi-Hong*, Sohn, Duk-Jae, Kim, Wondae*****
*Yonsei University, Korea
Dept. of Civil Engineering,
yeubm@yonsei.ac.kr
gihong33@hotmail.com
**Daejin University, Korea
Dept. of Civil Engineering,
djsohn@road.daejin.ac.kr
***Korea Institute of Construction Technology, Korea
kimwd@kict.re.kr

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ABSTRACT

Photogrammetric technique has been widely used for the qualitative and quantitative analysis of cultural assets because of its high accuracy and low cost. Recently developed laser scanning system emerges as another way to reconstruct 3 dimensional object. The system shows the potential usage for preserving and reconstructing the cultural assets. In this study, we applied both photogrammetric and laser scanning method to the analysis and reconstruction of Koran historic statue. Results show that we can estimate the year of the statue by analyzing the formative ratio of the statue. We also can successfully reconstruct the statue using laser scanning system.

1 INTRODUCTION

Together with its long history, Korea has many valuable historical cultural assets. Many of them date back to more than thousand years. It has been a social issue to preserve and reconstruct those historical structures. Besides having historical values, these structures can be used to identify cultural background.

Photogrammetric method has its long history to observe and reconstruct cultural assets. Recently laser scanning system emerges as a new method to generate 3-D object surface. We applied both photogrammetric and laser scanning method to the statues of Buddha which were built during Geryeo Dynasty (AD918-AD1392) to qualitatively and quantitatively analyze the statue.

Analysis of the statue shows that the statues of Korean megalithic Buddha have been built considering the characteristic formative ratio, which varies according to their historical periods. It is expected that this study can be applied to identify the history of other statue of Buddha. Both Photogrammetric and laser scanning methods show a great potential for preserving and analyzing the existing cultural assets.

2 PHOTOGRAMMETRY VERSUS LASER SCANNING SYSTEM

2.1 Photogrammetric Data Acquisition

Rolleiflex 6006 camera is used to obtain photographic image of the statue of the Buddha. Detail configuration of the camera is listed in Table 1. There are a lot of reseau marks. These marks are utilized for resolving the radial distortion of the film with calibration data. The average distance between the statue and the camera was about 25 m.

	Rolleiflex 6006
Used film	KODAK VP 6041
Lens	Distagon f/4 HFT No.:8110021
Focal length	50mm
Film length	60mm × 60mm
Exposure	f/9
Shutter speed	1/250 second
Distance	25m

Table 1. Configuration of terrestrial camera used in the study.

We used convergent terrestrial photogrammetric method because of obstruction in front of the statue. The geometry of convergent terrestrial photogrammetric method is shown in Figure 1. Figure 2 shows the statue of Buddha used in this study captured by the terrestrial camera. Together with image acquisition, we performed field survey to measure control points. We attached 30 targets on the surface of the statue and measure their location using Theodolite. The 3-D coordinates of 30 measured control points are calculated using intersection methods.

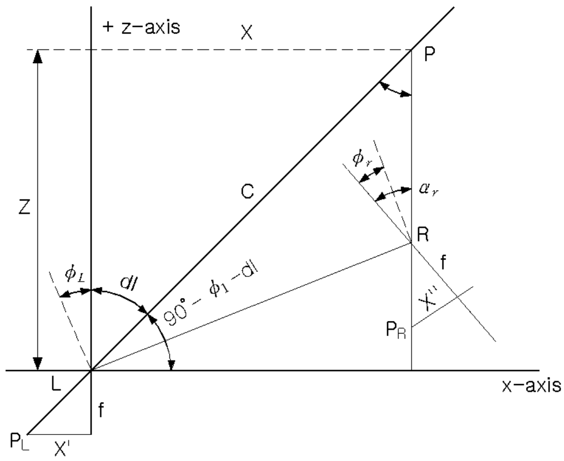


Figure 1. Convergent Terrestrial Photogrammetric Method.

Figure 2. Image of statue of Buddha

2.2 Laser scanning system

Laser scanning system can measure large structures and sites with an unprecedented combination of completeness, speed, accuracy and rage (Vanezis et al., 2000). Detailed 3-D geometry of exposed surfaces is remotely captured in minutes in the form of dense, accurate 3-D points. Figure 3 shows configuration of laser scanning system.

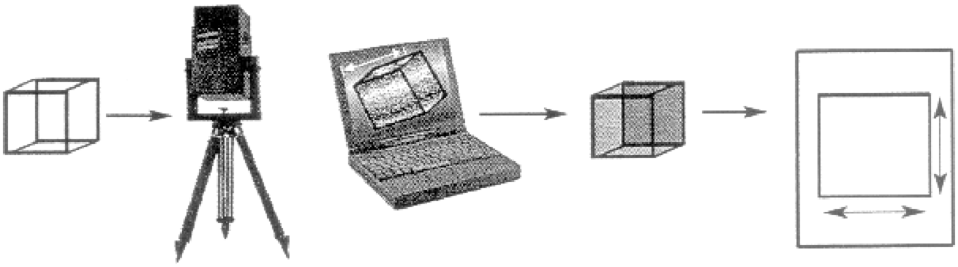


Figure 3. Laser scanning system.

From laser scanning system a pulsed laser/detector and auto-rotating mirrors emit a narrow, pulsing laser beam that sweeps over a large volume of space. Special electronics measure the "time-of-flight" of each laser pulse to-and-from impinged surfaces, while encoders accurately measure angles of the rotating mirrors. Laser scanning system can remotely capture 800 surface geometry measurements per second over a wide field-of-view. Each measurements is accurate to 6mm at range of 50m: surfaces can be modeled as precisely as 2mm. With measurement spacing as fine as 0.5mm, the system can capture detail in any lighting. To capture additional views of the scene, the scan head can be rotated and/or moved as needed. Scanning surveyed points allows geo-referencing of scans to local coordinate systems.

Cyrax 2400 laser scanning system was used for data acquisition of megalithic Buddha (Table 2). We scanned Buddha from four different look directions. A video camera located in the scan head captured the image of scene together with laser signal. We can select scanning scene and record positioning data in the laptop computer. Scanning procedure is shown in Figure 4.

	Cyrax 2400
Laser type	Pulsed; proprietary microchip
Color	Green
Spot size	<6mm from 0-50 meters
Range	Maximum 100m
Scan rate	800 points/sec
Scan density	0.5mm minimum point-to-point spacing (@50m)
Field of view	40° max

Table 2. Configuration of laser scanning system used in the study.

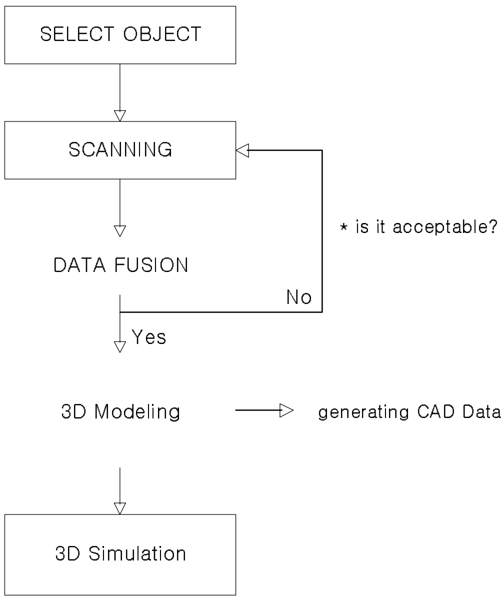


Figure 4. Laser scanning procedure.

3 LASER SCANNING RESULT

We scanned the megalithic Buddha with 10 mm spacing from four different locations. Scan results taken from different look directions were stitched together. After merging scan data from different look directions, we created 3-D surface models from the clouds of 3-D points. Surface rendering was performed after 3-D surface modeling.

In the following results of surface reconstruction using laser system are shown in detail. Figure 5 shows head of megalithic Buddha 3-D created from 3-D point clouds. Processing of points is divided into two categories as shown in Figure 5 to 8. The statue was scanned with 1 cm resolution but processed into 1cm and 2cm as clearly depicted in Figure 5 to 8. This procedure was done to reduce volume of recording data for some redundant points.

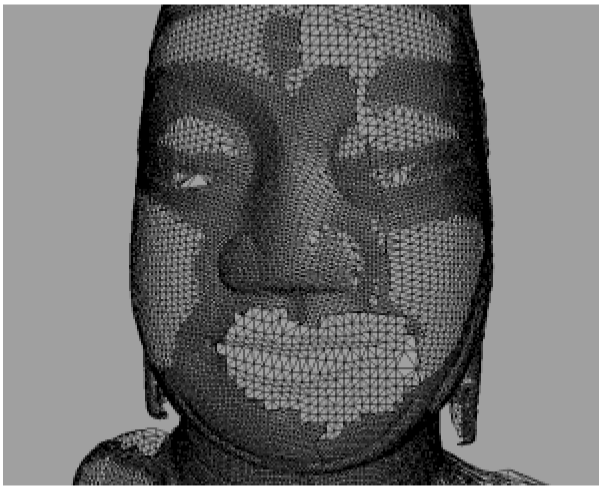


Figure 5. Head of megalithic Buddha

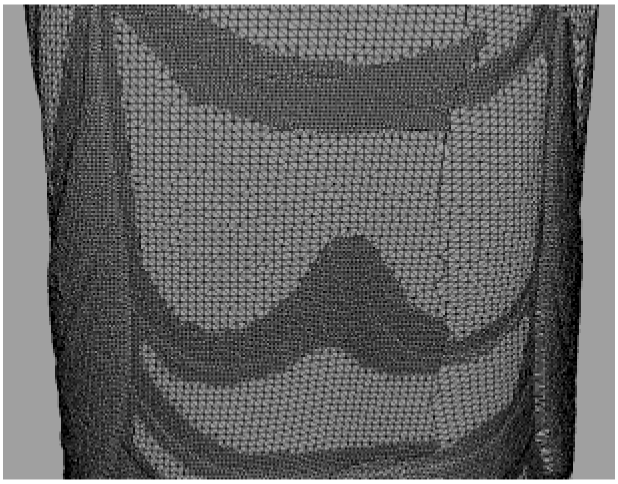


Figure 6. Body of megalithic Buddha

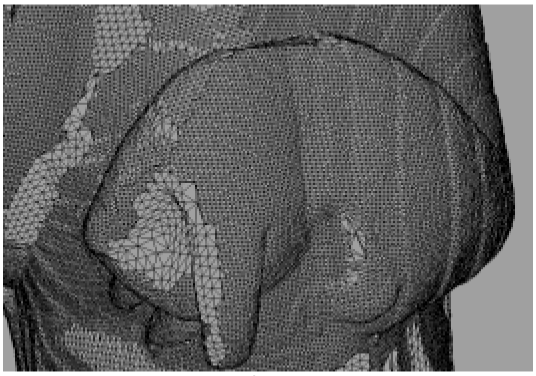


Figure 7. Right hand of megalithic Buddha

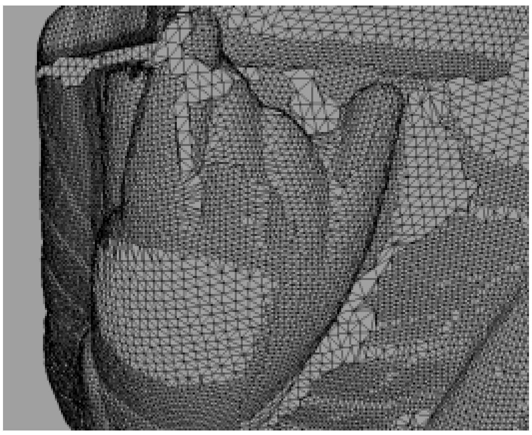
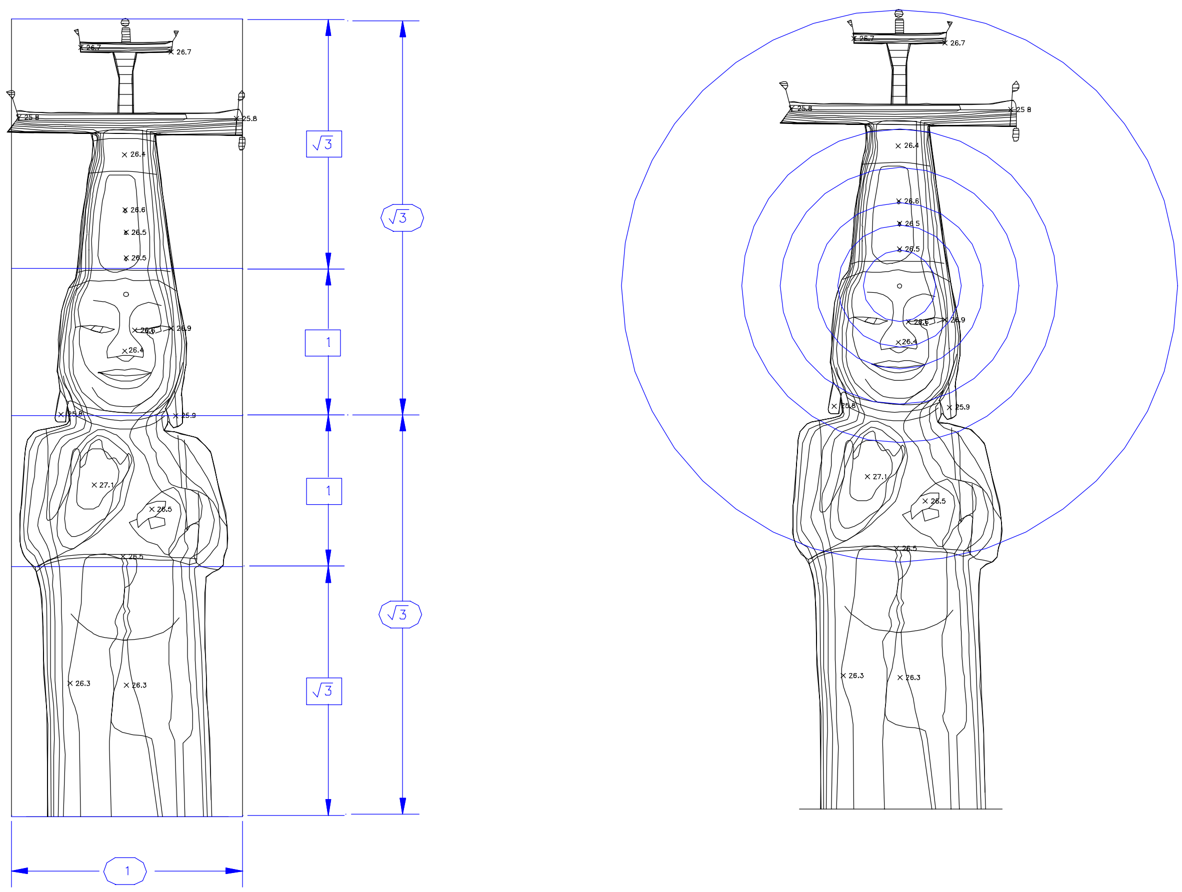


Figure 8. Left hand of megalithic Buddha

Figure 9. 3-D surface rendering

4 ANALYSIS OF MEGALITHIC BUDDHA USING PHOTOGRAMMETRIC METHOD

One of the most famous stone statue of Buddha located inside the Suk-Gul-Am was made in Unified Shilla Dynasty (AD676-AD935). Study shows that the formative ratio is used in determining the scale and structure of the main Buddha statue. Most of the formative ratio applied in the overall design was $\sqrt{2}$ (Yeu, 1994, 1996). The ratio of $\sqrt{2}$ comes from the shape of the square. The megalithic Buddha used in this research was made during the Goryeo Dynasty (AD918-AD1392). We identified the formative ratio of megalithic Buddha shows geometric ratio of $\sqrt{3}$ (Figure 11). The ratio of $\sqrt{3}$ comes from the shape of the equilateral triangle. Detail measurement of the statue shows this statue was built using $\sqrt{3}$ (Figure 10 (a)). The ratio of the statues was $\sqrt{3}$: 1: 1: $\sqrt{3}$. Also analysis of the head section reveals the symmetric geometry between three points on the head and eye, nose, and mouth (Figure 10(b)). The concept of $\sqrt{3}$ is considered to be more advanced design concept than the ratio of $\sqrt{2}$.



(a) (b)

Figure 10. Formative ratio of megalithic Buddha

5 CONCLUSION

We used two surface reconstruction methods for the analysis of cultural assets. One is photogrammetric method and the other is laser scanning system. We identified that both methods are useful for the analysis of the cultural assets. Laser scanning system showed excellent result for surface reconstruction of Buddha statue. The main advantage of the laser system over the photogrammetric method was fast and accurate acquisition of data sets. Laser scanning system, however, is very expensive and has limit in scanning distance of about 50m. Another disadvantage is that we can not get surface texture using laser system, since they acquire clouds of 3-D points rather than surface image. Using the photogrammetric method we can quantitatively analyze the statue and identify that the different formative ratio was used to build the statue compared with the earlier statue.

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