

## Precision Measurement of Cultural Assets using Digital Photogrammetry

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Commission V. Working Group I

**KEY WORDS** : *Cultural Assets, Digital Close Range Photogrammetry, Modeling*

### ABSTRACT

The objectives of this study is to handle and acquire preservation and reconstruction of culture assets using digital close-range photogrammetric technology. The object for use in this study is the seven story stone pagoda located at Tappyong-ri in Chungju city of South Korea. The 3 dimensional digital information is built in accuracy within 1cm (RMSE). The result of this study is capable of data acquisition and 3 dimensional modeling and the geometric analysis for each section is effectively performed. This study also give rise to built database based on accurate data.

### 1. Introduction

The digital photogrammetry is increased in many application fields because the use of digital image is easy to modify, maintain and preserve. We have studied to let many people in the world know korean superior traditional culture and to analysis the efficiency of digital photogrammetry technology for the preservation, maintenance and management of cultural assets. Beyond the 2 dimensional aquisition of spatial data, the 3 dimensional data collection to reappear cultural assets more accurately is necessary. In this study, we have applied precise survey and image analysis technology so as to acquire and analysis digital data of spatial figure more efficiently. We have made the measured data with the same coordinates and estimated accuracy of acquired digital data by analysing error property according to this process for the entire analysis and spatial reappearance of object.

Then, In this study, we have proposed the efficiency through establishing the database for the efficient maintenance and management of cultural asset, performing various spatial analysis such as the partial disposition and slope of the central axis, analysis of the section and modeling etc.

### 2. The basic data collection of an object

#### 2.1 History

This stone pagoda standing on an earthen platform by upstream of the Namhan-gang River, is the only seven-story pagoda dating from the Unified Shilla period (668-934). It is generally known as Chung-ang tap, meaning central pagoda because of its location at approximately the center of the Korean peninsula. It was dismantled for repair in

1917. There are three or four pillars engraved on each side of the two-tiered base. The distance between the pillars is not the same and this inconsistency is believed to be the result of poor repairs in 1917. The first through the fifth story, their stories and roofs are made up of several pieces of stone while only one piece of stone was used to carve out the sixth story and its roof or the seventh story and its roof. Each story has engraved corner pillar and the roofs all have five-step cornices. During the 1917 dismantling, a Koryo (918-1392) bronze mirror and sari cases were retrieved from the base and the sixth story roof.

**2.2 photographing and precise measurement**

In this study, we have made a actual survey plan of seven-story stone pagoda in tap-pyung ri and have taken a photograph and conventional ground survey of this pagoda to examine details of each story. The used equipment in this study is Rollei 6006 cameras, PC with pentium process, film scanner of Agfa corporation etc..

Also, for actual surveying, precise theodolite(Wild T2) is used and orientation points distributed uniformly on the pagoda to improve the entire accuracy.

The photographing to acquire digital image have performed at each 4 section because of embodying 3-dimensional object in 4 section photographs of the object, and we have defined control points on each side of object. The photographing of object has to be converged by 4 photographs in principal side and by 3 photographs in each side of object because all of object points have to be appeared in 3 photographs at least.

The processing of digital image is performed, using the acquired images, in order of the measurement of image coordinate, multi-image orientation, bundle adjustment, multi-image computation, the reappearance of 3 dimensional model. The interior orientation factor of the camera used in this study is shown in Table 1.

Because control points have to be appeared as the same coordinates in the area, we have established the 3 dimensional coordinates that the line between A and B as the origin points of coordinates means the base line, the base line direction is X-axis, the exposure direction is Y-axis and vertical direction is Z-axis. The control point to be arranged on the each side of object is the measured value from origin point. The base line and camera positions are shown in Fig. 1.

Table 1. The interior Orientation factor of an object

	Camera (f)	ck	xh	yh	a 1	a 2	r 0
seven story stone pagoda	42	-40.931	-0.0200	0.1500	-3.427E-005	2.136E-005	20.00
	152	-151.600	-0.1100	0.0100	-4.192E-006	-5.467E-011	20.00

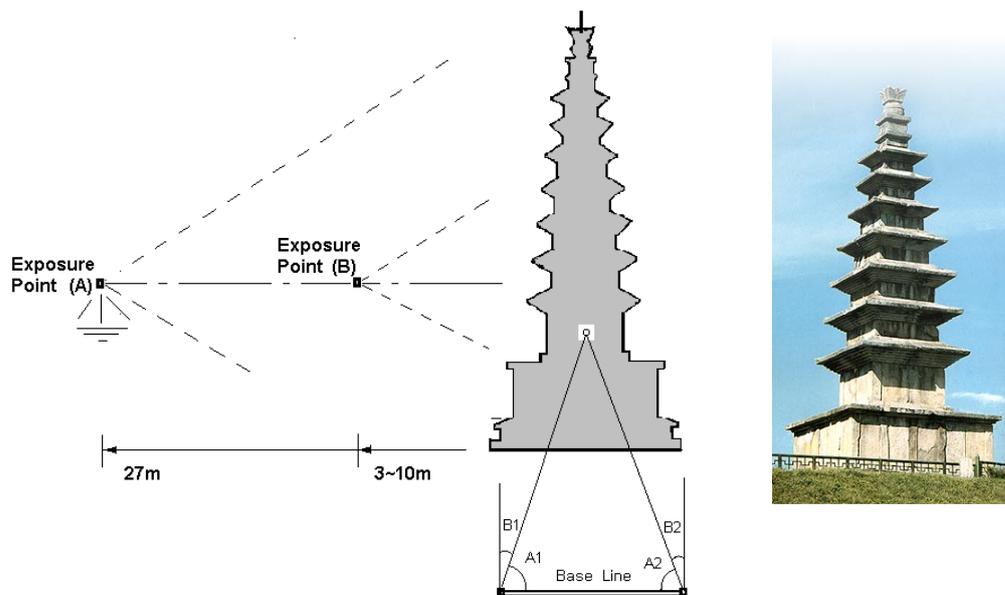


Fig. 1 Pagoda and measurement

### 3. Result analysis

The conclusions of this study are analysed of the digital data accuracy with related to unknown points of an object. The spatial analysis is performed using the cross section analysis of digital data, tilt, and 3 dimensional modeling.

#### 3.1 The object accuracy analysis of datum point measurement

The datum point for the whole section of an object set horizontally up the south section of an object. To product the coordinate and standard deviation of unknown points, targets adhere to all 4 sections with separately 4 - 6 points. The positional accuracy is calculated for 3 dimensional accuracy about an object that is a standard for datum coordinate values.

The standard deviation calculated appears in 1 cm. In this conclusion , the standard deviation occurs to the highest error in photographic direction because photographic distance is long relatively. Also, the order of accuracy is base direction(X), vertical direction(Z). The accuracy of unknown points is as follows.

Table 2. Analytical accuracy of a coordinate values in datum points

Average Simulated Error			Actual Standard Error		
X (mm)	Y(mm)	Z (mm)	X (mm)	Y (mm)	Z (mm)
4.3	7.8	3.9	4.1	8.6	3.7

#### 3.2 Precise drawing

For production of 3 dimensional coordinates values of digital image, The RolleiMetric CDW(Close-range Digital Workstation) is used in this study. This equipment can handle image processing of digital and analogue camera system. The characteristics of this system process automatically input of fiducial marks and photo coordinates. To digitize an image, DuoScan T1120 Color Scanner which can represent a 1200 DPI resolution is used. This equipment can be also possible that you can exactly measure orientation points with an multi-photo orientation module, NAWE Module and a bundle adjustment module, PROMPT Module. The digital data acquired is converted into DXF file which makes possible to produce 3 -Dimensional information of the object, and then this information is converted into DWG file to be handled conveniently in CAD program. Fig 2□6 are results of drawing with 2 dimensional and 3 dimensional data.

Fig. 2 A plane section of the object. Fig.3 Drawing of east section Fig. 4 Drawing of west section

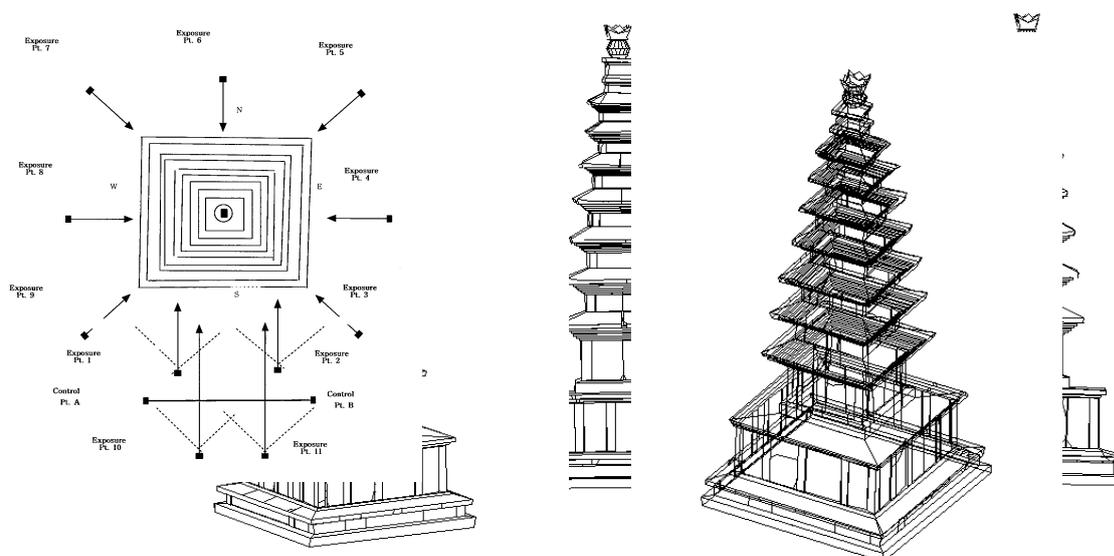


Fig. 5 3-Dimensional drawing Fig. 6 3-Dimensional perspective drawing

3.3 Tilt analysis

To find out stability and displacement of seven-story stone pagoda, first of all, is determined a center axis which sets vertically to pagoda, and then measured a tilt in each section. The result analyses of distances and angles in an object is as follows

Table 3. Output of displacement surveying

Method	X-axis (m)	Y-axis (m)	Height (m)	Angle	Remark
Photogrammetry	0.0491	2.5018	12.2549	0° 13' 45"	Tanθ = e / H
Trigonometric Leveling	0.0476	2.4921	12.2524	0° 13' 21"	

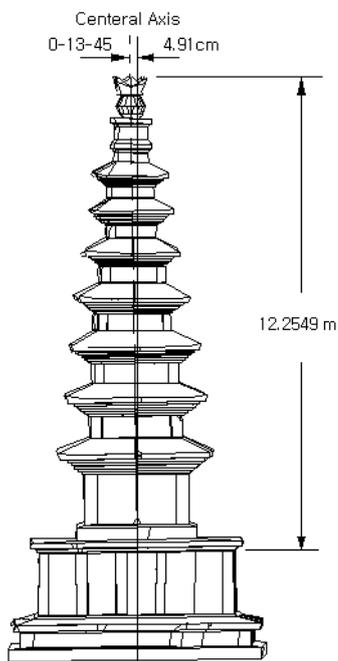


Fig. 7 Tilt analysis

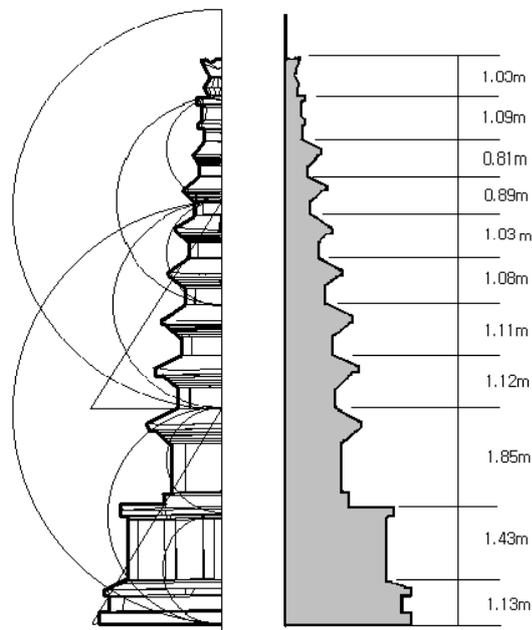


Fig. 8 Structure of pagoda and configuration ratio analysis

Table 3. shows that this pagoda tilts toward the west 4.91cm and 0°13'45" respectively. The difference between photogrammetric measurement and precise triangulation is 1.5 mm in distance, 2.5 mm in height and 24" in angle.

3.4 Analysis of structure ratio and section

The seven-story stone pagoda in Tappyong-ri standing on an earthen bank of the Namhan-gang River is consisted of total 8-Jidae(foundation stone) stones, This pagoda is formed of two double Jidae stone structure in each side.

There are some differences in each story. The first story is higher than another stories. The second and third stories are 1:0.61. The fourth and fifth are 1:0.52. The sixth and seventh are 1:0.45 respectively. These ratio values are involved in equilibrium because the ratio is small if the height of a pagoda is high as presented Fig. 8

The first Specific property of this stone pagoda is faced with two lines in upper sixth story(Oksin) if a line of 60° from the Jidae-stone bottom is drawn and the same angle of upper first story(Okae-stone) is again drawn.

Also, the second property is that the circle with the radius of a half of a height from the bottom of the Jidae-stone to the top of the Okae-stone in the first story could be intersected to the central height of Sangdaegap-stone and the top of the Okkse-stone in the first story, the top of the Okae-stone in the third story, the bottom of the Okae-stone and the top of Bockche. The total height is unknown because the Boju and Bogae which can measure a height is destructed. The total height of this pagoda could be about 1.5 times of a width of Jidae-stone

The section analysis of this pagoda using result of precise measurement occurs some construction errors that is not the same center line from the first to fifth stories. The first Wooju-stone and one and a half Myun-stones sited at the backside section of this pagoda is filled with a cement. Wooju-stone(the highest stone) in the second, fourth, and fifth stories is not a remind.

The left section of this pagoda is not existed in 2 story right section of Oksinbu. The Wooju stone in third story is a quarter of left Wooju stone. We know that the size and array of Wooju stone and Myun-stone is inconsistently rebuilt

### 3.5 3-Dimensional Modeling

GIS analysis is required of the 3-D modelling with a lot of information. The modelling method which is consisted of grid model, contour line and rendering is performed of multi-analysis with a visualization using computer graphic technology. The 3-D modelling is presented using grid model or contour line in the past. but it is using rendering method at present due to the development of computer technology.

Figure 9(a) is the result of rendering view from south side of seven-story stone pagoda. Figure 9(b) is view from west side and figure 9(c) is view from south-east side.

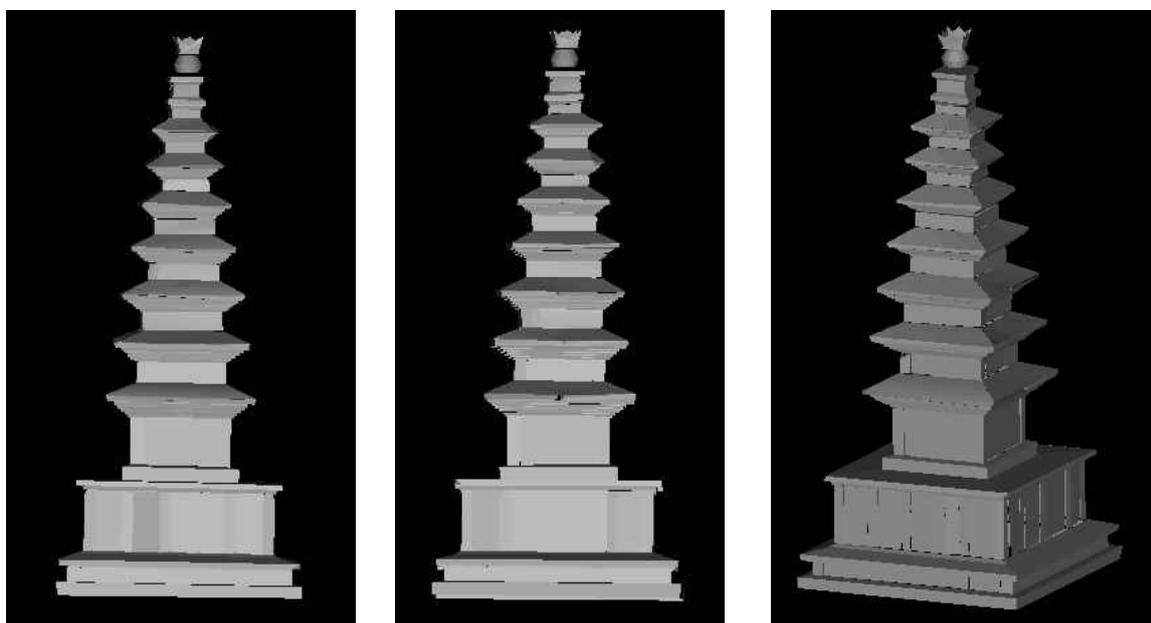


Fig. 9 3-D. Modeling

## 4. Conclusion

Some digital images and data about seven-story stone pagoda for preservation of cultural assets is acquired and then calculation and spatial analysis is performed by digital data.

1. The accuracy of this study was under 1cm(RMSE) which was a convergency tolerance in 3□27m distance of an object. Therefore The result values of this study can be useful for cultural asset surveying.
2. 2-Dimensional and 3-Dimensional precious drawings for each section were performed with close-range digital photogrammetric data. The cultural assets damaged like an original form can rebuilt using digital image information, and analyze the deformation and stability of an object.
3. The Spatial analysis technology such as section, structure ratio and digital modeling of an object were performed from digital information which is acquired of close-range photogrammetric system. Therefore, this method will be useful for a field of building database for investigation and preservation of cultural assets

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