3D MODEL OF GEDONGSONGO TEMPLE AND TOPOGRAPHY USING TERRESTRIAL LASER SCANNER TECHNOLOGY

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ABSTRACT:

The paper reports the result of measurement of the Gedongsongo temples and the surrounding topography using laser scanning technique. Gedongsongo is located in Semarang District, Middle Jawa Province, Indonesia. The research is carried out by the Geomatics Research Division of National Coordinating Agency of Surveys and Mapping (BAKOSURTANAL) is cooperation with Borobudur Heritage Conservation Office (HCO). BAKOSURTANAL has a program to investigate the suitability of relatively new instruments for surveys and mapping, while Borobudur-HCO concerns about documentation of cultural heritage objects in form of 3D model. Gedongsongo, located in a beautiful hillside of Mountain Ungaran, has nine temples grouped in five Gedong (complex of temples). Gedong-1, Gedong-2 and Gedong-3 and the topography surrounding the three complexes have been successfully measured. The result of measurement is still in form of point clouds based on the accuracy of the measurements, i.e. between 5 – 15 mm for the temples and 20 – 25 cm at 100 meters distance for the topography. The accuracy of the measurements and the integration of the 3D model results into the national coordinate system are still to be performed.

1. BACKGROUND

Surveys and mapping activities are not limited to conventional works for mapping the earth surface. Many surveys and mapping instruments are developed to support various objectives. In archaeology, Geomatics technology has a significant potential to map and to document cultural heritage objects using medium and high resolution satellite imageries both from active and passive sensors, large format and linear array digital aerial camera, and other terrestrial instruments (Campana etc., 2009). One of the latest technologies is measurement and 3D modelling of cultural heritage object using terrestrial laser scanner instrument.

Three dimensional (3D) models of cultural heritage objects are needed to document people's collective memory about the objects. When unwanted condition, like earthquake, flood, volcanic eruption, or vandalism, takes place so that the objects are destroyed, then the reconstruction of the objects can be done accurately. Directorate General of Historical and Archaeological Object (DG-HAO), the Ministry of Culture and Tourism (2007) announced with heritage cultural object conservation through improvement the quantity and the quality of practical research, human resources, and establishing an excellent information system based on informatics technology in a form of Geographic Information System. 3D modelling can also assist related institutions to process the inscription of the heritage objects on the World Heritage List based on the World Heritage Convention [World Heritage Center, 2008]. Clear identification on location and area of the object plotted in an up-to-date map are required. The description should be completed with photographs. To fulfil the requirement, 3D model can be used as an effective representation.

The Geomatics Research Division of BAKOSURTANAL has a program to investigate relatively new instrument for surveys and mapping. This paper reports the use of terrestrial laser scanner Leica HDS-3000 to map and model Gedongsongo Temple and its surrounding topography. The objective is to have an experience and skill of using the instrument and to produce a 3D model of the temple and its topography. The authors hope that the research gives a significant contribution to the Indonesian government for conserving heritage objects. Therefore the research in carried out in cooperation with Borobudur Heritage Conservation Office (Borobudur-HCO), which is a unit of DG-HAO.

2. APPLICATION OF LASER SCANNER FOR HERITAGE OBJECT

There are several methods to map and model 3D objects. Four of them are conventional terrestrial surveys, close range photogrammetry, airborne LiDAR and terrestrial laser scanner (Siu, 2007). Both airborne LiDAR and terrestrial laser scanner use laser to measure distance from the instrument to objects.

In principle laser scanner has five components, (1) a transmitter, laser pulse in HDS-3000, (2) a transmitter optics, two rotating mirrors in horizontal and vertical direction in HDS-3000 (3) a receiver optics, (4) a detector, and (5) an electronic system for data acquisition, processing, evaluation, display, and storage (see Figure 1).

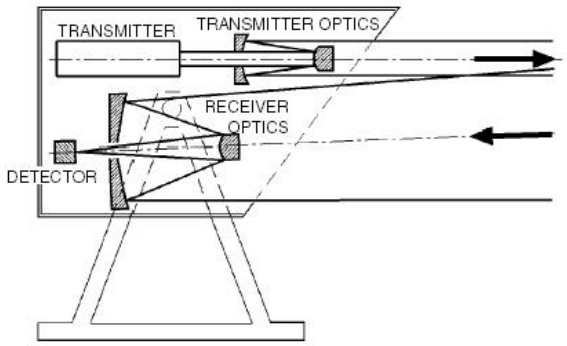

Figure 1. Optical components of a laser scanning system, from (Weitkamp, 2005)

3D laser scanner works using high-speed laser to scan the surface of objects which can capture a huge amount of 3D coordinate points of the surface model. These 3D coordinates can be integrated to form "point clouds" and high-resolution 3D models by using certain software. The distance of an object is determined by measuring the time difference of the emitted laser pulse and its return signal travel to and from the objects and the instrument. The angle of emission is controlled by two rotating mirrors.

Laser scanning technique has been used in 3D documentation important cultural objects, like the 3D mapping Old Star Ferry Pier area (Siu, 2007) using HDS-3000.

Meanwhile, in Indonesia cultural heritage area mapping has been rarely done. Borobudur HCO mapped Borobudur Temple, Prambanan Temple and other temples using HDS-3000 too, when an earthquake hit Jogjakarta city and the surrounding area in May 27th, 2006 to identify the damage on the temples. However, there is no scientific publication about the result of the mapping. Therefore the measurement of Gedongsongo temple becomes an important study to test the capability of laser scanning technique to map the temples and its surrounding topography.

Some technical specifications of HDS-3000 are summarized in Table 1.

Specifications	HDS3000
Metrology method	Pulsed time of flight
Field of view	360^0 horizon. and 270^0 vert.
Optimal scan distance	1 m – 100 m
Scanning speed	up to 1.800 points/seconds
Accuracy in distance (50m)	6 mm (single measurement)
Angular resolution	60 micro-radians
Divergence/spot size in 50m	≤ 6 mm
Calibrated video camera	RGB 64 mega-pixels, spatially rectified

Table 1. Some technical specifications of Leica HDS-3000

3. GEDONGSONGO AREA

Gedongsongo area is located in the Ungaran Mountain area, Candi Village, Ambarawa Sub-district, Semarang District, West Jawa Province, Indonesia. Gedong means building or temple, Songo means nine. Gedongsongo has, as reflected from its name, nine Hindu temples. These temples are however grouped in five complexes of temples.

The temples of Gedongsongo were found by Raffles in 1804. It is a Hindu culture heritage from the time of Syailendra Kingdom in the ninth century. The temples are located on the height on 1,300 meter above the sea level with a mountainous air temperature of about 19-27^0C.

The nine temples are surrounded with a beautiful landscape and pine-forest. Figure 2 shows part of the beautiful landscape.

Figure 2. Above photo is Gedong-2 potrayed from near of Gedong-3 location. The background in the lower place is Ambarawa-city. Below photo shows Gedong-3 with background of pine-forest and hillside of the Ungaran Mountain.

The position of five complexes of temples or Gedong, measured using GPS, is shown in Figure 3. In the figure contour lines, street or foot-path and river stream line are taken from the 1:25,000 scale topographic map produced by BAKOSURTANAL.

It is shown that the river crosses and divides Gedongsongo area into two parts. In the valley, near the river stream, hot volcano gas comes out from a small hole. A small hot spring swimming pool is located also there.

Gedong-3 and Gedong-4 are located in almost the same height, while the highest temple is Gedong-5.

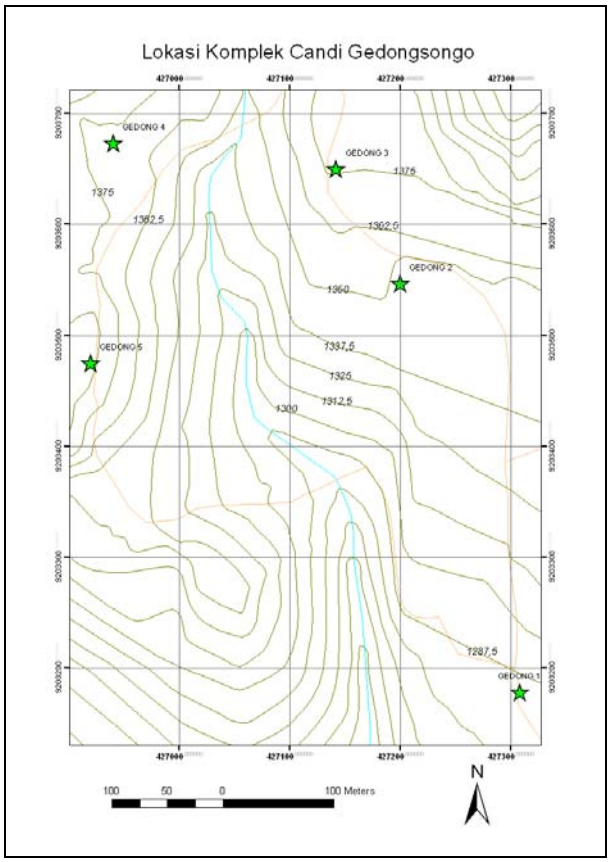

Figure 3. Location map of five complexes of Gedongsongo (symbolized with stars) drawn in the UTM Zone 49-South projection

4. PLANNING OF AND PROCESS OF MEASUREMENT

4.1 Instrument and Tie Points Location

Location of instrument and the target of tie points must be planned carefully before measurement. It is necessary to minimize un-scanned parts of temples and/or topography. Topographic measurement needs more systematic locations to ensure that the tie points can be seen from three or more locations in order to integrate all measurements and to get viewable height differences. In this study topography around Gedong-2 and Gedong-3 is constructed from five instrument locations.

4.2 Measurement Process

Before measurement, the instrument can be set up to capture images in 0^0-360^0 horizontal and certain angle interval in vertical direction. The images can be used to determine which part of landscape the surrounding area to be scanned and in which interval of angle the location of the temple by using measurement scripts. Once the scripts are set up, the measurement will be performed automatically.

In a normal weather, i.e. no rain and no fog, measurement of temple and topography from one point needs about two hours time. Detail measurement describing location of instrument, scripts, resolution and time is summarized in Table 2.

No	Instrument Location	*Script*	Resolution
1.	N-E of Gedong-1	Temple	5mm
2.	S-W of Gedong-1	Temple	5mm
3.	N-W of Gedong-3	Big Temple Small Temple Topography Target	10mm 10mm 20cm/100m 2mm
4.	S-E of Gedong-3	Big Temple Small Temple Topography Target	10mm 10mm 20cm/50m 2mm
5.	North of Gedong-2	Topography	25cm/100m
6.	50m S-W of Gedong-1	Topography	20cm/100m
7.	North of Gedong-2	Temple	15mm
8.	South of Gedong-2	Topography Temple	25cm/100m 15mm
9.	100m S-E of Gedong-2	Topography	25cm/100m

Table 3. Total measurement setting

5. RESULT AND DISCUSSION

The result of measurement is divided into 3D temple and topography. This study has measured Gedong-1, Gedong-2 and Gedong-3. Each temple is measured from two points, while topography around Gedong-2 and Gedong-3 are measured from six points.

5.1 Temple

Figure 4 and Figure 5 show the result of the measurements of temples.

Figure 4.
Measurement of Gedong-1 from SW direction (above) and from NE direction (middle). Left image shows location of the laser scanner, NE from the temple.

Part of the temples has not been scanned, because the measurement is carried out only from two points. Further analysis from the result, especially related to the detail of measured result has to be performed in collaboration with experts and practitioners in cultural heritage objects.

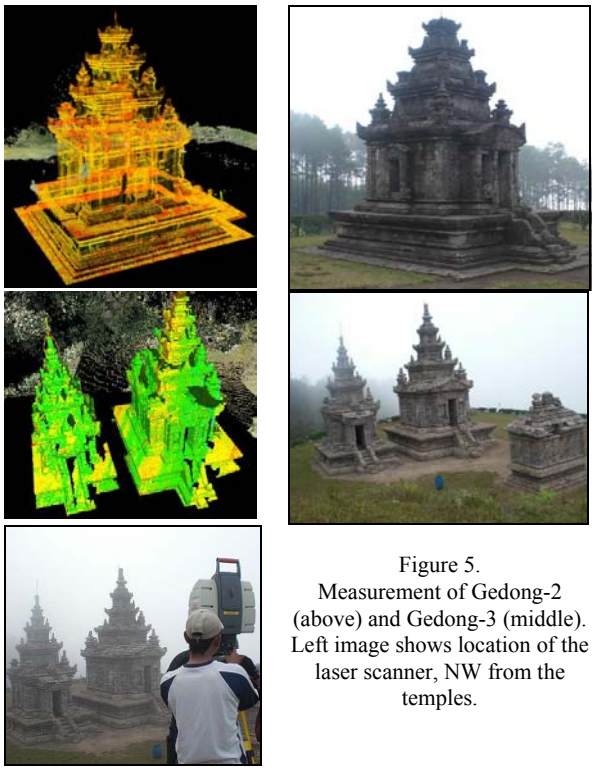

Figure 5.
Measurement of Gedong-2 (above) and Gedong-3 (middle). Left image shows location of the laser scanner, NW from the temples.

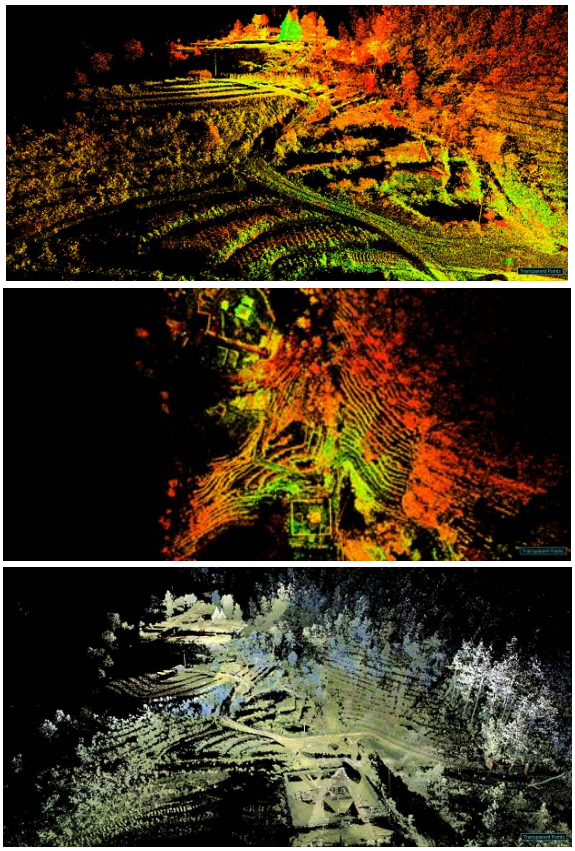

Figure 6.
Above image is topography of Gedong-3, measured from Gedong-2; Middle image shows area around Gedong-2 and Gedong-3 viewed vertically; Below image shows the total landscape around Gedong-2 and Gedong-3.

5.2 Topography

Gedongsongo area has a unique and beautiful natural hilly landscape. Like depicted in Figure 3, the temples are located in separate positions with relatively long distances from one to another. The distance between Gedong-1 and Gedong-2 is about 380 meters, while Gedong-2 and Gedong-3 are separated with about 120 meters. Therefore, surveys and measurements of Gedongsongo's topography cannot be separated in our study.

As mentioned in Table 3, positions of the instrument for measuring topography are the same as positions of it for measuring the temples except one location, namely at the distance of 100 meters in the SE direction from Gedong-2. The results of topography 3D points are shown in Figure 6.

The result of topography model shows that the integration of some measurements from five points can be done well using at least four tie points between adjacent measurements. The targets of tie points is used to integrate the model if only the error of them is less than or equal to 4 mm.

In the scanning process, laser signal ran to trees and leaves. Therefore, the measurement has not resulted in earth terrain or elevation model yet. It is still in a form of surface model. The result needs to be processed carefully to produce 3D topography of earth terrain. The result has not been connected to the national coordinate reference yet. It is in a local coordinate system. However, applying a simple analysis, the 3D model of topography can be displayed from side cross-section, as shown in Figure 7. Using the display, the height different among some positions can be determined visually.

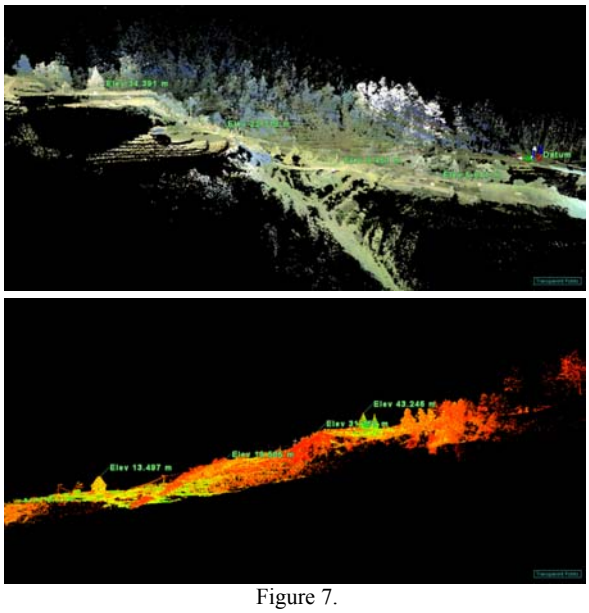

Figure 7.
Above image shows a cross-section from South. Gedong-2 is located in 5.8 m height from local reference, while Gedong-3 in 34.4 m; Below image is the same cross-section but from North.

According to the measurement, height difference between Gedong-2 and Gedong-3 is about 28.6 meters. It is consistent to the data from the topographic map (Figure 3). Gedong-2 is located near the contour line of 1,350 m and Gedong-3 is near the contour line of 1,375 m, so that the height difference is 25 m.

6. CLOSING REMARK

The paper has described and discussed the result of measurement of the temples and the topography of Gedongsongo area using laser scanning techniques. Measurement of three temples, i.e. Gedong-1, Gedong-2 and Gedong-3 and the topography of about 400 m x 400 m (16 hectares) around Gedong-2 and Gedong-3 and about 150 m x 150 m (2.25 hectares) around Gedong-1 has been finished in 3 days or about 21 hours, with an assumption of 7 hours/day working.

From this research the authors recommend the use of laser scanning techniques to map temple areas and other cultural heritages in Indonesia. By this, the instrument owned and maintained by Borobudur-HCO and also trained and skilful human resources can be utilized optimally to support the program of Ministry of Culture and Tourism through DG-HAO. A comprehensive recommendation will be formulated systematically together with experts and practitioners from archaeology.

This preliminary study shows that laser scanning techniques can be applied to map topography accurately. However post processing is still required to produce 3D earth terrain model and to be used as height information in the topographic or the base map.

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