Topographic Map Construction Using a Handheld Laser Range Finder and GIS at Kaman-Kalehöyük and Kültepe

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ABSTRACT

Detailed topographic maps for areas around Kaman-Kalehöyük and Kültepe were constructed using a handheld laser range finder and GIS. The equipment for laser measurement enables us to make a fine topographic map with less time and working effort compared to traditional measurement methods.

Keywords: Landform, Laser measurement system, DEM, GIS, Kriging

INTRODUCTION

Topographic maps are fundamental units of information for many types of field studies, including geosciences and archaeology. Although various surveying methods exist to measure land surface topographies, they are sometimes problematic in terms of time and money. Traditional methods of making contour-based topographic maps, such as plane-table surveying, total stations and GPS, often require heavy, large instruments and several operators, as well as a long time to complete field measurements. Recently developed surveying approaches such as aerial/satellite-image photogrammetry and airborne/terrestrial laser scanning systems allow one to obtain fine topographic contours, DEMs (Digital Elevation Models) and/or three dimensional surface data of the objects, but those high-technological measurement systems are usually too expensive to be casually used. To obtain a topographic map of a certain area of hundreds of square meters in and around the excavation sites of Kaman-Kalehöyük and Kültepe, we performed a quick and cost-effective survey of landform measurement using a laser range finder, following the methodology proposed by Hayakawa *et al*. (in press).

MEASUREMENT DEVICE

The laser range finder used in this study is LaserAce 300 by Measurement Devices Ltd., UK, which can measure range, vertical angle and horizontal angle. The device has a size of 175 × 106.5 × 56 mm and a weight of 650 g, which is small and light enough to carry easily. An operator looks at the target object through its viewfinder and a laser beam (wavelength: 905 nm; laser safety: Class I) is emitted onto the object when a button is pushed. A sensor in front of the device then catches the light reflected from the target object within 0.3 seconds. The range data are available without a target reflector, but they are often unavailable for some specific materials such as water surfaces and dark or rough materials which cannot reflect the laser appropriately. The measurable range is up to 300 m, with an accuracy of ±0.1 m and a resolution of 0.01 m. The maximum measurable distance changes depending on the atmospheric condition: the maximum distance generally decreases as the atmospheric humidity or dust density increases. Together with distance, an elevation angle and a horizontal angle are concurrently obtained. The range of measurable vertical angle is ±80˚ with an accuracy of 0.3˚ and a resolution of 0.1˚. The horizontal angle, of which accuracy is less than 1˚ and resolution is 0.1˚, is expressed as an angle from magnetic north. The resultant distance, vertical angle and horizontal angle are displayed on the window of the device at each measurement operation.

DATA ACQUISITION

The measurement device was handheld by a standing operator. The vertical offset, i.e., the height of the operator's eyes, was subtracted from the original data in the data conversion processes. Horizontal distance, vertical height and horizontal angle from the device to the target point were manually logged.

Measurements were carried out based on multiple control points. The first control point (the base point) was set at a distinct location in the excavation area, and its longitude (x), latitude (y) and altitude (z) were measured with the GPS. Other control points were then successively measured in areas where one can walk in. From each control point, target points on terrain surfaces were randomly measured. For areas covered with vegetation such as sunflower fields, the surfaces of the vegetation were first measured and the height of the vegetation (sunflower or other bushes) was subtracted during the data conversion processes later. Additional information about landmarks such as roads, electric poles and river banks was put into the data sheet and later used to identify the objects and to create their vector data.

Kaman-Kalehöyük

The base point was set at the southwest corner of the excavation trench on the tepe at longitude 33˚47' 11.1'' E, latitude 39˚21'46.2'' N and altitude 1069.6 m a.s.l. During the three days of our survey, the data of 2,049 points were measured with 42 control points. The data are mainly from the eastern side of the tepe and the adjacent hill slopes, covering an area of approximately 700 m × 1,100 m.

Kültepe

In order to cover a larger area in a shorter period than Kaman, we collected a total of 404 points with 45 control points in two days at Kültepe. The coordinates of the base point were 35˚38'17.0'' E and 38˚51'16.5'' N, at the altitude 1092.0 m a.s.l., located in the excavation area of the Karum. The data set, covering an area of approximately 800 m × 1,200 m, includes the current excavation area of the Karum, but not the mound of Kültepe / Kaniš.

MAP CONSTRUCTION

The field data were entered into a personal computer to handle them in a digital format. Three-dimensional coordinates (x, y and z) were calculated from the distance, height and horizontal angle data. The xyz data and the additional information of the local features (roads, electric poles and trench outlines) were then imported into GIS software (ESRI ArcView) as point data.

The coordinate of the base point was set in the global coordinate system. The longitude and latitude of the base point were projected on UTM coordinates, permitting the measured metric data to be put onto the map with other global data sets in the UTM projection. For Kaman, the coordinate of the base point is (567748.46, 4357336.74) in UTM Zone 36, while the base point coordinate for Kültepe is (208252.41, 4306012.91) in UTM Zone 37.

Land surface topography data (DEM) were created by interpolating the z-values of the obtained point data on the GIS. The interpolation was carried out by Kriging (e.g., Burgess and Webster 1980), which has been widely applied to estimate spatial distribution of various phenomena from scattered point data. The resolution of the DEM was determined by the density of the points calculated for each 100 × 100 m grid cell. The maximum density is 9.1×10^{-3} m^{-2} for Kaman and 3.9×10^{-3} m^{-2} for Kültepe. These density values indicate that the minimum of the mean distance between two adjacent points is 10.5 m for Kaman and 16.0 m for Kültepe. The grid resolutions (cell size) for Kaman and Kültepe were thus determined to be 10 m and 20 m, respectively. Testing the semi-variograms, the Kriging interpolation was carried out using the circular function with no nugget effect, for which, 12 adjacent points within a distance of 300 m were used.

Some errors were observed as anomalous z-values in the data set of Kaman, which included more than 2,000 points. These could be derived from protruding branches of the vegetation and/or the misalignment of the control points resulting from error propagation through the successive control points. The error points were excluded by looking into the tentative 1-m contour lines generated from the original point data set before construction of the final DEM and contour data. Anomalous points (spikes and sinks) more than 2 m higher or lower than surrounding points can be identified as points surrounded by two or more circular contour lines. Eliminating those anomalous points, interpolation was again performed over the remaining point data set. These procedures were repeated several times until most of the error data were diminished. Consequently, 2,035 points remained from the total 2,049 points.

From the interpolated DEM, topographic contour lines with 1-m interval were derived. Vector data (polygons, polylines) of the ground object features (buildings, roads, excavation trench outlines and riverbank lines) were also determined with the additional information attributed to the point data. Overlaying the layers of the contour lines and other vector feature data, high-resolution topographic maps for Kaman and Kültepe were obtained (Figs. 1, 2). Comparing the resultant map and the actual landscape, the distance accuracy seems to be within several meters. The vertical accuracy may also be within one to two meters, because the prominent errors eliminated during the error reduction stages were no taller than three meters. However, it is somewhat hard to fully assess the accuracy of the map because of the lack of accurate comparable data. More field surveys for further data collection will be necessary to obtain the topography data in a wider area and in more detail.

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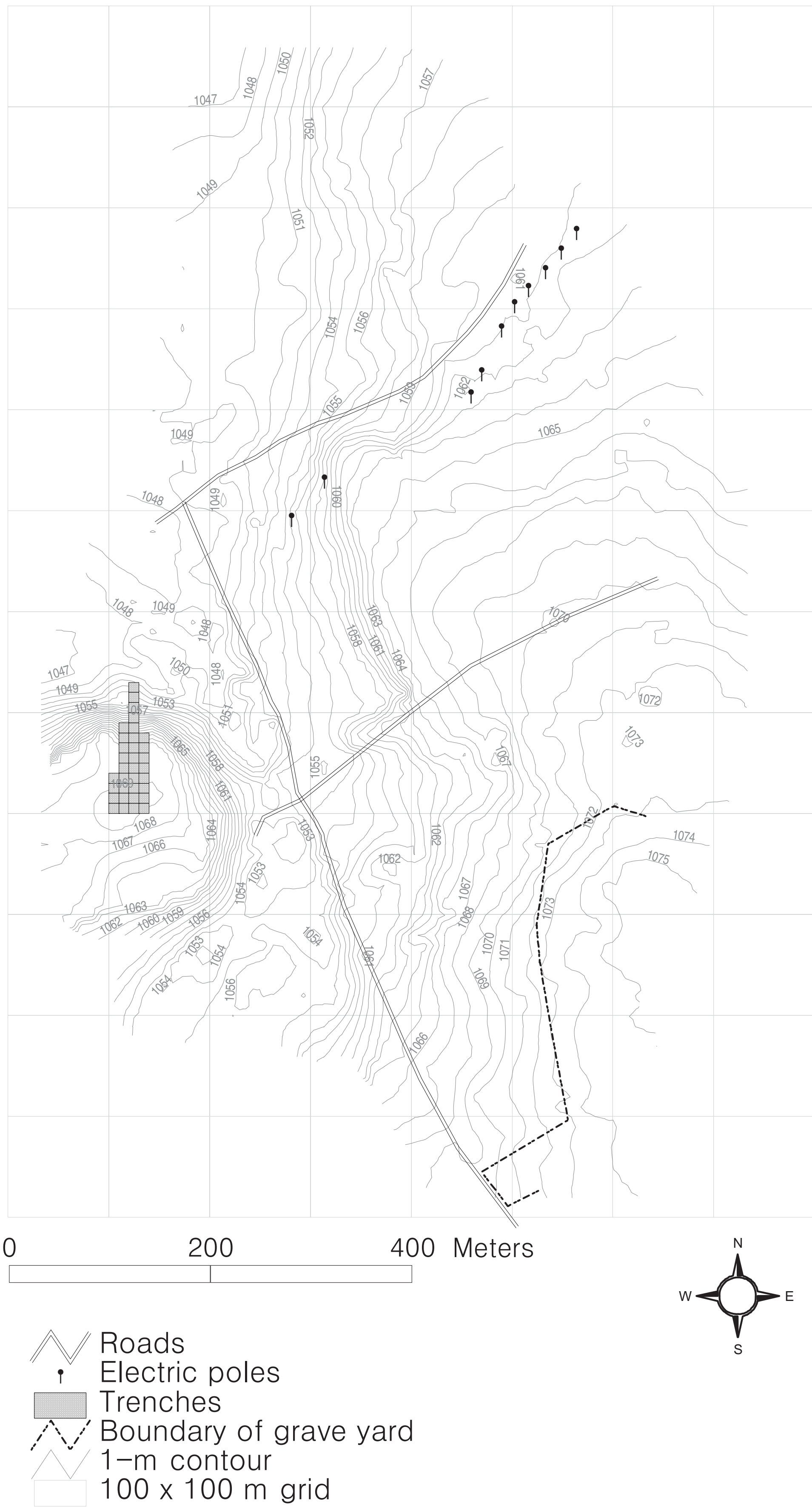

Fig. 1 Topographic map on the eastern side of Kaman-Kalehöyük. Contour interval is 1 m.

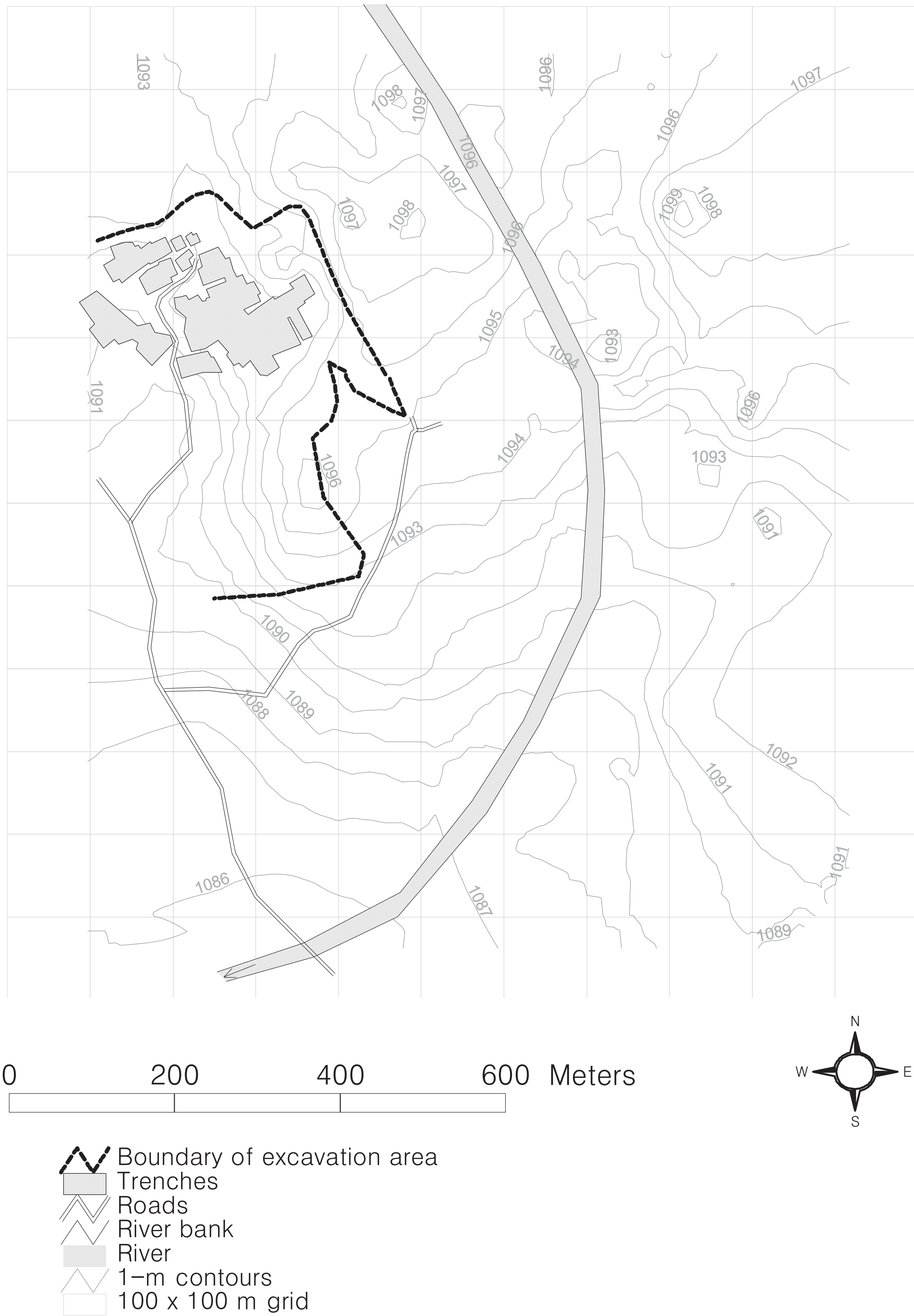

Fig. 2 Topographic map around the Karum of Kültepe.