Mobile laser scanning and 360° photography for the documentation of the Iron Age ring fort at Gråborg, Öland, Sweden

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KEY-WORDS: Öland, Iron Age, ring fort, MMS, Sweden, laser scanning, GeoTracker

INTRODUCTION

In May 2014, four prehistoric ring-forts on the island of Öland, namely Gråborg, Vedby borg, Bårby borg and Löts borg, were surveyed using a motorized ground penetrating radar (GPR) system. The surveys were carried out as a part of the project "The Big Five", financed by the Swedish research council and the Royal Academy of Letters, History and Antiquities, and included high-resolution GPR data collection, covering in total approximately 7.5 ha of land inside the forts.

As a complement to the geophysical survey the remaining walls and surroundings of Gråborg and Vedby borg were surveyed with a MMS GeoTracker. MMS systems are currently being used for high-resolution documentation of, for example, railroad tracks, but are also important for road planning and maintenance, asset management and for the generation of 3D city models (see Kutterer 2010: 293 ff.). It has also been tested and evaluated on archaeological sites (e.g., Studnicka *et al*. 2013). The GeoTracker system had not previously been used for the documentation of archaeological remains and the survey was considered a pilot study to evaluate its advantages and disadvantages for archaeological applications.

GRÅBORG

Gråborg is the largest Ölandic ring-fort with a diameter of approximately 200 m and an inner area of about 2.5 ha (Fig. 1; for a map showing the location of Gråborg, see Viberg 2015, 521-525). Based on finds collected during excavations and metal detection, the fort was constructed during the younger Roman Iron Age (AD 200–375) and was used until the Middle Ages (Stenberger 1933: 234; Malm 2003: 5). Several historical records and maps are available and show that the inner area of the fort has been farmed since the beginning of the 17th century at the least (Tegnér 2008: 44). This has seriously affected the preservation of the buried remains within the fort. However, masonry belonging to the outer fort wall is preserved in many places, although in collapsed form. The collapsed sections are as wide as 20 m today, but wherever the wall is in good condition, the original height can be estimated at roughly 6 m and width at 5 m (Swedish registry of ancient monuments, FMIS). The walls are constantly exposed to weathering and other chemical and physical degradation processes and additional sections of the wall are at risk of collapsing in the future. Because of this

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Fig. 1. Aerial photograph of Gråborg (top, photo Jan Norrman 1997, ©Swedish National Heritage Board); the MMS system (bottom: photo Andreas Viberg 2014)

risk, the importance of documenting the masonry structures becomes all the more urgent. Until now traditional archaeological documentation methods, such as photography and field drawing have been used at Gråborg. These methods have produced important results, but they are time consuming and the complete documentation of the entire ring-fort would be a lengthy and tedious process. Therefore, the use of 3D digital documentation methods, such as terrestrial laser scanning or photogrammetry, presents an interesting alternative (see Vosselman and Maas 2010).

THE MMS SYSTEM

The GeoTracker MMS system can connect up to eight laser scanners, standard SLR cameras, 1–4 stereo cameras, a 360° Ladybug5 camera, ground penetration radar systems etc. (Fig. 1). The advanced positioning system consists of a GNSS receiver (Novatel Propak V3), a high-precision wheel speed sensor (Pegasem WSS3) and a 250 Hz inertial navigation system with gyros and accelerometers. All sensor data are post processed to a trajectory (travel path) used for positioning of images and laser data with an accuracy of 2–3 cm. The 360° Ladybug5 camera captures true 12-bit

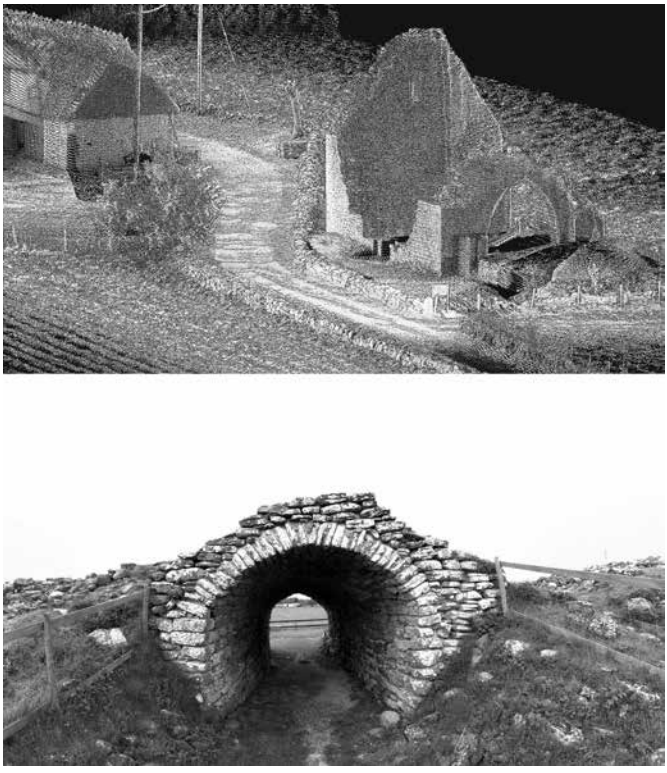

Fig. 2. Laser point cloud showing the chapel of St. Knut near Gråborg (top); still from the 360° photo documentation of Gråborg using a Ladybug5 camera (bottom) (© Magnus Larson 2015)

images from six highly sensitive CCD sensors with a high dynamic range even in shadows and highlights. During the survey at Gråborg four SICK LMS 511 Pro laser scanners were mounted on the platform. The point density in the laser point cloud is over 120,000 points per second. At a speed of 30 km/h this results in over 1500 points/m^2. It is possible to mount the platform on different kinds of vehicles, e.g., cars, rail vehicles, boats etc.

The GeoTracker software package makes it easy and fast to produce point clouds, stitch panorama images and even produce high quality coloured point clouds. There is also a free image viewer to help the user to evaluate images with online map functionality.

RESULTS AND DISCUSSION

The survey at Gråborg was carried out in the course of two hours and data was collected from the main road to Gråborg, at Borgs by, the chapel of St. Knut and finally inside and around most of the outside of Gråborg. This resulted in 180 million points in LAS 1.2 format with a point density of 3000–7000 points/m^2 around the vehicle. In addition to

the laser scanning data, 415 panorama images (18.3 GB of raw data) and 1644 stereo images (5 MP) were collected.

The system provided a valuable high-resolution digital documentation of the Gråborg area (Fig. 2). Even though access to the southern side of the fort was limited, an almost complete documentation of the fort could be accomplished within a matter of hours. The data will be made available to the public and will allow online remote visits to the site. The data is also valuable from an archaeological research perspective as wall construction and condition can be evaluated without visiting the site. The dense point cloud generated by the MMS system also allows for accurate measurement of the perimeter wall, which could form the basis of a very thorough documentation and analysis of the fort. The downside of the MMS system is that it requires that the archaeological site is accessible to the vehicle the system is mounted on. As these kinds of "drive through" ancient monuments are rare, the use of MMS systems will most likely be restricted (see Barber *et al.* 2011). The system could be used, however, for the fast documentation of urban areas, such as the Swedish world heritage sites Örlogsstaden Karlskrona, Hansestaden Visby and Världsarvet Gammelstads Kyrkstad, and similar sites in Sweden and abroad. Another restriction is the density of the point cloud on structures taller than the car. As the system cannot "see" these areas, it needs to be complemented by, for example, aerial photographs, airborne light detection and ranging (LiDAR) surveys or static terrestrial laser scanning (TLS), in order to produce a more complete picture of the surveyed structures.

ACKNOWLEDGEMENTS

We would like to acknowledge the Swedish Research Council and the Swedish Royal Academy of Letters, History and Antiquities for financial support. We would also like to thank Christer Gustafsson, Robert Danielsson, Börje Karlsson, Karl-Oskar Erlandsson and Aina Sevelin for fieldwork support and project assistance.

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