GEODESY MEASUREMENT TECHNIQUES AS AN ENRICHMENT OF ARCHAEOLOGICAL RESEARCH WORKFLOW

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Abstract

Use of geodesy techniques is widespread in different fields of science. Especially in such an emerging and dynamic branch of science as archaeology. Warsaw Institute of Archaeology, conducts many archaeological expeditions, among the others Polish-Georgian archaeological expedition in Gonio, where ancient Roman Bath has been discovered and excavated. Gonio is located in Adjara, Georgia, placed on the Black Sea coast. Fortress of Gonio is an ancient Roman fortification, the oldest reference to the fortress is dated for a 1st century AD. After decomposition of Roman Empire, the fortress came under a Byzantine influence. In XVI century Fort was occupied by Ottoman Empire until XIX century, where has been taken by Russian Empire. After decomposition of Soviet Union, and restoring Georgian independence, Gonio is located in the well-developing area and experiencing a tourist boom. Whereas very intense archaeological works are held in this area. Archaeological workflow demands significant labour effort and might be augmented and accelerated by the proper use of geodesy techniques. Reduction of work effort saves not only labour costs but also another important factor, time. This paper focused on a review of geodesy techniques which may have an application in archaeology, with especially insight on the use of remote sensing methods.

Keywords: Archaeology, Remote Sensing, Terrestrial Laser Scanning.

1. INTRODUCTION

Archaeology is a science which aim is to reconstruct a past of humanity. There is still relatively little known about our past, lots of earth hidden traces of human activity, accumulated through ages. Every archaeologist is an explorer, whose have a unique chance to come into contact with an unknown world. Profound historical and cultural knowledge is essential to explore the past in a scientific manner. Contemporary achievements of science and technique allow contributing from itself. Transition in a technology-based workflow of archaeological actions is inevitable. It is that branch of science which draws profusely from achievements of the most modern techniques. The paper reveals which of surveying techniques contributes to archaeological research.

2. GEODESY MEASUREMENT TECHNIQUES

2.1. Total Station

Total station, or as it is called TST (Total Station Theodolite) is a contemporary surveying device used widely in geodesy, in which have many applications. Along with the basic functions, the device allows contributing from features mentioned in following part. Angle measurement is one of such a functions, total station device measure angles by an analysis of digital bar codes etched on rotating reflective elements. Measurement capability reaches 0.5 arc-second and o average range between 3 to 7 arc-seconds. A subsequent feature of Total Stations is a coordinate measurement, which allows determining coordinates of a point in 3-demensional space. The essential condition is a clear path between a point and the optical module of the device. The device using angels and X, Y and Z coordinates of the point calculate a position of it, about the instrument, using triangulation and trigonometry. The absolute location of Total Station device requires line of sight observations, which might be established at a certain point or with a line of sight to two, over more certain points within resection (location). Part of Total Station devices are connected to Global Navigation Satellite System (GNSS) by the receiver (Janowski, Nowak et al., 2014, Kwasniak et al., 2016), in such a case a direct line of sight is not mandatory to determine coordinates. On the other hand, GNSS measurement have longer occupation periods (especially by conducting static measurement methods), have poorer vertical axis accuracy and calculation of altitude coordinate, the geoid (especially by conducting dynamic measurement methods, e.g. Real Time Kinematic, RTK). Conducting measurement in GNSS technology, require from the observer (surveyor, or archeologist) an awareness of many errogenus factors, which may influence the results, e.g. corrupt geometry of satelite segment, terrarian obstacles, difusse incidence angle, caused by the reflection from rough objects, such as building surfaces, or rocks and a poor quality of GNSS reciver (Naus & Nowak, 2016, Nowak, 2015). Casual use of this technology, may generate measurements errors, range between a few centimeters to a few meters, but standard measurement on avarage do not exeede 2 meters.

Furthermore, data obtained during the measurement is stored on internal storage disc. All measured features, distance, horizontal and vertical angle, might be transferred to the external drive and upload on the computer. The dedicated software allows computing obtained results and introduce a map of the surveyed area. Total Station device is used to measuring the distance. Within the instrument modulated infrared carrier signal are reflected by a prism reflector. Modulated signal is generated by the solid-state emitter. Reflected signal goes back to the device, and its modulation pattern is interpreted by the computation module in the apparatus. Multiple frequencies are emitting and receiving, allows determining the distance. Among the others, reflectors glass corner cube prism is the most popular one (Fig. 1). Distance measurement capability, for a device with the reflector, reaches around 1.5 millimetres + 2 parts per million above a distance of up to 1,500 meters, for devices without the reflector it is up to a few hundred meters.

Fig. 1. Glass corner cube prism, as a reflector Leica GPR111

2.2. Terrestrial Laser Scanning

Laser Scanning methods involve, scanning an object, or a surface by laser beam used technology. The scanner sends a laser beam to the object and receives the reflection, obtained data is used to recreate the real-world object in virtual three-dimensional space. In such a way device can retrieve significant information about the shape and overall appearance of the object. The real-world object is reconstructed in the form of a dense cluster of points, which is called point cloud. Nowadays, a variety of applications, available on the market allows processing point clouds and create detailed and precise three-dimensional models. The

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biggest advantage of laser scanning is that enormous numbers of points might be gathered in an efficient and quick way with high precision. Terrestrial Laser Scanner (TLS) is an instrument which is a part of Laser Scanners family. The device scans its surroundings by the use of Light Detection and Ranging for precise range measurement and angular calculation caused by laser beam deflection to derive the point cloud. In general, Terrestrial Laser Scanning is divided into two groups of measurement techniques. The first group uses a time-of-flight (ToF) method and the second phase shift (PS) method. Phase shift ranging involves the use of amplitude modulation of the light and continuous laser illumination to recognise the spectrum at high frequency. Time of Flight Ranging takes advantage of precise measurement of time, in which laser beam reflects from the object. Distance is calculated from the pulse time of flight and the speed of light (Burdziakowski et al., 2015, Nagrodzka-Godycka et al., 2014, Janowski & Rapinski, 2013, Janowski et al., 2014.1-2, Janowski et al., 2014.4-5, Mikrut et al., 2016.1). Terrestrial Laser Scanning might also be used for qualitative analysis of the object changing in time, such as deteriorating structures, several techniques has been described in the literature (Janowski, Nagrodzka-Godycka et al., 2016, Tysiac et al., 2016).

2.3. Photogrammetry

Photogrammetry, by its definition, is a technology, which is meant to obtain reliable information about considered objects through the process of capturing and interpreting stereo photographic images. Digital images processing allows generating 3-demensional digital models on measured object. X, Y, and Z coordinates define the position of an object in space. Subsequently, image coordinates define the location of pixels. The orientation of a camera centre defines its position in space and a view direction, geometric parameters of the imaging process are also defined. Mainly, the focal length of used lenses, but might include the depiction of lenses distortion as well. To perform good-quality photogrammetric surveys, a rule-based procedure must be followed, which contain information about configuration, positioning, and orientation of the camera about the considered object. The main goal of this procedure is to minimise the possibility of obtaining a corrupt data in measurement results. Contemporary technological advancement in digital high-definition cameras, computers, computation methods (e.g. sub-pixel image matching) made photogrammetry more mobile and efficient. It results in high precise model data, gathered in a short period (Bobkowska, K. et al., 2016, Janowski & Szulwic, 2014). By the use of unmanned aerial vehicles (UAV), it is possible to conduct inventory of archeological site from the air. UAV may be linked with internet technologies, thanks to that the images captures during archeological works might be processed remotely (Mikrut et al., 2016.2, Paszotta et al., 2015, Przyborski et al., 2015).

3. APPLICATION OF THE METHODS IN ARCHEOLOGY

3.1. Total Station

In 2009 one of the biggest excavation projects in Norway took place, called “Kveøya excavation”. The survey has been conducted exclusively by use of modern total station LeicaTPS1200+. Moreover, spatial data were operated by the Norway’s national grid. To document the structures, authors were imposing the perimeter of the feature with the prism rod to obtain the shape. The micro-topography of mechanical and historical layers, plus the topography of the entire site, has been surveyed when structures were excavated. Use of total station device has been showed in Fig. 2.

Fig. 2. Total Station in use, Leica TPS1200+ [www.leica-geosystems.us].

Archaeological expedition conducted by Institute of Archaeology at the University of Warsaw focused on the excavation of an ancient Roman bath, with the well-preserved floor. The area of excavation has been rich in historical terms due to expansion and fall of Roman empire and invasion of Ottoman Empire in XVI century. It is important that during excavation layers should be uncovered in stratigraphic order. The historical layer might be interrupt by cuts caused in the different archaeological period, e.g. Turkish pits, visible in Fig. 3. Proper geodetic measurement should be conducted in every historical layer (Karasiewicz-Szczypiorski & Misiewicz, 2013).

Fig. 3. Gonio's Fort archaeological site – documentation of historical layer.

3.2. Terrestrial Laser Scanning

The attraction of Terrestrial Laser Scanning (TLS) lay in speed and precision of the measurement. In general, TLS is much faster than Total Station measurement. Even though this technology is relatively new in its application in archaeology. On the one side because of the significant cost of the device and training that need to be conducted due to data processing of the point cloud. The good example described in publications of Engstrom and Johansson (Engstrom & Johansson, 2009). One of the major southern England monument, Stonehenge, has been digitalized by use of TLS. Due to data processing of the point cloud new unknown carvings were discovered, along with detailed archaeological site virtual documentation. In this case point, cloud data has been used to create a three-dimensional model of a structure as a whole. Fully operational 3-Dementional model of an archaeological site or a structure allows conducting advanced simulations, such as calculation of a position of the sun over the structure in a time of its operation in the past (such knowledge may reveal a function of the structure), shown in Fig. 4.

Fig. 4. Stonehenge monument, point cloud data [www.greenhatch-group.co.uk].

Traditional methods have limited capability in creating detailed topography documentation. First attempts to create a valid 3D rendering of the surface comes with the introduction of Total Station device and GPS system, but whole procedure was quite complicated (Janowski, Rapinski, 2013, Hejmanowska et al., 2015). TLS is the solution which is designed to gather a huge quantity of information in relatively short time. Therefore it allows contributing from that features. The historical human activity involves an active change of the environment, especially around ancient settlements. The position of sepulchres, roads, old water routes, places of worship might not be visible at first sight, but an analysis of the terrain might reveal significant hints, which guide where such places are located (Fig. 5).

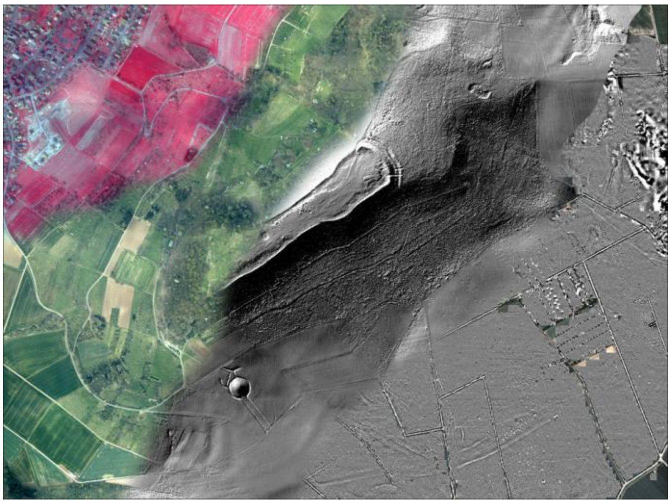

Fig. 5. Terrain surface [www.dayofarchaeology.com].

3.3. Photogrammetry

Digital photogrammetry is very efficient way to gather archaeological data and can improve both quantitatively and qualitatively workflow. One of the earliest published paper concerned the use of photogrammetry for archaeological purposes was work of Knut Jetlund from 1996. Jetlund conducted limited field testing of the photogrammetric methods on the ruins of a church in Trondheim, although obtained results were limited, because of erstwhile capabilities of the hardware. Manual approach, adopted by Jetlund included every single tie-point in the model have to be deliberately aligned and adjusted. However, such a solution was very time-consuming and demand monotonous labour. However, Jutland's paper proved that undoubtedly photogrammetry techniques might be used for a documentation of archaeological objects and the hybrid technique that he developed contribute significantly to the development of contemporary digital solutions. Nonetheless, Jetlund’s method is now obsolete his work revealed the potential of photogrammetry in archaeological applications. It is essential to understand know-how behind the use of digital photogrammetry as well as the process of data gathering, this allows obtaining proper spatial data. Artefacts obtained during archaeological excavation should be archived at the site, and photogrammetry allows preparing quick models on the object based on a few pictures on it (Kjellman, 2012; Blazek, 2014).

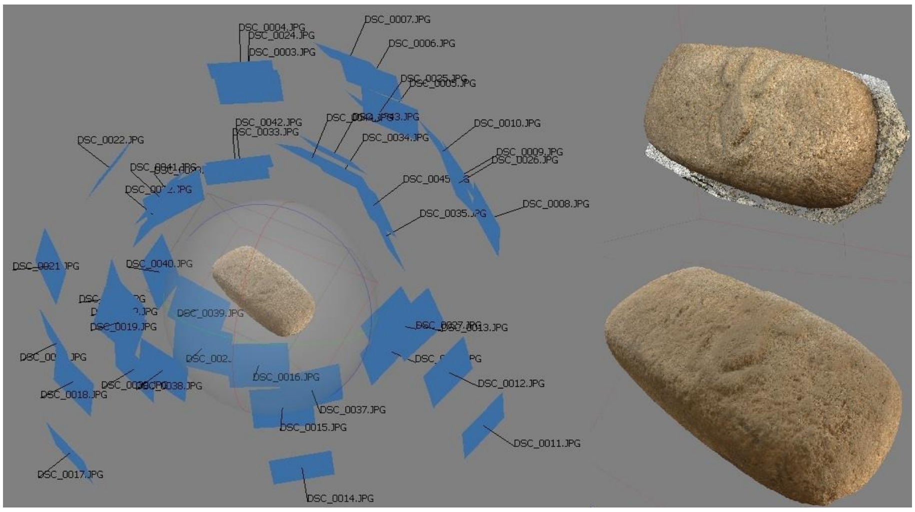

Fig. 6. Photogrammetry and use of matching algorithm [www.dayofarchaeology.com].

Dedicated software by use of matching algorithms might gather satisfying results in a relatively short period (Fig. 6). Moreover, a historical layer might by retrieved and archived, as shown in Fig. 7.

Fig. 7. Historical layer model obtained by use of photogrammetry – three-dimensional model [www.irlabnp.org].

4. SUMMARY

Nowadays archaeology contributes greatly from contemporary advancement and new technologies. Remote sensing techniques proving its usefulness in various fields of modern-day science, especially in archaeology and protection of cultural heritage (Bernat et al., 2014, Kwoczynska et al., 2016, Laskowski & Szulwic, 2014, Rucka & Wilde 2013, Rzasa et al., 2016). Authors identified three of the surveying techniques, which have particular application in archaeology, following the Total Stations measurement, Terrestrial Laser Scanning and Photogrammetry. Mentioned method has been describing and evaluates to prove its usefulness in the archaeological workflow.

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