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AIRBORNE LASER SCANNING FOR BURIED CULTURAL HERITAGE

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Abstract

The studies on spatial information in geomatics are required by the other disciplines related to spatial approach. In this context, different surveying techniques can be used according to the archaeological measurement scale, such as tachymetry, photogrammetry, airborne laser scanning (ALS), RADAR, global positioning systems (GPS), for exploring, positioning, archiving and modelling for related cultural heritage. There is always a possibility to damage archeological remains during excavation. Therefore, especially in terms of subsurface archaeology, it is significant to decide on a nondestructive method for modelling archaeological remains. Remote sensing technology provides varied methodology including different instruments that will be chosen due to requirements and financial support of the intended archaeological project. One of the methodologies is active remote sensing, which provides additional information to analyze in terms of buried archaeological remains. This study is targeted on evaluation of ALS data for buried cultural heritage in Carnuntum (Roman legionary camp in Austria). The newly approach is depended on radiometric calibration of additional recorded physical parameters per each echo and get more information on reflectance properties of related target. The procedure composed by Institute

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of Photogrammetry and Remote Sensing (IPF) in Vienna University of Technology was followed during radiometric calibration process. Result of the process (reflectance model) was analyzed in comparison with orthophotos and city plan of Carnuntum. The obtained reflectance model includes traces of buried archaeological remains.

Keywords: airborne laser scanning; radiometric calibration; buried cultural heritage.

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1. Introduction

Geomatics engineering models the earth geometrically by using numerous techniques and methods. Moreover, the studies on spatial information in geomatics, which covers data integration, analysis, and management (i.e., geographic information systems, CAD environments, digital image processing systems etc.), are required by the other disciplines related to spatial approach. In this context, archaeology utilize geomatic tools, such as tachymetry, photogrammetry, terrestrial or remote sensing (RS), global positioning systems (GPS) for extracting exploring, archiving and analyzing of cultural heritage including management from beginning to the end of archaeological project. Especially for the last decade, the improvement in active remote sensing technologies, i.e., RADAR and LIDAR systems provide fast, accurate, and quantified information for archaeology. Active microwave sensors, known as radars, transmit an electromagnetic energy that they produced and receive the backscatter energy from the target [1]. Radar systems use microwaves that are less influenced by atmospheric effects. It is also possible to obtain data 24 hours a day because radar produces its own energy and is not depended on sun energy. The analysis and interpretation of these results concerning archaeology also including subsurface archaeology is a new study area. The aim of this study is concentrated on the advantages of active remote sensing methods regarding airborne laser scanning technology in terms of buried archaeological studies in a comparable way by using diverse data sources (orthophotos, archaeological methods and knowledge).

2. Data and Methodology

Carnuntum is most important ancient Roman settlement in lower Austria, which is located on the main road halfway between Vienna and Bratislava. The main city was situated in the area between present-day Petronell-Carnuntum (civilian city) and Bad Deutsch-Altenburg (legionary city-military camp) with the area of 300 hectares.

ALS and orthophotos are two main spatial data sources. There is also Carnuntum plan and historical information on that area [2], [3]. ALS data was obtained from Institute of Photogrammetry and Remote Sensing, Vienna University of Technology. Data provider is airborne technologies and data acquisition date is 5th of June, 2010, platform is aircraft. The flight plan includes 14 strips (Figure 1) over Carnuntum and 4 points/m^2 is provided. Planimetric data accuracy (relative) is $\pm 20\text{cm}$, vertical accuracy is $\pm 75\text{cm}$. Data coordinate system in ETRS 89 and UTM Zone 33.

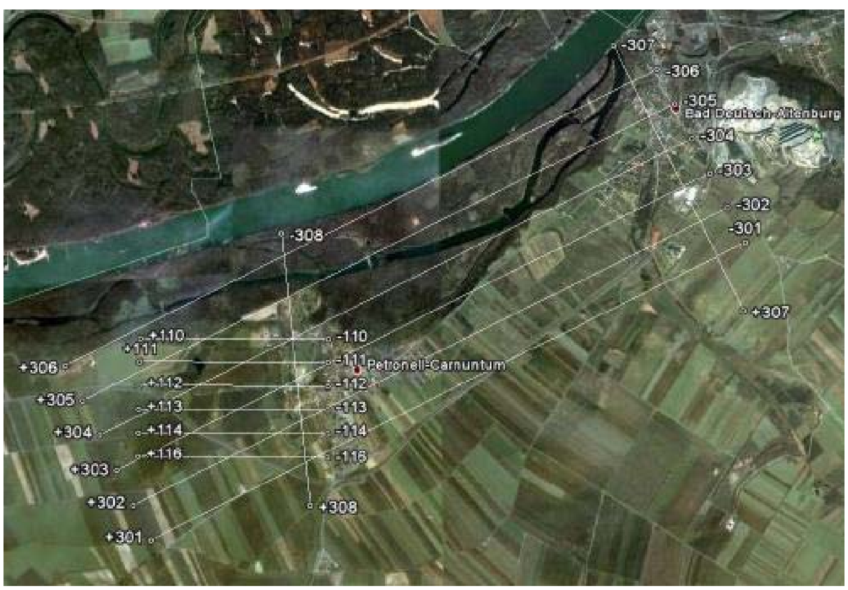

Figure 1. Flight plan of Carnuntum.

There were two orthophotos of Carnuntum and the acquisition dates are 05.06.2000 and 17.08.2006. In orthophotos of August 2006, the crop marks are not visible as orthophoto of June 2000. It is most likely related to the harvesting time of the crops. This confirms that the acquisition time of the optical imagery plays an important role for identifying crop marks and detecting of subsurface remains. Therefore, just orthophoto from year 2000 was evaluated in analyzing and comparison steps.

Ancillary information on Carnuntum from library, internet sources, and previous studies including a vector map of Carnuntum obtained from Michael Doneus, were also used as complementary data sources [4], [5], [6]. ALS data process was implemented by using IPF software, OPALS and SCOP++ for point cloud visualization and editing in some parts of study. OPALS stands for orientation and processing of airborne laser scanning data. It is a modular program system which aims to provide a complete processing chain for ALS data usage, consisting of small components (modules) grouped together thematically in terms of packages [7].

The Next ESA SAR Toolbox (NEST) is a user friendly open source toolbox for reading, post-processing, analyzing, and visualising the large archive of data (from Level 1) from ESA SAR missions and was used within some parts of study.

Advanced FWF ALS systems have capabilities to capture higher number of intermediate echoes as a discriminative property than discrete echo systems and are able to capture whole waveform. Moreover, in FWF systems, it is possible to derive additional physical attributes of target surfaces; width and amplitude of each echo after a processing procedure. This information gives the possibility to classify the target classes and evaluate the properties of targets regarding to their backscattering mechanism, namely, "backscatter cross section". The backscatter cross section is not only based on the peak power of received echo, but also includes all other target parameters, e.g., the illuminated area Ai, the reflectivity ρ, and surface scattering Ω [8], [9], [10], [11]. However, these physical attributes are influenced by various factors, e.g., backscattering properties of targets, flight parameters, atmospheric effects, etc. [12], [13]. Before further evaluation of ALS data, radiometric calibration is essential for a better classification and comparable analysis from different sensors or data providers [14], [1]. The formulation used for radiometric calibration is adapted from radar equation (Gaussian waveform decomposition) (1). Figure 2 shows a sample Gaussian decomposition of FWF ALS data. The peak power of received energy from four recorded echoes, namely, "amplitude, $\hat{P}$" is depicted by red arrow. Echo width (blue) can be defined as sigma sp or as full width at half maximum. Additionally within this study, the term intensity (I) is the amplitude of the return waveform, which is an integration of reflectance properties of related target within footprint, was depicted in filled area (orange) in Figure 2.

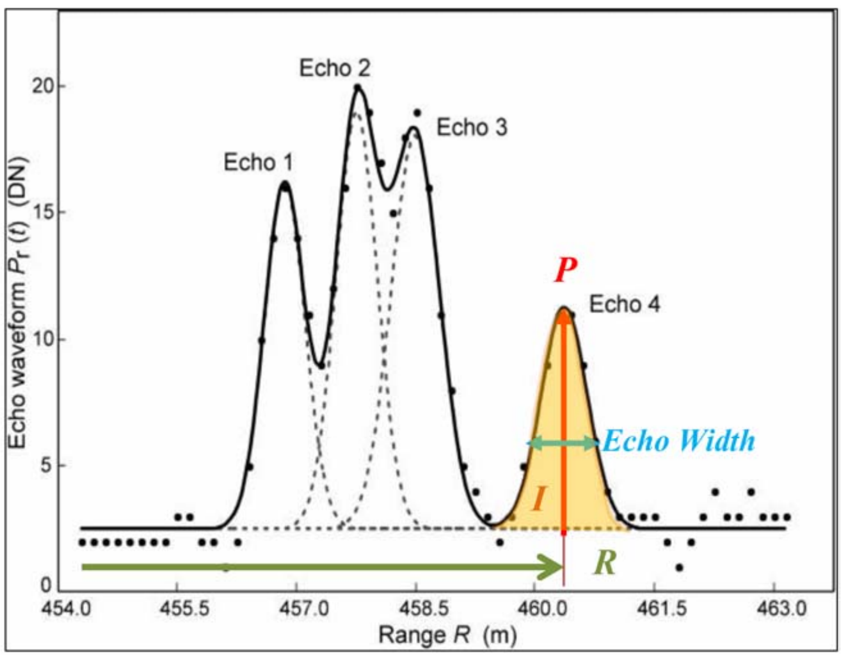

Figure 2. Gaussian waveform decomposition [11].

$$P_r = \frac{P_t D_r^2}{4\pi R^4 \beta_t^2} \cdot \sigma \cdot \eta_{sys} \cdot \eta_{atm}. \tag{1}$$

The unknown parameters in main formula are assumed as one constant, so-called calibration constant C_{cal}. In order to determine C_{cal}, the following formula is used:

$$C_{cal} = \frac{\beta_t^2}{P_t D_r^2 \eta_{sys}}. \tag{2}$$

The obtained formula for backscatter cross section is

$$\sigma = \frac{C_{cal} 4\pi R^4 \hat{P} s_p}{\eta_{atm}}. \tag{3}$$

Within study, in the first step, the calibration constant was calculated. Secondary the backscatter cross section and reflectance properties were derived by using calibration constant results.

In the first step, ALS full-waveform data (in Riegl Data format ".sdw") was converted into Opals Datamanager format (.odm) by using OpalsImport Module. All modules were executed by using "command prompt" after related scripts were written. The second step covers module OpalsNormals. It is aimed here to derive local fit plane for each echo within input ALS data and derive the normal vector of each point. In the third and fourth steps, radiometric calibration of data was performed by using RadioCal module. The reflectance properties of surface (reflectivity file), for a better interpretation, reflectance result was filtered by using different filtering methods (i.e., ENVI adaptive filters, NEST filters for detecting lines etc.). Visually better interpretable results, were obtained after filtering the reflectance result in NEST software by using Sharpen-High Pass filtering in 3×3 window size. Targets were taken into account in this step. The red arrows shows the similar traces of ancient structures as crop marks (Figure 3). Within this study, some obligatory files of processing step were obtained from IPF are "Trajectory File", "Region File", and "Reflectivity File". The latter part (fourth step) covers the use of calibration constant value for the whole

ALS data set and RadioCal module to get the backscatter cross section, backscattering coefficients, incidence angle corrected value, and reflectance properties of ALS data was performed.

3. Results

Preliminary step within this study was based on conventional approach, which was achieved by using orthophotos of Carnuntum from two different years. There are several traces used to extract information from the images; crop marks, shadow marks, and soil marks. It was possible to differentiate crop marks visually but just by using one of the orthophotos (from year 2000) covering these crop marks.

Depending on the data acquisition date, the crop marks can be visible or not. If the harvesting time is just before data acquisition, it is possible to get crop marks, but after the harvesting time, these signs get lost. The orthophoto from year 2006 is dated after the harvesting time so it was not adequate to analyze regarding to crop marks. As expected from previous studies in the literature, the crop marks were matched with buried remains.

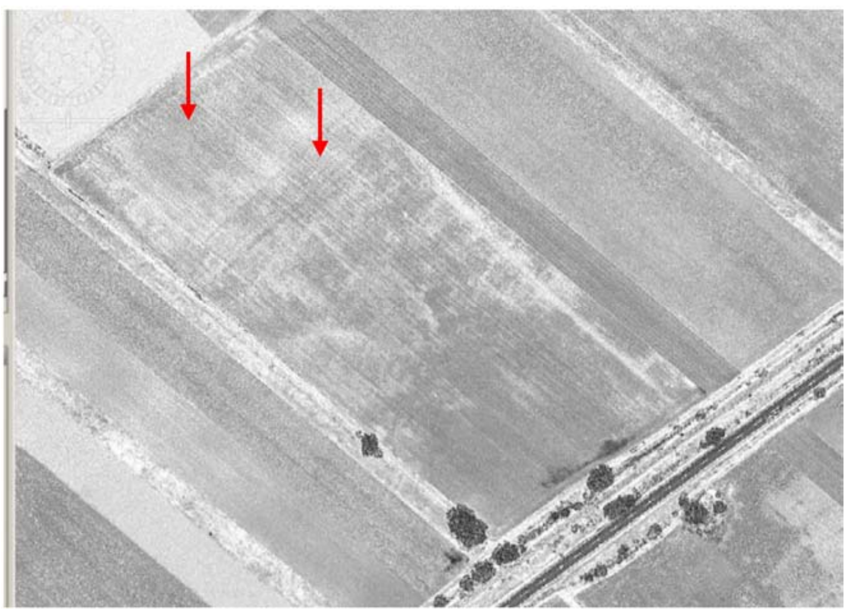

Figure 3. A part of reflectance after NEST filtering result.

Figure 4. Reflectance property of Carnuntum.

The active remote sensing tool within the study is airborne laser scanning. It is a new tool regarding to archaeological studies comparing to other remote sensing tools. Preliminary studies based on the DTM generation and for the last decade, like radar tools, additional properties acquired by ALS systems have started to be one of the research areas to analyze archaeological remains. Reflectance properties of Carnuntum ALS data was obtained after a series of process by using IPF software. Processed data later was coloured by using gray tones. The result is promising due to traces of buried remains. Despite, data acquisition was after harvesting, the signs are visible. The results were also compared with other data sources. Orthophoto and ALS results are similar to each other in terms of buried remains.

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