Between Land and Sea: A LiDAR field survey to detect Bronze Age sites in the Chekka region/Lebanon

An approach of automated pointcloud classification and geoarachaeological processing

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About the project "Between Land and Sea"

The project "Between Land and Sea" was initiated by OREA (Institute for Oriental and European Archaeology) and is an interdisciplinary approach to combine the geology, geomorphology and paleo-environment of the Chekka region (Lebanon) to investigate the history of the Bronze Age and its archaeological remains. It is known that in this time several cities along the Lebanese coast (most famous Byblos) traded across the eastern Mediterranean (Kopetzky, 2010). One of the most important commodities was cedar wood, which was felled in the mountains inland, transported to the coast and then shipped (e.g. Rich et al., 2016). Due to the difficult political situation and the civil war (1975 - 1990), Lebanon is not fully developed archaeologically but in recent years new sites, such as Tell Fadous-Kfarabida, have been discovered and explored (Höflmayer et al., 2014). In this work, possible settlement structures and transport routes of the cedar wood from the Lebanon Mountains to the Mediterranean coast near Chekka (Tell Mirhan) are to be identified based on a Digital Elevation Model (DEM) generated from high-resolution LiDAR (light detection and ranging) data.

Data acquisition

Fig. 1. Self-made construction to mount the Riegl VP-1 HeliCopterPod on a Bell UH-1D helicopter (© Rom 2018).

The advantages of data acquisition using LiDAR technology from a helicopter (airborne LiDAR) are, on the one hand, the acquisition of a large area within a short period of time with high accuracy. On the other hand, the study area is heavily anthropogenically affected with extensive olive tree plantations and large parts of the low mountain region are heavily forested. Some of the infrared impulses of the used laser scanner penetrate this dense vegetation and reach the ground, enabling the calculation of a DEM with high spatial

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resolution. The LiDAR data collection took place from 05. Nov – 08. Nov 2018 by the Chair of Physical Geography of the Catholic University of Eichstätt-Ingolstadt in cooperation with the OREA and the Lebanese military and is, according to the knowledge of the authors, the first scientific project ever to carry out a large-scale LiDAR data collection in the Lebanon. For this purpose, a Riegl VP-1 HeliCopterPod was mounted on the landing gear of a Bell UH-1D ("Huey") helicopter of the Lebanese military. The system was installed on a self-made construction, which was developed in Eichstaett and was afterwards approved by a technical commission of the Lebanese airforce (figure 1).

Under partially rough conditions (e.g. occasional GPS signal dips and air traffic) the Area of Interest of almost 500 km² could be scanned in previously planned flight strips. The generated raw data were then processed using dGPS (differential Global Positioning System) data which were acquired by own fixed reference stations placed within the scanned area during the mission.

Data Processing

Point Cloud Filtering and Classification

For the filtering and classification of the point clouds the LIS (Laser Information System) software package provided by Laserdata (http://www.laserdata.at) was used, which is a commercial extension of the geoinformation system SAGA (System for Automated Geoscientific Analysis). To speed up the data preparation, steps 1 to 4 of the workflow from figure 2 were adapted to the source data, scripted in the statistics software program R and applied to all point clouds.

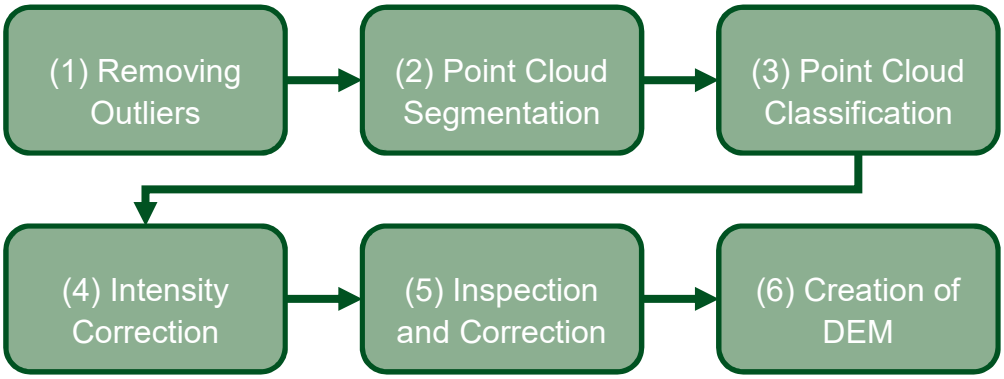

Fig. 2. Workflow for automated Point Cloud Filtering and Classification.

In the first step (Remove Outliers), all points with errors in the Z-direction were sorted out. Next, the point cloud had to be segmented. For this purpose, a plane was adapted for each point, taking into account the 50 neighbouring points at a maximum distance of 2 m, and its normal vector was calculated. All points of a 3D neighbourhood with approximately the same value for the normal vector were combined to a segment. In the next step the points were assigned to the classes *ground*, *vegetation* and *building* by a geometric approach considering the segments. First, all ground points had to be identified using an iterative TIN (Triangulated Irregular Network) mesh. Then, building and vegetation points could be classified, divided into low vegetation (< 0.3 m), medium vegetation (0.3 m - 2 m) and high vegetation (> 2 m). Since strongly weathered karst formations of light limestone in the study area are incorrectly classified as vegetation in some places by this method, all vegetation points exceeding an intensity threshold of 1900 were additionally assigned to the ground class. Points that could not be assigned to any of the above classes remained unclassified.

Figure 3 illustrates the postprocessing of the point clouds. The upper two images, 3A and 3B, show input data at the beginning of the processing. Besides the Z-values, each point has a colour information (RGB - Red Green Blue - value) and its intensity as a proxy for the reflectance of the surface. Using the steps described above, the points could be divided into different classes (ground, vegetation, building) (figure 3C). It is clearly visible that other structures, such as power lines, remain unclassified. Since the vegetation must

be filtered to detect archaeological traces, only ground and building points were used to calculate the DEM. An extract of the resulting terrain model with a grid cell length of 0.75 x 0.75 m is shown in figure 3D.

Geoarchaeological evaluation of the LiDAR data

The geoarchaeological evaluation of the DEM is already in progress and uses various methods, some of which are mentioned hereafter: An important point will be a multi-criteria analysis to find favoured areas of possible Bronze Age settlements. Morphological factors such as slope inclination and geographical factors such as the availability of water will play an important role. Least-cost-path analyses can be used to reconstruct possible prehistoric transport routes between mountains and coast and thus serve as a point of reference for further archaeological investigations. Another important part of the evaluation is the direct detection of archaeological features (e.g. buildings) that influence the topography to this day. With the help of various visualization methods (Štular et al., 2012) such as a Local Relief Model (LRM) as described by Hesse (2010) or the sky-view-factor, prehistoric structures that change the terrain surface by only a few centimetres can be made visible.

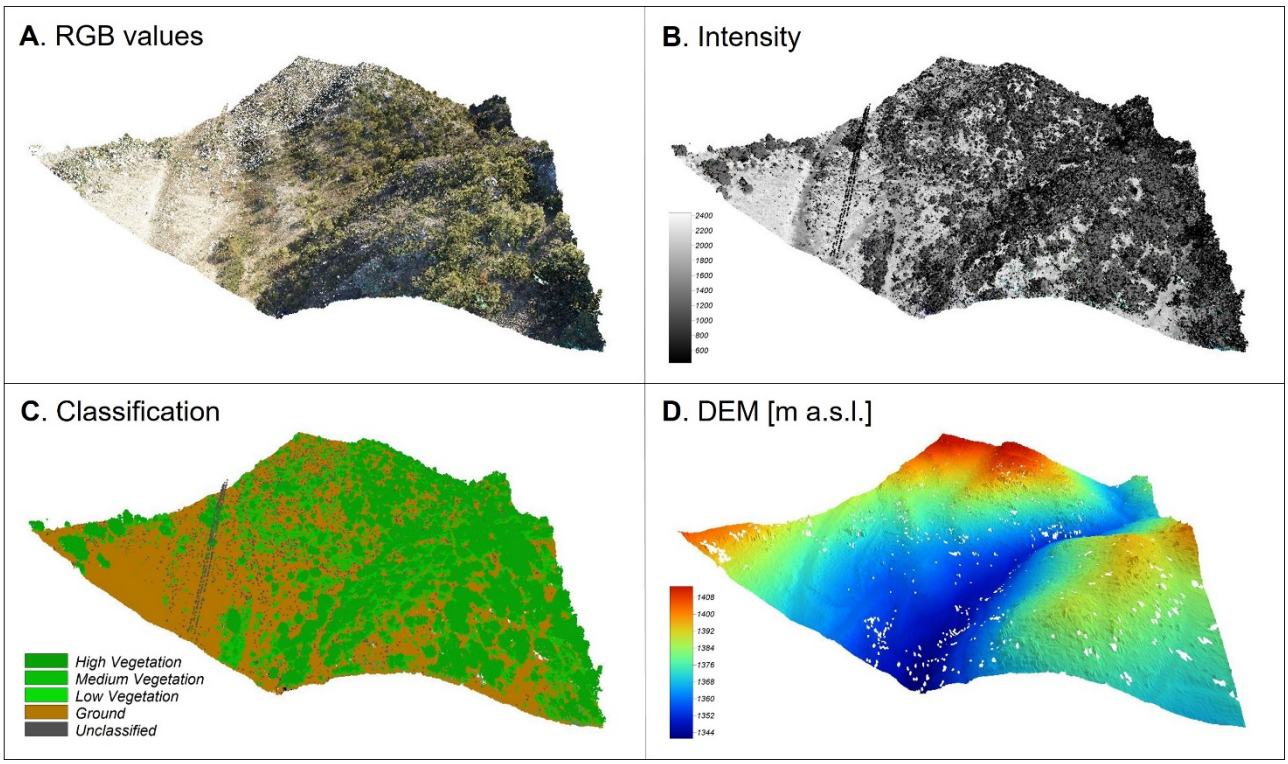

Fig. 3. Data processing of LiDAR pointclouds: Input data and results on an example of an extract. A: Input pointcloud coloured by RGB values. B: Input pointcloud coloured by intensity. C: Result of the classification process. D: Resulting DEM.

With the help of these analyses, possible excavation sites will be identified for a huge area and future surveys will help to learn more about life and trade in the Bronze Age in this part of the Mediterranean Sea.

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