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An approach to the automatic surveying of prehistoric barrows through LiDAR

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ABSTRACT

In this paper a method for the detection of megalithic barrows from LiDAR height data is presented. The methodology is grounded on the joint application of morphometric and morphological classification of digital terrain models, segmentation and detection of circular patterns (Hough Transform). Since the segmentation of the data is proposed it can be considered as a GEOBIA (Geo-Object-based Image Analysis) approach to remote sensing in Archaeology. There are three major strengths in the proposed methodology: 1) the use of supercomputing (High Performance Computing) for the analysis of topographical information, 2) the development of own specific code, and 3) the use of accurate topographic descriptors for terrain analysis. The method is able to provide concrete locations that can eventually match the theoretical morphometric features of this kind of sepulchres. The application has leaded to discover new barrows in a region from Western Spain.

1. Introduction

Barrows are one of the more representative and ubiquitous cultural features of prehistoric landscapes from Western Europe. From the point of view of its interpretation, archaeologists have considered that the analysis of locational aspects can lead to a deeper understanding on how prehistoric communities shaped the landscape according to their social and ideological beliefs. Additionally, the analysis of these funerary landscapes can be related also to more conventional changes, like the analysis of demographic variations or, perhaps more accurately, to determine the degree of appropriation of landscape. Thus, knowing the patterns of locations and the concentration of sepulchres becomes essential to comprehend a great variety of behaviours from prehistoric communities.

Remote sensing techniques together with systematic surface surveys can collaborate to form a better picture of the cultural evolution of prehistoric landscapes. Both techniques can offer meaningful relationships on aspects that have been barely analysed in vast regions of Europe, including the Iberian Peninsula. When posing the question about the origins of megalithic monumentalization of landscape, the central issue is to define the relationship between settlements and barrows. This is the aim of several research projects that we have conducted during recent years in West Central Spain (Cerrillo-Cuenca, 2011), in an area located close to Portuguese border. The whole area, including also neighbouring regions from Portugal, holds one of the denser concentration of megalithic sites from Europe, as several noticeable contributions have demonstrated (Bueno Ramírez et al., 2013). Their chronology ranges from the 5th to the 3rd millennia cal BC, although some reutilizations have been reported during later periods of Bronze and Iron ages (Almagro, 1962).

Vast territories from this wide area have not been systematically surveyed yet, which might vary the assumptions with respect to the distribution of megalithic monuments and settlements. Moreover, our experience tells us that the intensive analysis of isolated sites, or a low density of them can lead to record denser concentrations of monuments, but also significant traces of habitats. The exploration of extensive surfaces through LiDAR data can be combined with surface surveys to extract meaningful relationships between monuments and habitats, which in last instance allows for a more accurate comprehension of prehistoric landscapes. Furthermore, and concerning the cultural heritage preservation policies, the detection of barrows by the means of remote sensing techniques can contribute to register series of unknown monuments and improve the assessment of risks in both public and civil works.

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In 2015, the Spanish National Institute of Geography made publicly available LiDAR data for several regions of the country. As in other European countries, this will surely have a positive impact on the archaeological studies. In our case, we have taken advantage of this circumstance to explore a large section from Extremadura region in search of megalithic barrows, by the design of a semi-automatic method for detecting barrows along the whole region. This paper presents the method and its preliminary results.

2. Methods

From a strictly topographic point of view, barrows are archaeological earthworks that alter the terrain, what makes possible to detect them through a topographic analysis of LiDAR datasets (Doneus et al., 2008). For this task, the visual interpretation of shaded relief images has been the most applied procedure (Harmon et al., 2006; De Boer et al., 2008; Corns and Shaw, 2009; Chase et al., 2011, 2012; Štular et al., 2012; Lin et al., 2013). Such an approach has been successful in flat terrains with almost no interferences from vegetation, where the finding of prehistoric earthworks is likely to be more possible (Bewley et al., 2005). A major issue in this process is the visual interpretation of LiDAR data, which does not allow distinguishing natural and anthropic features from barrows at a glance, so confirmation on terrain needs to be performed for the most part of the cases (De Boer et al., 2008; Gallagher and Josephs, 2008).

Some procedures to enhance visually topographic “anomalies” have been published for archaeological purposes (Hesse, 2010). However, they require in any case detailed supervision and interpretation of results. The aim of the method here described is to provide accurate and discrete locations, which can match the topographic and morphological characteristics that define the barrows. That process is possible through the classification of local height data. Previous methods for automating the detection of barrows from LiDAR DTMs have already been proposed (De Boer et al., 2008; Riley, 2012). De Boer et al. (2008) based their method on the comparison of a digital model from an idealised barrow with LiDAR height data, whereas Riley (2012) proposes a two steps method that combines the calculation of slope and aspect from the elevation model in order to detect anomalies in terrain. The current paper presents a robust method that combines the application of morphometric and morphological classification of LiDAR DTMs for recognising the topography and the shape of barrows. Another interesting feature of our method is the use of High Performance Computing (HPC) for the processing and classifying of the large datasets that the method requires. Due to the nature of the methods applied in this paper it can be considered as a contribution to the application of a GEOBIA (Geo-Object-based Image Analysis) methodology (Blaschke, 2010) to archaeology.

We intend to improve our archaeological knowledge from an extensive area from Western Spain (Fig. 1), where geomorphological and land-use variations are accentuated. Thereby, any methodological design should be adaptable to provide outcomes in heterogeneous conditions. Since a high number of variables can influence the automatic recognition of barrows, an aim of the present work is to determine the success of the method by comparing predicted locations with the ones where archaeological sites has been already recorded.

2.1. Processing of LiDAR datasets and vegetation filtering

For the present paper, we used LiDAR datasets from PNOA (Spanish National Plan of Aerial Ortophotography). A LiDAR file offers high resolution observations of terrain, represented as a dense 3D point cloud (0.5 points per square meter). Although the datasets were supplied without classified points, they kept the information about the number of returns. The filtering of outliers and vegetation is crucial in our method, since many false positive identifications can be avoided. Several procedures have been published for filtering vegetation, some of them in the field of Archaeology (Doneus et al., 2008; Lasaponara and Masini, 2009). In order to filter the vegetation and to obtain a DTM of bare terrain, we used a Multiscale Curvature Classification (MCC) algorithm (Evans and Hudak, 2007) (Fig. 2) that classifies the LiDAR measurements into terrain and non-terrain points (Kraus and Pfeifer, 1998; Chase et al., 2011). The MCC algorithm was implemented in a HPC that decreased considerably the time invested in classifying non-terrain points. An estimated decreasing of 95% of time was achieved by splitting each file in 36 tiles, which were independently processed in a single node and later reunited in a file with the same geographic extent as the original one.

Additionally, it was necessary to remove the outliers in each file, which was achieved by fixing a threshold on the standard deviations of local heights. A piece of code was written for the automatic removal of these anomalous points. The terrain points were later interpolated by the splines method to provide accurate digital terrain models (DTM) of 1-m spatial resolution. More than 5000 tiles with a 2 × 2 km size were processed during several months of intensive work.

2.2. Detection and segmentation of areas of interest

As the objective of our methodology is to provide areas of interest, we seek to extract areas from interpolated DTM, rather than concrete pixel values, which is the objective of OBIA (Object-Based Image Analysis) methods and more specifically from GEOBIA (see Blaschke, 2010 for a broad discussion). The obtaining of areas of interest can be achieved through the segmentation of concrete regions from DTMs that might hold a semantic meaning for archaeologists, but this requires a previous classification of terrain proprieties and the determination of thresholds for classified datasets. The term “segmentation”, in the sense that is used in this text, comes from the domain of image processing, with diverse techniques for partitioning regions from the images into homogenous groups (Pal and Pal, 1993).

The proposed method for detecting the sites is based on a prototypical description of barrows that match the following conditions: 1) they can present a more or less eroded mound that usually rises from a meter to few meters in the terrain, 2) circular or slightly elliptical plans, and 3) a diameter that ranges from few meters to more than 30 m in exceptional cases. The basic outline of the method applied in the present work is depicted in Fig. 2 and can be summed up as follows: 1) morphometric classification of terrain, 2) segmentation and discrimination by morphological properties of objects, and 3) classification of circular shapes by means of the Hough Circle function (HCF). A descriptive and graphic workflow of points 1 and 2 can be consulted in Fig. 3.

All the methods here described were implemented on a HPC facility. The code was written in Python programming language, making use of several scientific libraries as Numpy and Scipy (Van de Walt et al., 2011), GDAL (GDAL, 2015) or scikit-image (Van der Walt et al., 2014). The DTMs were converted to matrices through GDAL bindings for Python. Each file was processed individually and the final results were merged into a single text file that held the absolute coordinates of each predicted location along its surface. A pipeline of the complete methodology can be consulted in Fig. 2.

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