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Combining terrestrial stereophotogrammetry, DGPS and GIS-based 3D voxel modelling in the volumetric recording of archaeological features

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ABSTRACT

Archaeological recording of structures and excavations in high mountain areas is greatly hindered by the scarce availability of both space, to transport material, and time. The Madriu-Perafita-Claror, InterAmbAr and PCR Mont Lozère high mountain projects have documented hundreds of archaeological structures and carried out many archaeological excavations. These projects required the development of a technique which could record both structures and the process of an archaeological excavation in a fast and reliable manner.

The combination of DGPS, close-range terrestrial stereophotogrammetry and voxel based GIS modelling offered a perfect solution since it helped in developing a strategy which would obtain all the required data on-site fast and with a high degree of precision. These data are treated off-site to obtain georeferenced orthoimages covering both the structures and the excavation process from which site and excavation plans can be created. The proposed workflow outputs also include digital surface models and volumetric models of the excavated areas from which topography and archaeological profiles were obtained by voxel-based GIS procedures. In this way, all the graphic recording required by standard archaeological practices was met.

1. Introduction

While aerial photogrammetry has a long tradition in its application to the recording and analysis of archaeological landscapes (Poidebard, 1939; Newcomb, 1971; Fant and Loy, 1972; Mattiseck, 1980 and, more recently, Reindel and Grün, 2006; Brenningmeyer and Begg, 2007; Orengo and Palet, 2010; Orengo et al., 2010), terrestrial photogrammetry has been mainly applied to the recording of standing buildings, or structures, or archaeological objects (Grün et al., 2004; Bryan, 2006; El-Hakim et al., 2008). Few examples of the application of terrestrial photogrammetry to the recording of archaeological excavations can be encountered (Whittlesey, 1966; Fant and Loy, 1972 and, more recently, Barceló and Vicente, 2004; Tschauner and Siveroni, 2007; Orengo, 2010).

This is chiefly due to the high investment required in both equipment and training the personnel for its application, which are not usually available in archaeological projects. Nonetheless, the appearance of new easy-to-use software and the significant decrease in price of both computing hardware and software and geomatics equipment has rendered these technologies more accessible and a ready increase in their archaeological application is expected during the next years. Not in vain, photogrammetric modelling has been regarded as the most complete, cheap, portable, flexible and widely used approach for the 3D reconstruction of heritage and archaeological features (Remondino and El-Hakim, 2006: p. 299).

The use of photogrammetrical techniques in high mountain archaeological projects such as the Madriu-Perafita-Claror, the InterAmbAr and PCR Mont Lozère projects was chosen in accordance with the limitations posed by the scarcity of time and resources available to record archaeological features and excavations. These international research projects were aimed at studying the long-term human-driven landscape changes of high mountain areas. In order to do so it was necessary to locate all human structures in the study areas and, subsequently, dig archaeological test pits within them so their typology and chronology could be assessed. Four-hundred and twenty-one archaeological structures were located during the Madriu-Perafita-Claror and 317 in the InterAmbAr field surveying campaigns. Fifty-seven test pits of 1×2 m were excavated in 55 different archaeological structures in the Madriu-Peraftia-Claror valley. The application of these techniques in the InterAmbAr and PCR Mont Lozère projects is still in progress.

Work on these high mountain areas was greatly hindered by their geographical setting which includes heights of between 2000 and 2600 m a.s.l. These areas are covered in snow for most

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of the year, being accessible only during the summer months. Since there were no roads which permitted access to these areas, the transport of personnel, material and food had to be done by helicopter. This circumstance hindered the development of long campaigns which had to be reduced to two 10 days-long campaigns per year (food preservation issues prevented longer stays). Besides, the teams had to be reduced in size and they usually comprised eight to ten archaeologists. Lack of electrical sources also posed a problem since the use of surveying and photogrammetric material was limited by the amount of batteries available.

Archaeological recording is today a standard procedure that requires much precision and care. It includes the recording of all materials recovered, usually carried out off-site, but also the drawing of site plans, archaeological strata plans and profiles. The later procedures involve a large amount of time which may easily equal the time required in the actual test-pit excavation.

It soon became evident that these standards could have not been achieved with the time and human resources available by employing traditional on-site drawing techniques.

2. Material and methods

Due to the scarce amount of time and resources available, and the extent of archaeological structures under investigation, a methodology that allowed for a fast and reliable recording of structures and test pit excavations needed to be developed. This methodology had to be able to produce both georeferenced plans of the structures and 3D data from which the test pit profiles could be derived.

The methodology followed integrated differential Global Positioning System (DGPS) measurements, terrestrial stereophotogrammetry and geographic information systems (GIS) based volumetric modelling. The workflow followed five stages (Fig. 1):

2.1. Ground control point (GCP) identification and DGPS measurement

This was carried out by marking and numbering with a pen marker the GCPs in the structures. Then the points were measured with a survey-grade Topcon HiperPro DGPS+ with a RTK base station. The data collector, a Topcon FC-100 incorporated the program Topcon TopSURV v. 6.04 which numbered each control point according to the numbers assigned to the GCP. This program allowed the exporting of georeferenced files which could be loaded directly into commercial GIS and photogrammetrical packages. Apart from the projected *XYZ* coordinates, the files incorporated attributes such as structure number and GCP number which greatly facilitated data classification. The use of a Global Navigation Satellite System GNSS receiver was preferred due to its ability to record the GCPs in a much faster fashion than total station system without significantly losing the spatial accuracy necessary to conduct subsequent photogrammetrical analysis. It also provided georeferenced measurements avoiding thus further georeferencing work. The projected coordinate systems employed were, in the case of the Madriu-Perafita-Claror and InterAmbAr projects, European Datum 1950, UTM 31 N and, in the case of PCR Mont Lozère, Lambert Conformal Conic, France II.

2.2. Acquisition of photographic stereo pairs

The camera employed to obtain the structures and test pit images was a consumer-grade Canon PowerShot Pro 1 digital compact camera. The inner camera geometry was previously calibrated in a laboratory environment using Topcon Camera Calibration Software v. 2.10. The Canon PowerShot Pro 1 presented a series of advantages. Its small size and resilience made it especially useful for fieldwork. It also presents semi-professional Canon 'L series' optics and an 8 mega-pixels objective which permitted the

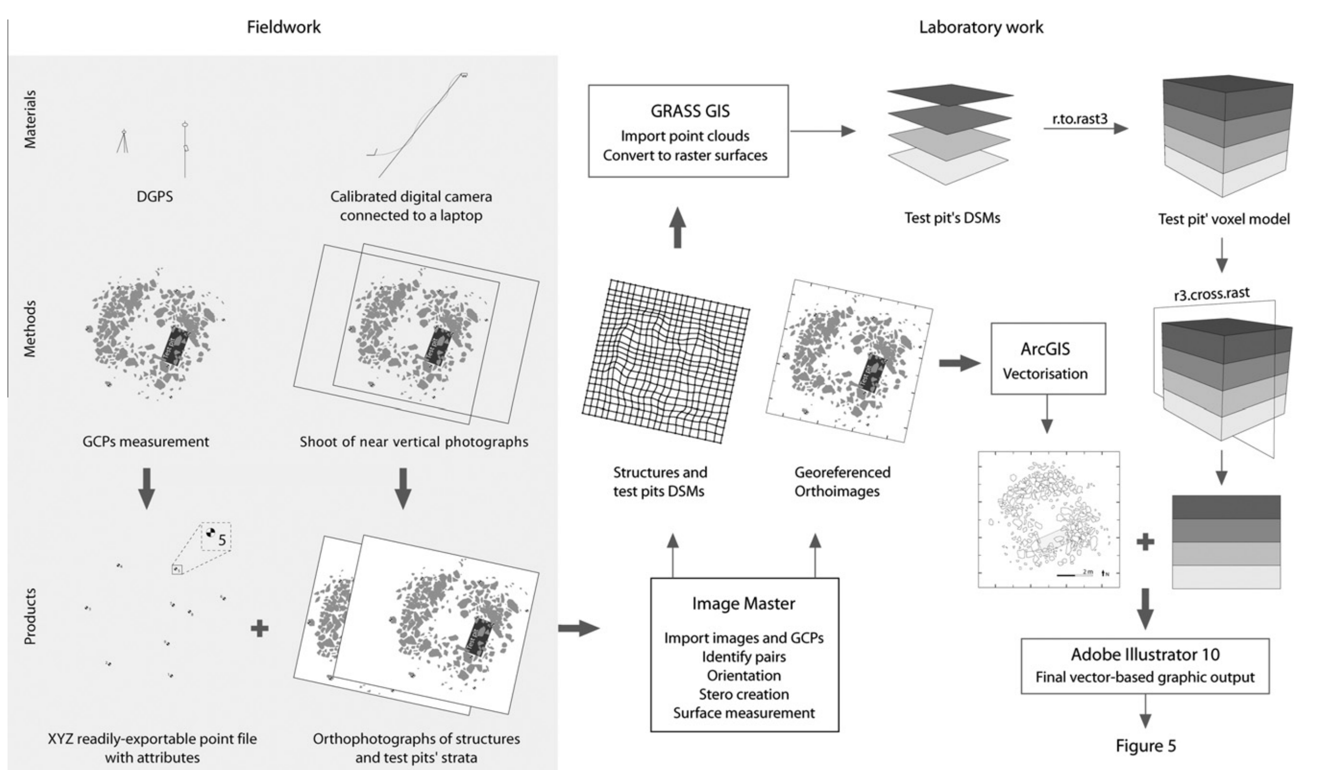

Fig. 1. Graphical scheme of the workflow.