For a Digital Repository of Rock Art in Portugal

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ABSTRACT

The international community is nowadays trying to foster multidisciplinary research efforts to the implementation of digital libraries to render accessible repositories of human knowledge.
One of the main objectives concerns the creation and preservation of data banks of cultural heritage, providing tools for a correct retrieval of information and presentation, and making it accessible to both science and the general public.
These were in fact the guiding principles that lead the Portuguese Institute of Archaeology (IPA) and the National Center for Rock Art (CNART), together with the National Institute of Engineering, Technology and Innovation (INETI) to join efforts in order to develop a technological process to produce 3D models of rock art in Côa Valley, containing a fantastic repository of Palaeolithic art, an huge amount of information and knowledge of that period of world history, discovered in the north of Portugal in the last years of the 20th century.
This paper presents the framework assumed for the completion of this goal, stressing the effort to cover the several facets of this task, starting from the process 3D image acquisition using a laser scanner on site, the 3D image processing required to obtain the complete models, the production of replicas in several materials, and providing the tools to retrieve specific information of particular features of the Côa engravings.
Several new features are made available with this work, namely a contactless dimensional analysis of the engravings, their profiles and the possibility of correlating that information with the type of tools used to produce those engravings since c. 25000 years ago, allowing that such incredible testimony could reach us to tell their story.
The developed process is non-contact, accurate, has the required resolution for the majority of the engravings, and is user friendly, based on portable equipment.
By these means, we expect to give a strong contribution for the complete capture and storage of those models and to fill in the database that can lead to a true repository of Palaeolithic and pos-palaeolithic rock art in Portugal.

INTRODUCTION

This paper describes supported by the work done to the Portuguese Institute of Archaeology (IPA), the National Center for Rock Art (CNART) by the Optoelectronics Department of INETI, concerning the activities associated with the execution of project 3DCôa, that addressed the acquisition of 3D image of a set of Palaeolithic rock art engravings found in the Côa Valley since 1992 (ZILHÃO, J., 1998).
For Archaeologists, the new method described in this paper, allows the capture and recording of rock art engravings, and may be the new tool which will overcome limitations of traditional methods, usually tracing techniques, used until now to record the relevant information.
These activities are also inline with major current research developments and achievements regarding the constitution of digital repositories of significant cultural materials, and are undoubtedly triggered by the most recent technological findings in digital imagery, digital storage and tools for cultural diffusion.
Furthermore, techniques used allowed the production of rigorous numerical models, which lead to a complete new set of possibilities, namely, study of erosion effects, cracking and conservation of substrates, production of 3D models for easy cultural diffusion and, finally, the production of scale replicas using different materials and techniques.

1. THE EQUIPMENT

The equipment used to perform all the image acquisition process was quite reduced and portable, taking into account that there was the need to travel to locations where limited resources were available. The equipment used for the image acquisition was a laser triangulation system, mounted on a tripod (or other lightweight structure to hold the scanning head), a portable PC and few tools.
Cultural heritage objects, such the ones retrieved in the Côa Valley, present quite often a profusion of details and features, along with significant areas, lead to stringent spatial resolution requirements. These circumstances lead typically to large amounts of data and to critical processing tasks. Furthermore, the specific nature of the objects and their location, imply the use of practical and portable equipment with critical specifications, compliant with such requirements.
These constraints, lead us to a portable laser triangulation system, using a laser scanning head, mounted on a rotary stage and light enough to be operated on a tripod.

This scanner is being updated over the years, both in hardware (sensor) as with respect to the software control, having a resolution better than 70 micron in every direction and a maximum field of view of 50 cm by 30 cm.
We have to note that this method has important limitations, because the resolution of the measurements is inversely proportional to the depth of field and to the distance to the object plane. This technique is very sensitive to image contrast and brightness, which is easily degraded when imaging natural objects in natural conditions.
To overcome these problems we used, in addition to the traditional laser triangulation approach, a sensor head that implements in parallel the defocusing technique to perform more accurate measurements (BERALDIN, J. A., 1995).

2. METHODOLOGY

2.1 LOCAL LASER SCANNING

Among dozens of image clusters found scattered along the riverside of the Côa, the archaeologists of CNART (the Portuguese Centre for Rock Art) choose a set of 15 images of different sites, as the most representative of this cultural legacy, to be a test set for this project (CABRITA FREITAS, J., *et al.*, 2004).
The constraints identified lead to the choice for an image scanner – based on laser triangulation techniques – to produce numerical models with a final resolution of 2/10 of a millimetre, capturing small individual mosaics with the required precision and then merging them in a single view covering the complete engraving. We must add at this point that, due to the profusion of markings on a rock, sometimes made at different periods over the ages, each figure typically covered an area of more than a square meter.
With these particular image characteristics, it is only possible to cover small parts of each engraving. To capture the whole image we have to scan sequences of images according to particular rules, building up a matrix of small mosaics that once merged, using a pre-defined overlap strip, allow the reconstruction of the whole image.

2.2 POST-PROCESSING

Having completed the image acquisition task, the raw data had to be processed on specific platforms, in order to remove all the image defects (missed data due to the shadowing effect, occlusions and the absence of laser reflection) and merge all the individual images into a complete 3D model.
From the resulting 3D models, it was then possible to produce data files, of a convenient size, which can be processed and viewed on any platform, for scientific, cultural diffusion or other purposes.
The production of the final 3D model is done after a complex process of post-processing of the information acquired in the field. Since it is not possible to use physical references, over the rocks, all the merging process, done at a later phase, is based only on particular details on the rock substrate. These references are crucial during the merge process for the correct matching of the overlapping areas. The software uses the range information and complex algorithms to overcome image distortion and the different standoff distances used during the acquisition phase.
Due to the nature of the rocks, there are very different conditions of light diffusion, either induced by the surface texture, colour, presence of fungus or lichens, or even dust or inclusions of different materials at the surface of the rocks. These conditions are in many circumstances responsible for the lack of information in areas with different characteristics, due to poor reflection characteristics.
To correct the image "defects" that occurred during the acquisition process, it is possible to rescan only particular areas of the entire rocks are and merge them again with the complete model. It is also possible to fill missing data over the image using interpolation techniques.

2.3 REPLICATION

The production of exact replicas of these ancient rock art engravings has to take into account the typical details on the surface, which are in the sub-millimetric range. This dimensional scale is possible to obtain with direct moulding techniques over the rock surface, but the degradation induced by chemical activity proved to be critical for the rock surfaces.
To overcome this circumstances and as a tool for the diffusion of the results obtained, replicas were produced by rapid prototyping techniques, namely, direct laser sintering of powders originating metal substrates, stereo lithography by means of UV laser processing of photopolymers and, Laminated Object Manufacturing (LOM), using lasers to cut very thin layers or films that, when superimposed, define the whole panel (ESPERTO, L., *et al.*, 2004).
To some extent, these techniques impose also the same type of limitations due to the overall size of the replica that is possible to obtain. Because of that, the solution was similar: – the combination of small parcels to reconstruct the whole.

2.4 CASE STUDY: A FEATURE EXTRACTION EXAMPLE

As an example of the flexibility of this tool for the analysis of this kind of cultural object, bringing a virtual model to the lab, besides making it accessible to everyone, it is now possible to analyse specific features of the image, in an easy way, non available with traditional methods.
The example we bring here is the analysis of the profile of particular details that form the figures.
Archaeologists may possibly use this kind of analysis to characterize the tool that was used as well as an indication to the dating process.
The engraving techniques used in the set of rocks covered by this work seem to have been essentially four (with variants): fine line incision, pecking, abrasion and scraping. It is also possible to find the combination of several of these techniques in the execution of a single figure. Sometimes, these different engravings were made at different periods.
In Fig. 1 we can see a profile associated with a section, obtained from the intersection of a plane, perpendicular to surface, with the rock crossing an engraved line.
In Fig. 2 we can see the lines used for the placement of the reference planes, intercepting the surface, which will determine the longitudinal cross sections along a detail as shown in Fig. 3. The software tool allows the measurement of the relative displacements between the two lines along the profile, showing the depth variation.

2.5 DATA BASE

For each and every one of the scanned rocks a set of information was aggregated so that everything from raw data to the final 3D model, together with descriptions and notes may be used in an easy way.
Despite the, so far, limited number of images that was possible to digitize, due to limited financial support, we have initiated what we think to be an important first step that can lead to a true representative digital repository of rock art in Portugal.

3. RESULTS/FUTURE WORK

The results obtained so far proved to be in accordance with the main objectives defined in the 3D Côa project, as defined by IPA – The Portuguese Institute for Archaeology.
The achievable resolution needed to scan incised engravings with details of the order of magnitude of 1 micron, which is virtually impossible to achieve in the field, in adverse and poorly controlled environmental conditions and to overcome that important limitation we foresee as future work, at the cost of increased processing power, the use of the full capacities of the laser scanner using smaller steps and increased values for the number of points per unit of area acquired during scanning.
We believe that we achieved a good trade-off in the set of results obtained so far. The major trend at this stage is indeed the possibility to implement the techniques, already established under 3DCôa project, and to use them extensively in field campaigns, to scan, digitize and pos-process, at least the more representative examples, in different regions and at different ages, in order to fill in the database and leading to a true digital repository of rock art in Portugal.

REFERENCES

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FIGURES

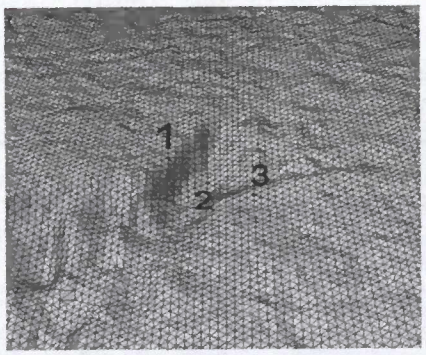
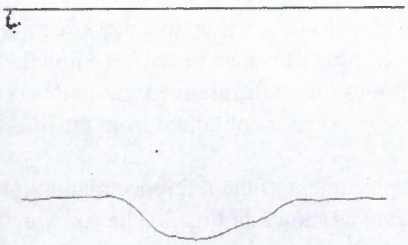
ROCK 1 – CANADA do INFERNO: Measurements				
Engraving	Cross Section	Angle	Width	Type of Engraving
		120°	3.84 mm	Incised

Figure 1

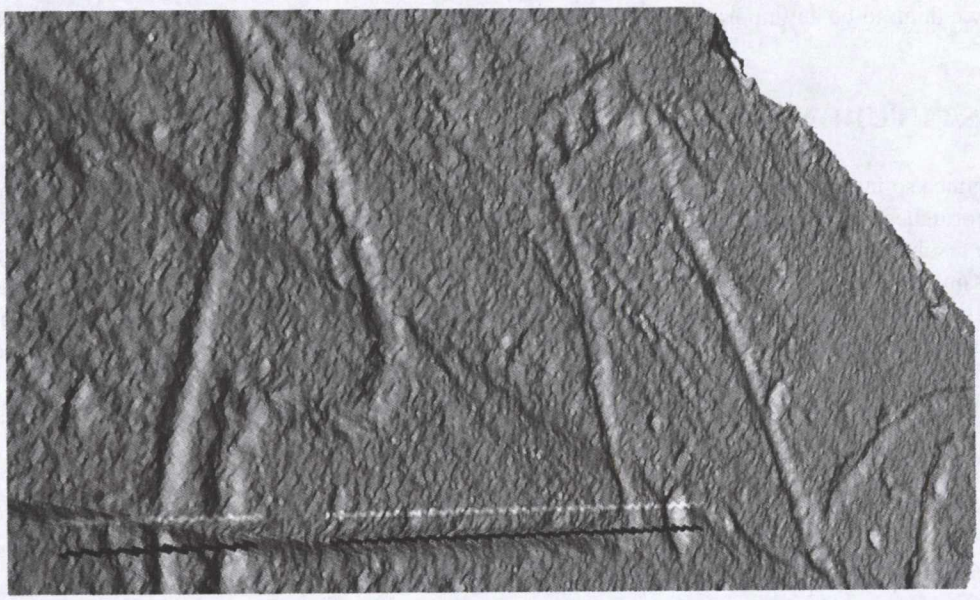


Figure 2

Figure 3