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# Evaluating conventional and advanced visible image enhancement solutions to produce digital tracings at el Carche rock art shelter

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ABSTRACT

Advances in rock art recording techniques through non-destructive methods are a priority in rock art research. Developments on computer science, digital photography and more specifically on digital image enhancement have revolutionized the way rock art motifs are recorded and documented today. Conventional software for digital image processing is widely used to produce digital tracings, with reasonable results so far. But this manual process is still time consuming, especially when motifs are either faded, deteriorated or part of complex superimpositions. This paper explores the potential of two advanced digital image enhancement decorrelation techniques, principal components analysis (PCA) and decorrelation stretch (DS) to facilitate and accelerate motif recognition on visible digital images, as a first step in the rock art recording process. Statistical analysis revealed that the performance of PCA is slightly better (5%) than DS, when compared to the results of conventional image enhancement solutions.



## 1. Introduction

Rock art is considered a fragile cultural heritage dating back at least 40000 years (Pike et al., 2012; Aubert et al., 2014). It is produced on active rock surfaces (affected by running water, surface exfoliation, etc.), which are constantly exposed to different natural and human altering agents gradually threatening and degrading the art. Levantine rock art in particular is located in open-air sites directly exposing the art to harmful environmental influences. These include constant climate changes (temperature, moisture), exposure to direct sunlight, physicochemical weathering and erosion of the rock surface, biodeterioration, and so forth. Thus, rock art recording is necessary for the long-term preservation of this threatened and unique visual sample of our past.

Rock art recording methods are constantly implemented to meet the different requirements that have emerged over more than a century as the discipline progressed. Alongside its role as a tool to either publicize new findings or study rock art, today rock art recording methods are also used for both monitoring degradation processes and disseminating the art to different audiences through different channels. Traditional direct recording methods may have some sort of impact on both the art and the rock surface, and thus they have been gradually replaced by other non-invasive techniques. A brief overview of some of these methods can be seen at Fritz and Tosello (2007) and Domingo (2014). In the last few decades, computer science has offered professional rock art recorders and archaeologists a wide range of software packages for editing and processing digital photographs to produce digital reproductions or "tracings", thus replacing traditional manual methods. These computer image techniques aim to: (1) minimize the impact of rock art recording processes on rock art preservation; (2) search for more objective and accurate analysis, both for motif recognition and for the metric reproduction of motifs and the rock surface; and (3) accelerate the rock art recording process. Furthermore, computer enhancement methods allow researchers the opportunity to record, examine and present heavily deteriorated images that would have been missed (undetected) using conventional techniques (David et al., 2001; David, 2004; Brady, 2006, 2007).

Digital image and colour space enhancement (Mark and Billo, 2002) fall within the category of conventional computer image enhancement techniques. Today a large number of researchers are using photo editing techniques to produce digital tracings of both rock art paintings and engravings (Vicent et al., 1996; Montero et al., 1998; Cacho and Gálvez, 1999; Villaverde et al., 2000; Clog et al., 2000; Domingo and López-Montalvo, 2002; López-Montalvo and

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Domingo, 2005, 2010; Brady, 2006, 2007; Rüther, 2007; Martínez-Bea, 2009; Cassen and Robin, 2010; Ortiz et al., 2010; Domingo et al., 2013a). We all work towards a common aim: to provide accurate working documents including interpretative readings of all the motifs, preserving its scale, regardless of their degree of preservation, visibility or spectacularity. Furthermore, graphic recording also seeks to show visually the relationships among motifs (whether they are isolated or included in some sort of scenic or non-scenic compositions, as well as interpretative readings of superimpositions and the possible relations with the rock surface). These visual reproductions usually show the conditions of the art at a specific point in time, although in the last few years there is an increasing interest in displaying 4D reproductions showing the site over time.

Today tracings for each motif are generally produced using visible light images taken in situ, which are then processed with digital image processing software. To record rock paintings, colour selection tools are usually used to select and separate pigments from the rock surface. This technique is quite easy to use but, when motifs are quite faded or complex, it could be time consuming. Moreover, the results depend heavily on our visual perception, on our capacity to identify faded paintings, on our experience in the study of rock art and on our familiarity in the use of digital image processing software.

Besides, many digital image processing techniques can be found in literature, such as classification algorithms, filtering, data decorrelation, spectral profile analysis and index elaboration. These are non-invasive techniques, more objective, since they are automatized, and they can be used to enhance paintings that cannot be easily distinguished. There are many publications dealing with these techniques. To name some, Lerma (2002) applies supervised classification to rock art panels using three visible spectral bands and one near infrared. Rogerio-Candelera et al. (2011) tests the value of PCA. Mark and Billo (2002) apply DS to enhance rock art paintings. Harman (2005)'s modification and implementation of decorrelation stretch technique in the Dstretch plugin to the imaging program ImageJ has allowed the widespread use of DS to identify faint rock art painted motifs or even to discriminate superimposed paintings (Gunn et al., 2010). The use of decorrelation image analyses based on advanced computer image enhancement before tracing the art can contribute to automatize the initial part of the process, facilitating motif identification and accelerating the process in most cases (Díaz-Andreu et al., 2006; Rogerio-Candelera et al., 2011).

This paper focuses on the use of image colour decorrelation techniques and compares the results with those obtained with conventional software tools for digital enhancement, editing and colour selection (specifically the tools available in Adobe Photoshop). The decorrelation of digital colour image levels is applied following both techniques, PCA and DS. PCA and DS can both be used to transform the image content onto new non-correlated bands based on its variance. False colour spectral bands are created to better visualise rock art motifs. The resulting documents are then used to produce digital drawings or tracings for each of the identified motifs. To test the strength of both methods two relevant motifs involved in complex superimpositions have been selected. The results achieved with PCA and DS, and the corresponding tracing solutions are compared with conventional digital deliverables produced by rock art specialists.

## 2. Materials and methods

Visible imaging sensors such as digital colour cameras are devices able to acquire the reflected radiation coming from a scene (composed of multiples objects) onto solid state sensors that typically incorporate filters that block the incoming electromagnetic radiation in three spectral bands: Red (R), Green (G) and Blue (B). As the three visible spectral bands (RGB) are most of the times highly correlated, the application of decorrelations algorithms allow users to either reduce or remove any correlation between spectral bands. Therefore, the information content on the visible image is optimised and can be used to highlight differences between spectral bands.

The decorrelation analysis on rock art motifs after digital colour image acquisition follows. In particular, PCA and DS are presented, tested and analysed. PCA is a multivariate analysis technique that allows the reassignation of digital number (DN) values from different spectral bands in a new non-correlated reference system. Each new component decreases the variance in each band. The last components can be used to detect invisible features and their plotting. These components contain the non-correlated residual information (Rogerio-Candelera et al., 2011).

DS technique is a PCA variant that sometimes improves the multispectral analysis and provides more information. This technique transforms the initial colour values following the Karhumen–Loève theorem. A PCA is performed on the three spectral bands, afterwards, the variance values are normalised and a Gaussian contrast enhancement is undertaken on each component. Finally, the three principal modified components are combined. The primary purpose of DS is visual enhancement. Decorrelation stretching is a way to enhance colour differences in a multispectral image. The result is an image with higher colour contrast, highlighting complex details.

There are many software package solutions in the market to undertake fully automatic spectral and/or multispectral image analysis based on PCA and DS. Just to name a few, DStretch plugin to ImageJ; Hypercube and Multispec, in the category of open source; and ENVI and ERDAS Imagine in the category of commercial software packages for image processing and geospatial analysis. Nevertheless, the final deliverables (tracings or drawings) with the painted rock art motifs are not achieved yet without human intervention due to the complexity to determine the true motif. The workflow followed in this paper is presented in Fig. 1. The starting point is always the visible (RGB) image acquired on site, normally with a digital camera.

### 2.1. Case study: Carche rock shelter

Carche rock art site, also known as Poveda or Fuente del Candil rock shelter, is located in the eastern part of Spain, and more specifically in Jalance (Valencia) (Fig. 2). The son of a local historian discovered the site by chance in 1997, when walking through those lands (Poveda, 2001: 30–31). The site is located in the Murell seasonal stream, at an altitude of 446 m over the sea level. The shelter faces southeast and measures 7.29 m long and 4.43 m high (for further details see Domingo et al., 2013b). The site includes painted motifs corresponding to two different post-Palaeolithic rock art traditions: Levantine rock art and Schematic rock art. Both traditions are listed in the Spanish National Heritage list as *Bien de Interés Cultural* since 1985, and were also included in the UNESCO World Heritage list in 1998.

Interestingly Carche rock art site includes a significant number of complex superimpositions, which are key to figure out rock art sequences between different traditions (Levantine and Schematic arts) and within each of them.

During the recording process with conventional methods (i.e. modification of hue, brightness and contrast, and the subsequent use of colour selection tools to produce digital drawings or tracings for each motif), we experienced some problems that turned this site into the perfect case study to test image enhancement techniques:

- First, it was difficult to visualize highly eroded motifs and to define their limits, especially since most of them are included in complex superimpositions.