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The detection of petroglyphs through digital image processing. The particular case of the stone inside the chapel of Saint Bartolomé (Lugo-Spain)

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Abstract

Purpose:

This study explains the process of identifying a petroglyph detected in a rock for its subsequent analysis. As the petroglyph is practically invisible to the naked eye, photography and digital image processing is used to make its study possible.

Method:

Several bands generated from digital photographs captured in the region of the spectrum of the visible and NIR permit the digital analysis of the information as in remote sensing: the application of diverse algorithms, true colour composites, false colour NIR composites, filters and enhancements.

Result:

The best results obtained correspond with the true colour composite image filtered with a Gaussian filter 3x3 and enhanced with an adaptive enhancement. The inverse image also provides useful information for the analysis of the petroglyph. The highlighted features of the stone are, finally, digitalized.

Discussion & Conclusion:

The processing applied, allows emphasize the existence of a petroglyph. NIR image analysed has not contributed to provide notable information to the possible existence of rests of paintings or micro-vegetation.

1 Introduction

Petroglyphs are engraved features where rock has been scraped or pecked away in a subtractive process [1]. Some petroglyphs have deep cultural and religious significance extending over long periods of time.

1.1 Traditional techniques of identification

Archaeology has traditionally used three methods to document rock art graphically: freehand drawing, rock rubbing and photography [2].

One of the most common techniques involves taking an impression by means of tracing paper (fig. 1). To do this, it is necessary to superimpose the paper on the stone in question and rub it with a pencil or charcoal. In this way, it is possible to observe, quite precisely, the characteristics of the figure that forms the petroglyph. The edges that stand out from the stone, are those that are outlined by the tracing paper [3]. A problem with this method is that it can damage the stone when brushing it in such a way [4].

1.2 Current techniques of identification

Recent studies show great potential for recording rock art [5] and current simple low-cost photogrammetric techniques to obtain 3D models demonstrate their potential for the study of petroglyphs [6, 7]. These techniques do not have any of the limitations associated with previous ones, which were limited in accuracy or were too time consuming.

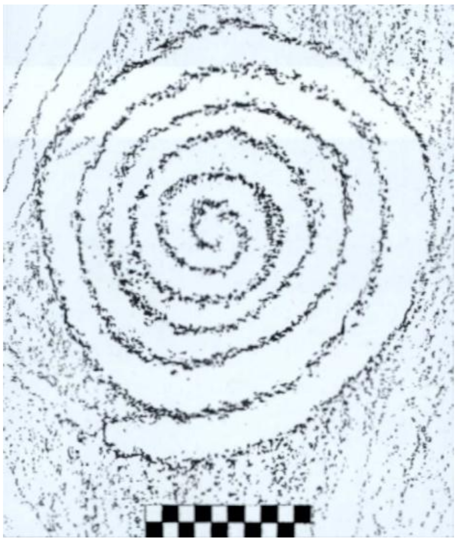

Fig. 1 Rock rubbing. Published in [18, fig. 85]

Digital image processing is proposed for the recording of rock art [8]. The application of non-contact recording techniques to an elusive rock art motif is defined as a ground-based remote sensing survey [5]. Various survey analysis and interpretation techniques applied to archaeology are described in [9] and such techniques have been applied to detect carvings on the stones of the famous Stonehenge megalithic monument. Likewise, the possibility of visualising subtle, dissimilar behaviour of materials in near infrared (NIR) helps archaeologists to depict certain object features less apparent to the human eye. NIR imaging in archaeology has been used in the investigation and deciphering of documents, inspection of paintings, pottery study and aerial photography. NIR reflectance of particular pigments, dyes and materials, assists in their identification and analysis [10].

1.3 Objectives

The present work is part of a study of rock art identified in the interior of the chapel of Saint Bartolomé do Burgo in Lugo (Spain) during its restoration (fig. 2). The study involves the 3D virtualisation of the stone and the digital treatment of the captured images, the latter digital treatment being the subject of the present work in an effort to make clearer the engraving in the petroglyph under study.

Fig. 2 Identification of rock art by the arqueological team prior to restoration

1.4 The location of the rock art

The rock art decorates a stone (part of the original structure of the building) which is inside the chapel. This site is visited by thousands of pilgrims every year as it is located on the Camino of Santiago. The location on which the chapel was built included a rocky site formation which was considered sacred by the pilgrims on the route.

2 Method

Techniques and algorithms available in commercial processing software are used for the digital analysis of the identified petroglyph to make its study possible.

2.1 Material and Data

A digital Canon EOS 400D camera of 10 megapixels with a Canon EF 20 mm f/2,8 USM objective was used to take the photographs. It has a fixed focal length that is ultra angular. The infrared light filter used is the B+W 58 093 IR-Filter which is commonly known as infrared black. It only allows luminous energy to pass within the range of the infrared electromagnetic spectrum. A conventional tripod is used to support the camera.

2.1.1 The photography

Two photographs are obtained, one in true colour and the other in NIR.

Prior to the capture of the images, the dimensions of the stone are approximately measured so that its centre coincides with the optic axis of the camera when the photographs are taken. The camera distance is such that the entire stone image fits within the photograph. This is achieved with the camera focused to infinity and assures the exact centering of the image. It also allows for the maximization of the area to be photographed and in the best possible conditions (fig. 3).

Fig. 3 Taking the images of the possible petroglyph

In addition to using the aforementioned tools and methods to achieve the infrared photograph, the infrared filter is added to the objective of the camera. Given the special characteristics in the interior of the chapel (limited illumination and cloudy conditions whilst taking the photographs) the exposure time of the camera together with the sensitivity of the sensor was increased to maximum. An hour long exposure time was required to take this photograph.

As can be noted in fig. 3, the stone is surrounded by some diana plates used in the photogrammetric process. These plates are used in the present study to correct the images.

2.1.2 The obtaining of the four multispectral channels

Adobe Photoshop CS3 Extended software was used to separate the three channels of the visible spectrum image in the true colour image. This program allows each generated channel to be passed to a grey scale [11].

2.2 Digital processing of the images

PCI Geomatics software [12, 13] is used for the application of all digital treatment which is described subsequently. The objective of the selected digital treatment is to highlight the spatial characteristics and lines of the image [14].

2.2.1 Preprocessing

The NIR image has to be treated previously before introducing it into the same file as that of the visible image given the presence of noise which fundamentally exists as a result of lost pixels (they appear in white in the image). The application of the average low-pass filter with a filter size of 3x3 allows us to resolve this problem. Following this, a Gaussian high-pass filter with a filter size 3x3 is employed to achieve greater clarity of the data.

2.2.2 Correction and image adjustment

The correction performed has been limited to achieving the precise superposition and adjustment between the true colour image and that obtained with the infrared filter. For this purpose, the coordinates obtained from the colour image are considered correct while the infrared image is modified in relation to it.

A polynomial math model of first order, is used [15] and coordinates and control points are pixel type. The true colour image is used to capture the control points identifying the same points in both photos: the corrected photo (true colour) and the one to be corrected (the NIR). The control points are distributed uniformly throughout the image and special attention is paid to the zone of the study of greater interest where the points have greater density. A RMSE (root mean square error) 1.72 pixels in X and 1.41 pixels in Y are obtained. It has not been possible to use rational functions employing a digital elevation model given that the software requires choosing the cartographic projection for this.

It should be pointed out that given the horizontal camera axis when taking the photo and the flat surface of the rock, a product assimilating the properties of a document with metric quality can be obtained. This is proven on comparing the dimensions of the stone measured on the software with those obtained physically.

2.2.3 Colour composites

Once we have oriented the NIR with respect to visible channels, we proceed to performing colour composites. The correspondence of the channel number with the layers in our multispectral image is as follows: blue, green, red, NIR, with channels 1, 2, 3, and 4 respectively.

The image is achieved in true colour by applying the colour canons R (Red), G (Green) and B (Blue) to the spectrum channels with which they correspond, that is 3, 2, and 1 respectively.

A common colour composite in remote sensing is the so-called colour infrared (4, 3, 2) which applies the R, G and B colour canons to the NIR, Red and Green Channels. This false colour composite allows us to detect possible traces of vegetation or pigmentation.

2.2.4 IHS algorithm

The IHS algorithm (Intensity, Hue, Saturation) is used to separate spectral from spatial information in the image. The spatial information will be registered in the Intensity channel.

The algorithm used to convert RGB to IHS values uses the single-hexcone colour model obtained from [16, 17].

2.2.5 The filtering of the images

The predefined filters of Geomatic software that best highlight the photographic zones, where we expect to identify rock art, are applied to the image in true colour and the generated intensity channel. In addition, custom filters are tested.

2.2.6 Enhancements

Provided enhancements in the Geomatic software are tested on images in order to better improve the contrast.

2.2.7 Inverse image

Various algorithms have been checked for their effectiveness in highlighting the relief of the stone object in question. One of the most appropriate is IMAGEINV (Arithmetic Inverse of Raster Data) which finds the inverse of the image by multiplying each pixel of the matrix which forms the photograph by 1/DN, the DN (Digital number) being the numeric value associated with each pixel. In this way, a new image is created which is the inverse of the original in which the dark elements appear as clear and vice versa (fig. 4). This allows the engravings in the stone to be highlighted and thus the observation of the possible petroglyph.

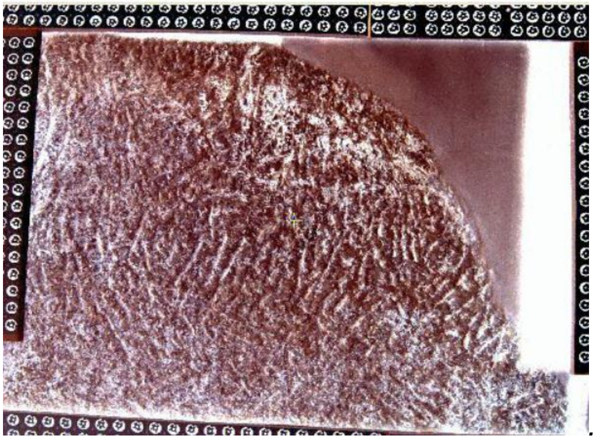

Fig. 4 The inverse image with Adaptive enhance outlines the relieve of the stone

2.2.8 Negative Image

Another useful algorithm for the analysis of the image is IMAGENEG (Arithmetic Negation of Raster Data).This module multiplies the raster information by -1 thereby producing an arithmetic negation of the raster data. On multiplying each DN of each pixel in the photograph by -1 the new image presents sign values that are different from the original photograph.

3 Results

The digital processing, that has proved to be more useful in relation to the objectives of this work, is described in the following sections.

3.1 Colour composites

The true colour image is one of the most useful images at the outset for further digital treatment. The NIR channel does not provide different data with that obtained from the three visible channels. This indicates that traces of micro-vegetation or artificial pigments that could have passed unnoticed within the visible range of the spectrum are unobserved.

3.2 IHS algorithm

The Intensity channel is, of the three IHS artificial channels, the one that most highlights the line features of the image (fig.5). We can appreciate the relief of the stone reasonably well with this channel; the features appear sharply and the appearance is ideal for this analysis. This channel, as a result, and in addition to the true colour image will be used to test the various digital treatments.

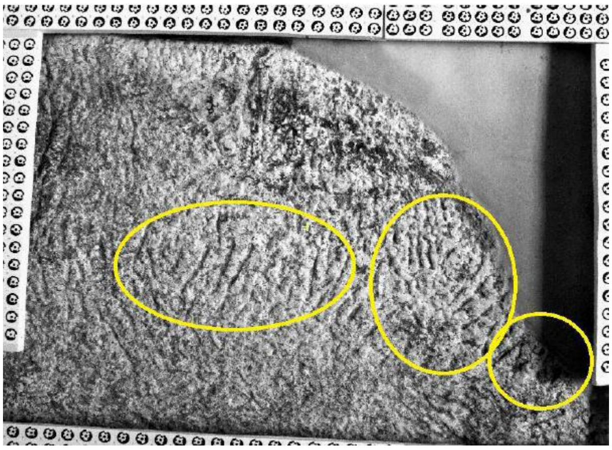

Fig. 5 Interest areas on the intensity channel

3.3 Filters

The filtered images improve the visualisation of the features of the stone and those which provide the best results are:

- Gaussian filter 3x3,
- Average filter 3x3,
- Edge Sharpening filter 9x9 and 11x11,
- Custom filter.

The custom filter which provided the best results is as indicated as follows with its corresponding kernel elements.

0	0.5	0.1
0	1	0
0.1	0.5	0

This is a high pass spatial filter which emphasizes edges and therefore sharpens the image.

Although the Edge Sharpening Filter highlights the relief detail, it is the Gaussian, Average and custom filters that provide improved visualisation. They are quite similar and the use of one or another depends on the channel or image used as the source filter.

As such, the best results are obtained by applying the corresponding images to true colour and the intensity channel of the Gaussian filter 3x3 or the Edge Sharpening Filter 11x11.

3.4 Enhancements

The enhancement, which best contrasts the characteristics of the stone, is the Adaptive one and is therefore applied to the selected filtered images.

3.5 Other algorithms

Of the two algorithms selected for their effectiveness for this analysis, IMAGEINV (fig. 4) is the one that allows us to see the features of the stone with the best clarity: we see them in inverse form, that is, the grooves in the stone are perceived as elevated areas, while the raised areas are perceived as grooves. This is particularly useful given that when we have doubts about relief in areas in the true image we can compare it with this image to contrast information.

3.6 Selection of the image for its digitalization

The image that has been selected as the most appropriate for the work of archaeologists is the actual colour image that has the Gaussian filter 3x3 applied with an Adaptive Enhancement (fig. 6). This image can, in addition, be used with the inverse image to complement the analysis of rock art. Fig. 7 shows a simplified diagram of the steps followed to achieve the final results.

Fig. 6 The petroglyph Gaussian filter 3x3 and Adaptive enhance applied to the actual true colour image

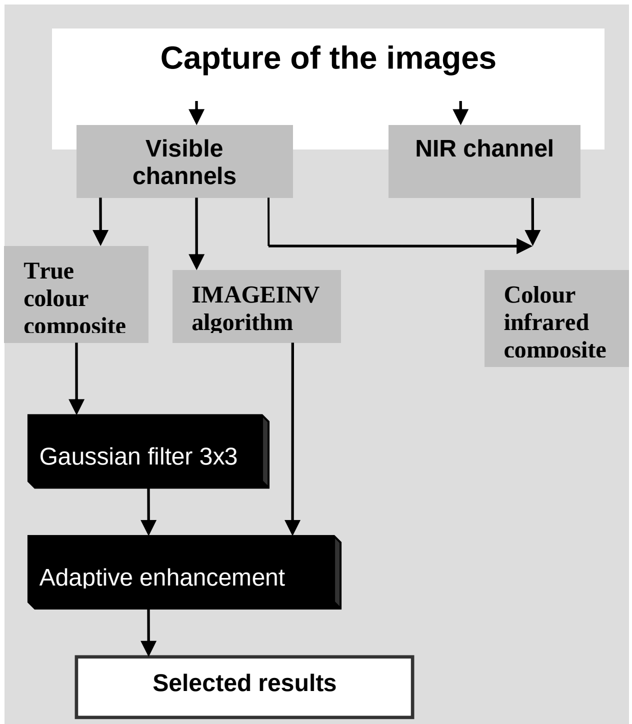

Fig. 7 Data processing workflow

Figure 8 presents an example of where the motifs have been digitalized and highlighted through the digital treatment described.

Fig. 8 Example of a digitalization of an identified figure

4 Conclusion

The work carried out in this project has contributed to and facilitated the identification of the petroglyph.

The restoration and cleaning work in the chapel has eliminated all traces of micro-vegetation and pigment on the stone which could have been analysed in the present study.

The digital treatment employed: Gaussian 3x3 filtering, adaptive enhancement and inverse imaging has highlighted and verified the existence of a petroglyph represented on the stone subject of this study. Ground-based remote sensing has proved itself to be an effective tool for petroglyph detection.

The principal limitation of the software is that, having been designed for satellite imaging, it does not allow orthocorrection of terrestrial images therefore other software is required for this purpose.

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