DOCUMENTATION AND RECOVERY OF RUPESTRIAN PAINTINGS: AN AUTOMATIC APPROACH

José Luis Lerma

Departamento de Ingeniería Cartográfica, Geodesia y Fotogrametría, Universidad Politécnica de Valencia
Cº de Vera, s/n. 46071 Valencia, Spain
Phone: ++34-963877550, Email: jllerma@cgf.upv.es

KEY WORDS: archaeological photogrammetry, spectral classification, multiband classification, rock art.

ABSTRACT

This paper describes an automatic approach in archaeological photogrammetry for the documentation and recovery of rupestrian paintings. Visible and near-infrared images were taken from an opened-cave before and after moistening the stone wall. Digital image processing techniques, specially multispectral and multiband classifications, were used to recognise and extract non-destructively the primitive paintings and shapes, i.e. arrows, hunters and animals.

Images of rupestrian paintings are presented, before and after human restoration. Additionally, thematic plots of work art obtained semi-automatically and independently before the cave restoration are shown in order to check the profitability of the methodology; statistical accuracies are also presented. Furthermore, some guidelines for future documentation and recovering of rupestrian paintings are pointed out.

1 INTRODUCTION

Rupestrian paintings are a valuable legacy that should be well known and safeguarded for future generations. Each set of rock paintings has a universal relevance as exceptional cultural expression, and they constitute an important part of the whole rock art.

Particularly, levantine rupestrian cave paintings keep certain features: high fragility and vulnerability; inner and outer beauty (the former refers to the paintings themselves and the latter to the natural environment). Most of levantine rock paintings are placed in opened areas, i. e. opened-caves, that offer unsuitable conditions for protection. On the one hand, human vandalism is a negative factor: paintings are sometimes overpainted (graffitis) or just partially extracted. On the other hand, weather effects (for instance, high temperature variation, acid rain and pollution) as well as geodinamical processes produce slow but continuous alterations.

Photogrammetry is an optimal way of plotting archaeological sites, either from aerial images or from terrestrial photographs (Perdrizet, Grussenmeyer, 1997); there are lots of experiences within CIPA dealing with this subject, and one specific working group! The digital era offers new possibilities within this field, not only for the automatic capture of points, lines, and subsequent creation of orthoimages, virtual models, etc., but also for the identification and recognition of surface features. This paper describes an automatic approach in archaeological photogrammetry for the documentation and recovery of rupestrian paintings.

The methodology presented herein uses multispectral photography, as pointed out by Vicent (1996), and applies digital multiband classification (Lerma, J.L., 2001). This choice gets exhaustive data from photographs in order to get thematic maps for cave paintings (mainly pigments and stones). This way of graphical documentation follows a different approach compared to traditional tracing. It is quick and objective, and offers the possibility to extract non-destructively the primitive paintings prior to restoration tasks.

2 ARCHAEOLOGICAL SITE AND FEATURES

The archaeological site is a piece of the Civil cave ('*Cova Civil*') located on the Valltorta ravine (Tirig, Castellón, Spain). Some qualities of this cave belong to the levantine rock art, i. e. naturalistic rock art with a large variety of drawings: mainly hunting, harvesting and warlike scenes, although there are also agricultural and farm ones. The greatest part of figures are red monochrome, representing men and women; animals, objects and abstract motives also appear but they are less important (Arte Rupestre, 1999).

The most important feature to be identified within the scene is the reddish pigment, although there are also further features, for instance, oxide and calcareous stones. The reddish pigment shows the primitive paintings and shapes, i. e., hunters, arrows and animals.

After a direct observation of the cave and depending on characteristics such as material, colour, texture and relevance, several archaeological features are identified: (1) (reddish) pigment, (2) (yellowish) oxide, (3) whitish stone, (4) rosy stone, (5) reddish stone, (6) brownish stone, and (7) darkish stone.

3 IMAGE ACQUISITION

The archaeological cave was photographed with a standard 35 mm camera using both colour and near-infrared B&W films (Fig. 1). In order to bring out pigments, the stone wall was again photographed with colour film after moistening.
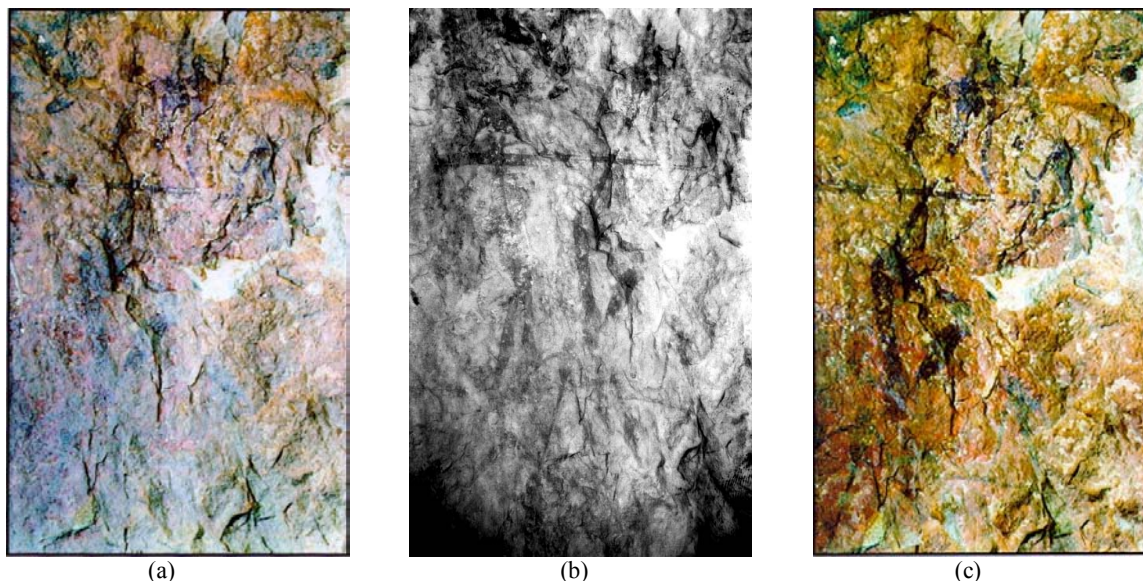

| (a) | (b) | (c) |

Fig. 1: Original images: visible (a), near-infrared (b) and visible after moistening (c).

Each visible photograph was scanned with a resolution of 600 dpi and a quantization level of 24 bits/pixel; the near-infrared photograph was scanned with the same resolution and 8 bits/pixel.

Warping was required because images were neither taken with the same camera nor taken from the same location. Besides, the images needed to be georeferenced to cave in order to get useful, profitable and real data from them (Fig 2). After warping and resampling, the multiband set had in total seven spectral bands: three visible (r,g,b), one near-infrared and three additional visible bands (after moistening).
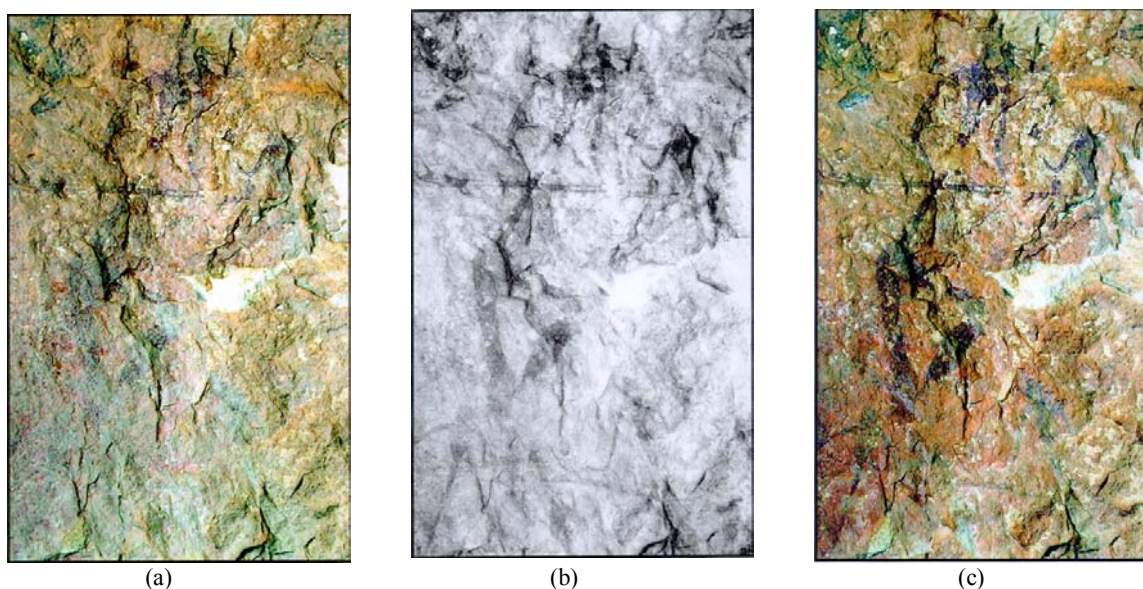

| (a) | (b) | (c) |

Fig. 2: Images warped and extracted: (a) visible, (b) near-infrared, (c) visible after moistening.

4 SPECTRAL CLASSIFICATION

Several supervised classifications were performed taking into account multispectral and multiband images, although herein only appears one of the best multiband classifications (Puertas, 2000). Training sets were collected for the seven features from well-distributed and separately placed polygons all over the cave. A class for the supervised classification procedure was assigned to each feature.

The classifier used in this study was the maximum-likelihood with a 99% confidence level threshold. Therefore, after classification the non-classified pixels were assigned as Null class. This item was not considered by itself in the error matrix form for the accuracy assessment. The resulting image appears in Fig. 3.
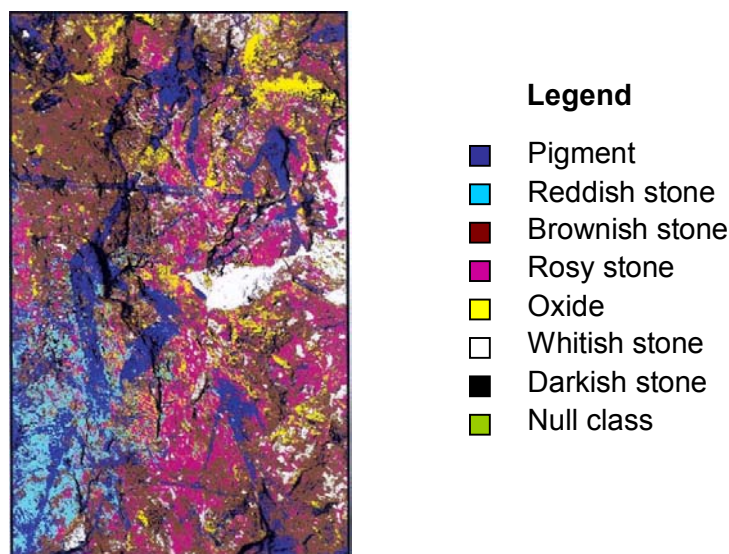

Legend

■ Pigment
■ Reddish stone
■ Brownish stone
■ Rosy stone
□ Oxide
□ Whitish stone
■ Darkish stone
■ Null class

Fig. 3: Maximum-likelihood classified image taking into account seven bands.

5 RESULTS AND DISCUSSION

After the pixel assignment was completed, the accuracy assessment within the entire study site was carried out by means of a set of test pixels and a set of classified pixels. The results were presented in error matrix form (Table 1); the producer´s accuracy and user´s accuracy were computed afterwards (Table 2).

Table 1. Error matrix form for accuracy assessment.

Class	Oxide	W.s.	Rosy s.	Red. s.	Br. s.	D.s.	Pig.	Total
Oxide	**962**	0	8	3	42	0	0	1015
Whitish stone	0	**2552**	1	2	7	0	1	2563
Rosy stone	31	2	**1066**	28	25	0	0	1152
Reddish stone	0	0	6	**946**	2	0	54	1005
Brownish stone	35	12	48	15	**1023**	0	24	1157
Darkish stone	5	0	0	7	5	**1233**	239	1489
Pigment	0	2	2	127	10	3	**1644**	2088
Total	1033	2568	1126	1128	1114	1236	2262	10469

Table 2. Producer´s accuracy and user´s accuracy.

Class	Producer´s accuracy (%)	User´s accuracy (%)
Oxide	99.1	94.8
Whitish stone	99.4	99.6
Rosy stone	94.5	92.5
Reddish stone	83.9	94.1
Brownish stone	91.8	88.4
Darkish stone	99.8	82.8
Pigment	85.9	93.1

The overall classification accuracy achieved was 92.9 percent. The producer´s accuracy for five classes were around or exceed 91 percent; the producer´s accuracy for *red stone* and *pigment* classes were around 85 percent, mainly due to the similarity (and finally interference) between both classes.

The same number of classes achieved a user´s accurary better than 94 percent, only *brown stone* and *dark stone* classes were below 90 percent; the commission error in *brown stone* was the highest one, around 20%, most of it afecting unfortunately the *pigment*

class. However, user´s accuracy with *pigment* class was 93.1 percent. Both classes, firstly *pigment* and secondly *brown stone* were required for restoration tasks: they were properly defining and extracting the original pigmentation.

It should be pointed out that visible bands after moistening the stone wall had positive noticeable effects on the accuracy assessment, even higher than expected. The inclusion of those three bands (red, green and blue) was fundamental to reach accuracies around 90 percent. Unfortunately, it was not possible to verify the moistening effect by means of the near-infrared radiation; photographs were not available.

6 CONCLUSIONS

The supervised classification works effectively when it is applied to the identification and recognition of different kind of stones and pigments. This first study showed that the multiband classification is an optimal tool for the recognition and extraction of rupestrian paintings prior to restoration tasks. The effective delineation and shape recovery of primitive figures in rock art should help restorers to carry out their interventions, mainly when pigments are hardly visible and covered by pollution.

The methodology developed in this study with multiband images seems promising to document opened-caves as well as to recover original paintings. Nevertheless, the more number of spectral and temporal bands, the more promising results. Further research needs to be done in order to know if this methodology is optimal to distinguish additional features or just inner materials.

ACKNOWLEDGEMENTS

REFERENCES

Arte Rupestre del Arco Mediterráneo de la Península Ibérica, 1999. Conselleria de Cultura, Educació i Ciència-Generalitat Valenciana.

Lerma, J.L. , 2001. Multiband versus Multispectral Supervised Classification of Architectural Images. Photogrammetric Record, 17(97): 89-101.

Puertas, África Adela, 2000. Procesado Digital de Imágenes de Arte Rupestre. Escuela Técnica Superior de Ingeniería Geodésica, Cartográfica y Topográfica, Universidad Politécnica de Valencia. Proyecto final de carrera.

Vicent, J.M., Montero, I., Rodríguez, Á.L, Martínez, M.I., Chapa, T., 1996. Aplicación de la Imagen Multiespectral al Estudio y Conservación del Arte Rupestre Postpaleolítico. Trabajos de Prehistoria: 53(2): 19-35.

Perdrizet, F., Grussenmeyer, P., 1997. Multi-Scales Photogrammetry for Archaeology. International Archives of Photogrammetry and Remote Sensing. Vol. XXXII Part 5C1B, pp. 101-107.