APPLICATION OF SPECTRAL AND TEXTURAL CLASSIFICATIONS TO RECOGNIZE MATERIALS AND DAMAGES ON HISTORIC BUILDING FACADES

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ABSTRACT

Spectral and textural classifications were evaluated for the identification, detection and recognition of outer materials and alterations in an architectural monument. A corpus of seven bands, including the spectral blue, green, red and near-infrared bands and further three red-textural bands was used in different classifications in order to evaluate the profitability of combination of both methods, spectral and textural. This study showed either that multispectral classification with visible and near-infrared bands increased the degree of recognition among different materials and damages and that the addition of textural bands to the multispectral classification allowed to discriminate similar materials, as rocks, on a historic facade.

1   INTRODUCTION

The study and evolution of historical monuments usually involves rather different kind of technicians and disciplines, in order to know and understand their reactions, and the actions required just to preserve or restore them for further generations, as part of the humans legacy.

Actually, the recognition of materials, their spatial distribution, shape and area recovered in our architectonic facades is one of the most important and tedious tasks in the documentation, conservation and restoration of monumental buildings. Until recent years, the conservation and restoration works have been done by visual and direct inspection in the field, drawing and sketching the materials or features identified directly on the facade. Furthermore, these tasks were somehow time consuming and required previous to the conservative treatments. Once the restoration work had begun, special care was fixed on the specific deterioration. On the contrary, little attention has been drawn as regards automation in surveying, recording, documentation and monitoring the external features on Cultural Heritage by multidisciplinary conservation teams, although last decade it was a new goal for a technical working group within CIPA (Waldhäusl, 1997).

Studies regarding the application of spectral classifications for the automatic plotting of materials and damages on masonry walls have already been done by Grunicke et al (1990), Herráez et al (1997) and Lerma et al (1999). All of them used reflected-light imagery, i.e. visible and near-infrared wavelength energy, meanwhile the first one recommended the application of unsupervised classification, the formers required supervised classification due to the higher accuracy reached.

Anyway, problems arise in segmenting images either when the pixels which comprise individual objects are spectrally heterogeneous (Ryherd et al, 1996) and when identical spectral features have got different image texture. Unfortunately, both conditions appear quite often in architectural facades, and they should be taken in mind before attempting the classification.

The benefits of applying independently spectral and textural classifications have been appointed by the authors in previous studies: Lerma and Ruiz (1999), Lerma and Ruiz (2000). Herein, several classifications have been carried out to examine the materials and their alterations applying successively visible spectral classification with three bands (B,

G, R), visible and near-infrared spectral classification with four spectral bands (B, G, R, near-IR) and finally, spectral (with the last four bands) and textural classification of multispectral close-range images; the three textural bands were computed from the grey level co-ocurrence matrix (GLCM) (Haralick et al.,1992): homogeneity (3x3 window), mean (50x50 window) and homogeneity (50x50 window).

2 STUDY SITE AND MATERIALS

The study site is the *Santos Juanes´* Church located on the old part of the city of Valencia. The materials consisted of limestone and brick rendered with masonry cement (inside the rosette). After a careful direct observation of the facade and depending on characteristics such as material, color, texture and relevance, several masonry wall materials and damages (features) were identified: (1) *cleaned cement mortar* used to render the rosette, (2) *dirty cement mortar* used to render the rosette, (3) *flaking* (thus, appearing at least the bricks), (4) *polished limestone*, (6) *washed limestone*, (7) *dark limestone*.

3 IMAGE ACQUISITION AND PREPROCESSING

The facade site was photographed with two cameras, a metric one (9 x 12 cm) used for the visible radiation and an amateur one (35 mm.) used for the reflected near-infrared radiation. For the latter purpose the following material was required: a black-and-white infrared-sensitive film, a Kodak Wratten gelatin filter No. 87 (Kodak, 1990).Each analogue photograph was digitized in order to get digital images; the quantization level of each digital image was of 8 bits/pixel.

The spectral images were digitally rectified because they were taken with different cameras and they were also taken from different locations. The four spectral images were merged altogether and resampled with a bilinear interpolation. A view of the extracted spectral set can be seen in Fig 1.

(a)   (b)   (c)

(d)
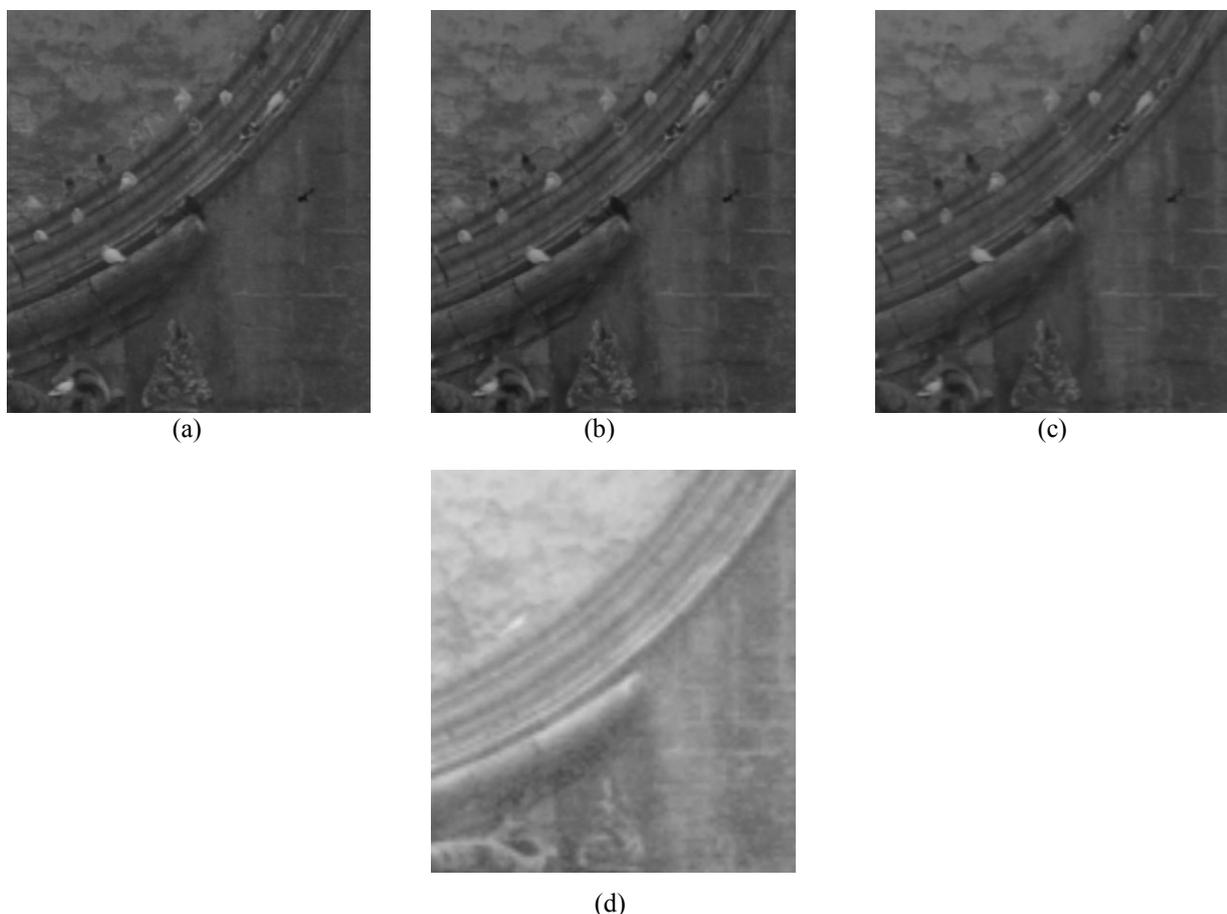
Figure 1. Spectral images: (a) blue, (b) green, (c) red and (d) near-infrared.

The texture filtering generated the texture images to be used in conjunction of the four spectral bands. In fact, only the most representative parameters (for these monument) were selected for the red spectral band applying the GLCM, the mean and the homogeneity. In Fig. 2a appears the homogeneity image for a window of 3x3, whereas in Fig. 2b and 2c appear the mean and homogeneity images for a window of 50x50. Finally, the whole set of seven images was extracted in order to have the same physical size (resolution).

(a)   (b)   (c)
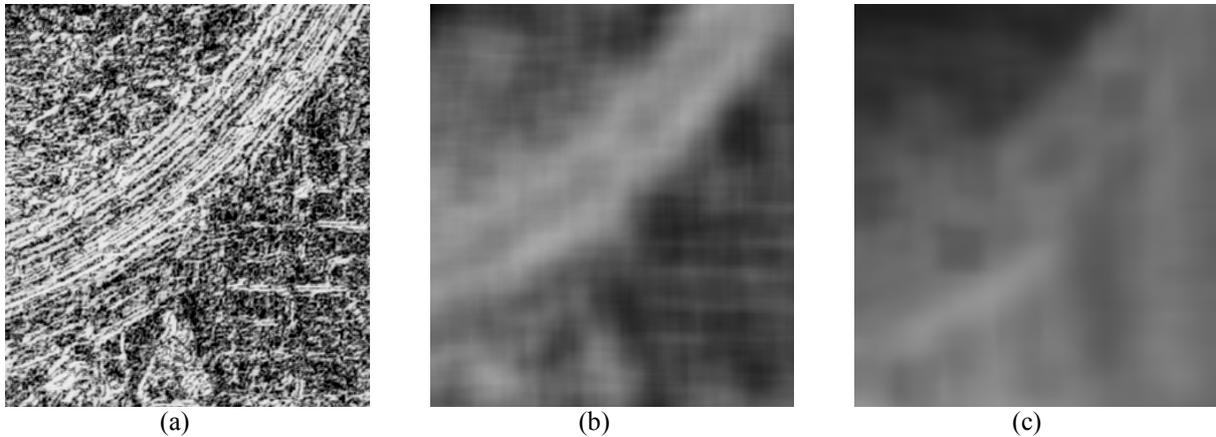
Figure 2. Textural images: (a) homogeneity (kernel 3x3), (b) mean (kernel 50x50), (c) homogeneity (kernel 50x50)

4 SPECTRAL AND TEXTURAL CLASSIFICATIONS. RESULTS

The informational classes used for the classification were defined in the selection process and proved to be distinguishable. Three sets of extracted images were classified by means of the standard supervised rule of maximum likelihood. All the classified images were evaluated by means of visual inspection in the field, and qualitatively analyzed. The first set was only integrated by the visible bands; the result is shown in Fig. 3a. The second set was integrated by the visible bands and the near-infrared band; the result appears in Fig. 3b. The last set used the whole set, the three visible bands, the near-infrared band and the three textural bands; the result appears in Fig. 3c.

(a)   (b)   (c)
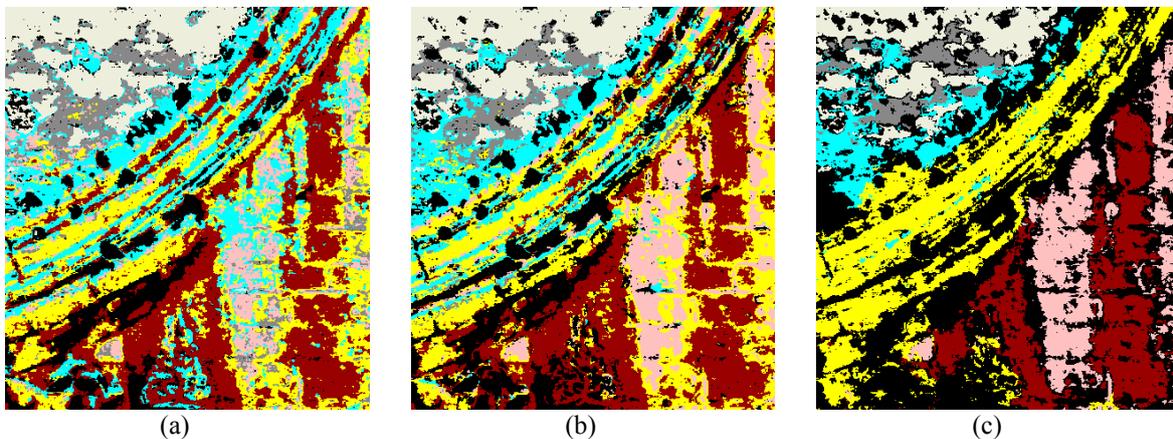
Figure 3. Classified images: (a) spectrally (G,B,R bands), (b) spectrally (G,B,R,IR bands),
(c) spectrally (G,B,R,IR bands) and texturally (3 bands, Fig. 2)

The visible spectrally classified image, Fig. 3a, shows only one spectral class properly recognized, *clean cement mortar*. Most of the other classes have too many defect or excess errors. For example, *flaking* is neither well placed nor well distributed; *polished limestone* is rather confused, mainly over the other kind of limestones, *clean and dirty*; *dark cement mortar* offers flooding over *washed limestone*. On the other hand, *washed limestone* only fits the area and follows the traces; and finally, *dark limestone* seems well-classified although it has some expansion over *polished limestone*.

Regarding the second classified image, Fig. 3b, there is a better discrimination between *cement mortar–limestone*, as well as among *flaking–washed* & *washed limestones*. Unfortunately, this classification still has got a general confusion among polished limestone and *washed* & *washed limestones*.

Finally, the classified image using spectral and textural bands offers the best results, Fig. 3c. By defect, it fits very well. The confusion areas on the other classified images (Fig. 3a, 3b) are now classified as null class (black color). Although there is an increment of null class there is also and a higher probability of classifying properly the six classes. Particularly interesting is the right difference among *polished limestone* and *washed & washed limestones.*

5   CONCLUSIONS

The results achieved in this study seem promising as regards the combination of spectral and textural classifications for the characterization of architectural monuments, not only for the identification of different materials but also for the recognition of similar materials.

The union of the supervised spectral and textural classification has been found to work effectively when applied to the identification and recognition of masonry wall materials. It has been shown that the near-infrared band increases discrimination of rather similar materials (mortar and limestone) and that the addition of textural bands allows a better (much real) recognition of different kind of limestones. Anyway, although textural images require more time of processing it is worth working with them altogether as additional input bands for classification.

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