Automatic Feature Recognition Technique on Stone Monuments Using Visible and IR Photography

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ABSTRACT
Visible photography has long been used in the field of architecture for documentation and restoration tasks. However, the automatic extraction and analysis of facade features, i. e. materials and alterations, is unusual in most of multidisciplinary teams involving documentation, conservation and restoration projects. This paper shows the profitability of applying digital image analysis on stone monuments, in order to provide exhaustive, global and accurate information from visible and near-infrared photographs. Output data are rectified and automatically classified images from which it is possible to obtain, among others, detailed positions of materials and degradations on facades, real measures of distances, areas of architectural features, as well as statistical documents of the accuracy achieved in the whole process of automatic recognition.

KEYWORDS: architectural photogrammetry, digital image processing, feature recognition, multispectral classification

INTRODUCTION

Before any conservation and restoration work, it is advisable to compile all kind of information regarding the stone monument. The monuments are in complete interaction with inner and outer factors that contribute to its maintenance and, inevitably, to its deterioration. Whatever the actual state of the monument, it is necessary to carry out multidisciplinary studies in order to chose the right present/future action. Furthermore, the higher the quality and the completeness of the analysis the better diagnosis of the Cultural Heritage.

The recognition of constituent materials and the evolution of their damages over the time is an important task in the documentation work [6]. Besides, it is not a quick process; it takes long to get all the necessary sampling data, mainly by means of direct methods. Data capture depends either on the accessibility of the monument, its emplacement and dimensions, and on the way of inspection and analysis.

The objective of this paper is to present a way of analysis –objective, global and non-destructive– based on the automation of topographic surveys by means of digital photogrammetry and digital image processing. The output data are just metric rectified images (orthoimages) and classified images showing the different kind of materials, features and alterations of stone facades.

This study applies spectral classifications of visible and near-infrared images on stone monuments as pointed out in [1] and [2], although the methodology follows the guidelines that appear on the latter paper. Additionally, it was unnecessary the application of both spectral and textural analysis [3][4] because there were not many different materials on the facades; limestone was the predominant material.

STUDY SITE AND FEATURES

The study site is the *Saint Agustin's* Church located on the old part of the city of Valencia. The constituent material mainly consist of limestone. Two facades are studied, the main one and a piece of the lateral facade. After a direct observation of the main facade, several masonry wall materials and damages (features) were identified: (1) *washed limestone*, (2) *polluted limestone*, (3) *very polluted limestone*, (4) *dark areas* (lampposts, indoors and shadows).

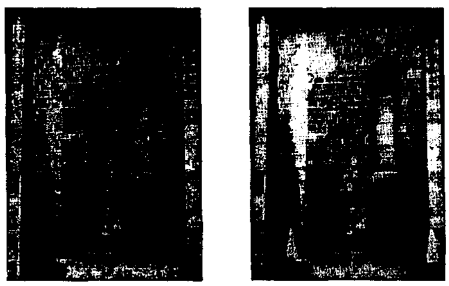
Regarding the lateral facade, similar and additional features were found: (1) *washed limestone*, (2) *polluted limestone*, (3) *white limestone*, (4) *humid limestone*, (5) *spot* covering the limestone, (6) *painting* on the limestone, and (7) *plants* in front of the facade.

METHODOLOGY

The main facade was photographed with a conventional colour digital camera requiring three shots to acquire the whole facade, meanwhile the lateral facade was photographed with two cameras, the digital one and a standard analogue 35mm camera. This second camera was used for the reflected near-infrared radiation.

Within the digital preprocessing stage some tasks were performed: image enhancement (histogram modification of individual images), multispectral image rectification (Fig. 1) and image extraction of the whole set of visible and near-infrared images and, finally, the construction of a digital mosaic from the set of overlapping rectified-images.

Besides, image rectification also allowed the creation of the mosaic image for the main facade (Fig. 2). The applied method of rectification always was the two-dimensional transformation. The mosaic image was a metric image (orthoimage) from which real data could be obtained afterwards (distances, areas of interest, etc.).



(a) (b)

Figure 1: Visible (a) and near-infrared (b) images of the lateral facade after rectification

Supervised classifications were performed on both facades. Spectral classes were assigned to each of the four features from the main facade and seven features from the lateral facade. Training sets were collected from well-distributed and separately placed polygons over the study sites. The classifier used was the maximum-likelihood with a 95% confidence level threshold [5]; the non-classified pixels were assigned as Null class. Fig. 3a displays the multispectral classified image of the lateral facade; the main facade appears spectrally classified in Fig. 3b.

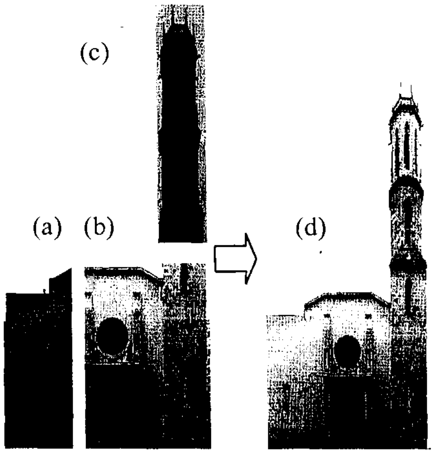


Figure 2: Mosaic image (d) of the main facade constructed from rectified images (a,b,c)

Figure 3: Classified images of lateral (a) and main (b) facades

RESULTS

The accuracy assessment among the actual classes (inspected areas) and the predicted classes (classified data) was evaluated by means of an error matrix for the lateral image. Null classes were not taken into account for the accuracy assessment; only the assigned classes after their classifications were evaluated. The overall accuracy achieved is around 96 percent. Regarding the main facade, identical statistical analysis was carried out; the overall accuracy reached is approximately 84 percent.

As regards the user's accuracy, most of the classes achieved an accuracy around 95 percent. Only the user's accuracy of *Washed limestone* class is below 90 percent although it is not worrying because of the spectral closeness with its partner *Spot* class. Furthermore, the producer's accuracy of *Washed limestone* class is approximately 80 percent because the excess errors coming from *Spot* and *White limestone* classes.

The overall accuracy of the main facade is lower than the accuracy achieved on the lateral facade mainly because the near-infrared band was left (not available). Omission errors within *Washed limestone* class influenced negatively the classification accuracy; however, its user's accuracy is high. Other important fact is the similar spectral response between *dark areas* and *very polluted limestone* classes. It might help us to focus on the areas needing inevitably restoration.

CONCLUSIONS

This study shows that the recognition and characterization of features by means of digital processing tools on stone monuments not only are possible but also offer a high degree of completeness and accuracy. Furthermore, when photogrammetric techniques are used to create the metric photographs, output data obtained from them are ready for measurements and fit to exact positions.

The near-infrared image is essential to distinguish properly the different features of the lateral facade. Results from the main facade could have been even better using more spectral images (not only visible).

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