ARCHEOLOGICAL MOSAIC IMAGE INDEXING BY COLOR-BASED SEGMENTATION AND SKELETON EXTRACTION

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I. - INTRODUCTION

Islamic visual art related to architecture has been at the zenith of its glory in Morocco, during the XIVth century. But this heritage from the middle ages has been slowly damaged by the inclemency of weather and, more recently, under the pressure of excess population in the towns due to rural depopulation.

This threatened heritage is in danger of falling to pieces. Fortunately, a huge number of photographs have been taken by lovers of this art, by professionals and by experts of Islamic arts. However, these pictures are scattered through a number of books, private collections and libraries, so that it is difficult to collect material for archeological studies. The demand for a fast and accurate access to these images by means of an image retrieval system is very strong. Fully aware of this growing demand, many owners of these valuable photographs are ready to lend them in order to build databases of mosaic color images. In this context, the retrieval of target images that are similar to a given query image has become a challenging task.

The traditional Islamic art is based on a visible geometry and its abstract nature is one of the characteristics of these mosaics. These planar surface decorations – known as zellij technique – are made by inlaying small pieces of colored enameled ceramic tiles (cf. Fig. 1). Simple basic shapes are assembled with no empty space in one motif that uses symmetry to cover an ideal infinite surface. The thirty-five basic shapes of elementary mosaic pieces shown in Fig. 2 offer infinite amount of mosaic variations.

This type of assembly creates secondary shapes that enrich the repertory available to artists. The rules for this geometric decoration have been carefully summed up in [1], where the author has introduced the concept of skeleton. The skeletons of most of the mosaics are created from alternating polygonal structures consisting of pieces of a limited number of colors and of elementary shapes.

Until now, the extraction of the skeleton has been done by drawing the motifs manually on grid paper [1]. The rules for geometric decoration and the existence of image processing algorithms suggest the possibility of developing a system that would perform this task automatically.

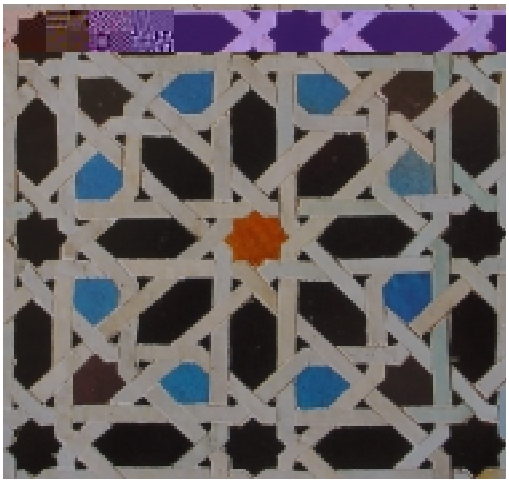

Figure 1: Zellij in Attarine Madrasah, Fez

In this paper, we use a color-based image segmentation procedure to extract regions that represent the different pieces of tiles (section II). These elementary pieces are characterized by their colors and moment invariants (section III). The skeletons are extracted from the mosaics as polygonal closed curves connecting similar pieces. They are characterized by Fourier descriptors (section IV) that are used to retrieve similar images in a color mosaic image database (section V).

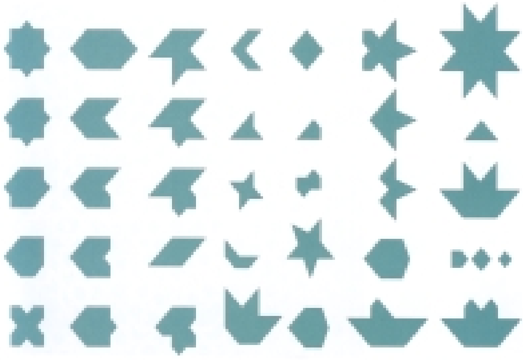

Figure 2: Basic shapes of mosaic pieces.

II. – COLOR-BASED SEGMENTATION AND PIECES LABELING

The segmentation of the color mosaic images and the labeling of the regions are of primary importance. We assume that each piece forms an homogeneous region, i.e. a set of connected pixels which must be assigned to the same class of pixels. The segmentation is achieved by an unsupervised pixel classification scheme that takes into account both the colorimetric and spatial pixel properties, in order to determine the number of classes and their cores without any a priori knowledge on the image. This scheme splits a color image into different sets of connected pixels with homogeneous colors. A measure of the connectivity degree of all possible sets of pixels that an image can contain is used to determine the most connected sets. The colorimetric and spatial relationships between the pixels are merged into a table called “color connectivity degrees pyramid”. Local maximums of these connectivity degrees correspond to candidate classes of pixels. The cores of the pixels classes are finally constructed by means of a multiscale analysis of these local maximums.

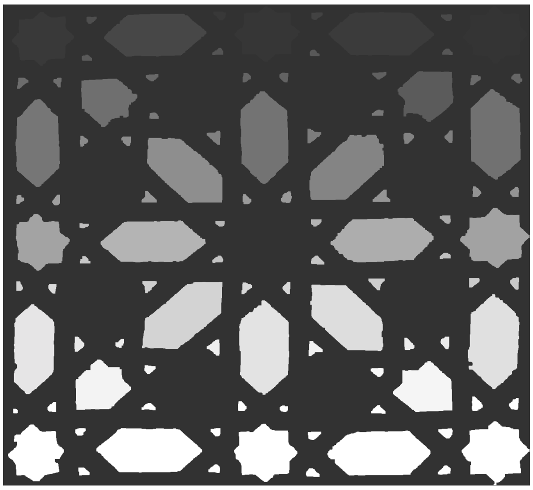

Figure 3: Labelled pieces of the image of Fig. 1

In order to segment the image, each pixel that does not belong to any class core is assigned to the class for which its Euclidean distance to the class center is the smallest one. A specific label is associated to each class of pixels, which corresponds to an individual region of the segmented image. The labels are chosen in the range [0,255], so that the labelled pieces, which correspond to the homogeneous regions, can be displayed as a gray-level image (cf. Fig. 3). This color image segmentation procedure is detailed in [2], [3] and [4].

III. - PIECE SHAPE IDENTIFICATION

The next step of the procedure is now to recognize to which of the basic shapes of Fig. 2 corresponds each labelled piece extracted from the image.

The algorithm for processing images of labelled pieces and identifying the shape of each individual piece is divided into two successive steps: computation of moment invariants [5], [6], and classification.

Moment functions

Mosaic pieces recognition should not depend on deformations caused by rotation, position, and scale. Moments associated with each labelled piece are very useful for shape analysis. They can be made invariant to position by translating the origin to the center of gravity of the shape and defining the coefficients:

$$\mu_{ij}^{p} = \sum\sum\left(x - \bar{x}^{p}\right)^{i}\left(y - \bar{y}^{p}\right)^{j}$$

where x and y are the coordinates of the pixels that represent the labelled piece number p, while $\bar{x}^{p}$ and $\bar{y}^{p}$ are the coordinates of their gravity center. The following three polynomials of μ_{ij}^{p} are the first out of the seven introduced by Hue [7]. They remain unchanged under the transformations of rotation.

$$\phi_1^p = \mu_{20}^p + \mu_{02}^p$$

$$\phi_2^p = (\mu_{20}^p + \mu_{02}^p)^2 + 4(\mu_{11}^p)^2$$

$$\phi_3^p = (\mu_{30}^p - 3\mu_{12}^p)^2 + (3\mu_{21}^p - \mu_{03}^p)^2$$

If they are normalized with μ_{00}^{p}, the expressions :

$$\psi_1^p = \frac{\phi_1^p}{(\mu_{00}^p)^2}\ ,\ \psi_2^p = \frac{\phi_2^p}{(\mu_{00}^p)^4}\ ,\ \psi_3^p = \frac{\phi_3^p}{(\mu_{00}^p)^5}$$

become invariant with respect to size, location and orientation [6]. These parameters have been selected for mosaic labelled piece recognition.

Piece classification and identification

A classical nearest neighbor classifier is used to assign each piece characterized by these three moment invariants to its nearest prototype in the feature space. Representative prototypes of each class are selected interactively.

IV. - MOSAIC SKELETONS FOR IMAGE INDEXING

The efficiency of the image retrieval process depends on the relevance of the indexes selected to represent the specificity of the mosaics [8].

Each labelled piece extracted from the image by the segmentation scheme is characterized by three kinds of features: the mean RGB color components of its pixels, the coordinates of gravity center of its pixels, and the identified shape, which is one out of the 35 basic shapes presented in figure 2. These data are analyzed to construct the skeletons which are used for indexing the mosaic images.

The specific pieces constituting these skeletons are easily identified and extracted from the whole image. For example, Fig. 5 shows the gravity centers of the pieces belonging to the skeleton, which is composed of the red pieces of Fig. 4 whose shape is the second one on the second line of Fig. 2.

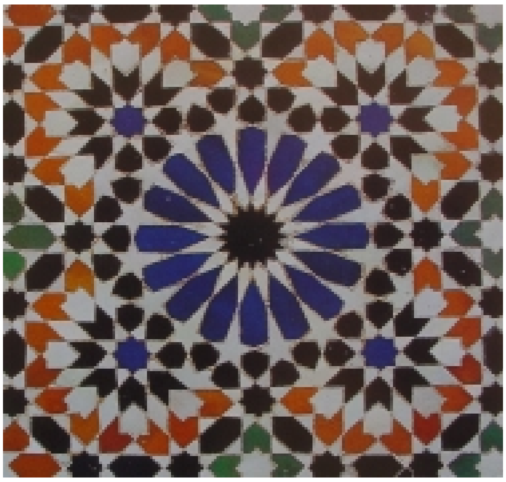

Figure 4 : A 4-leaf mosaic [1]

Connecting all the gravity centers of the pieces constituting a skeleton along its perimeter yields a closed polygonal curve that is used for the overall recognition of the mosaic design in the retrieval context. It can be expanded in a Fourier series. This frequency-domain description provides an accurate characterization of the skeleton, which is independent of size, translation, and rotation of the shape [9].

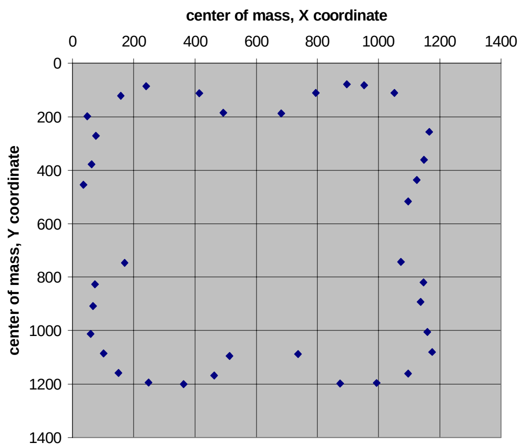

Figure 5 : Skeleton of the 4-leaf mosaic

The first low-order terms in the expansion of the skeleton, properly parameterized, constitute an index vector that is used for retrieval purpose.

V. – IMAGE RETRIEVAL

The content-based image retrieval is performed by means of a matching scheme, which compares the index vector of the query image with those of the target images in the database. The matching scheme is based on a similarity measure between these image index vectors. The target images are ranked according to the distances between their index vectors and that of the query image.

The proposed method has been tested on a database containing a few hundreds of color images of zellijes of different buildings of Fez. These images have been acquired with a simple color digital camera (Sony DSC-S70), under various natural lighting conditions. The only constraint was to place the camera such that its optical axis was approximately perpendicular to the plane of the mosaic.

Each image was characterized by the four first Fourier descriptors of its skeleton, extracted according to the above scheme.

A result of the retrieval is presented in Fig. 6, where the target images are ranked in order of decreasing similarity with the query image, which is the leftmost image in the first row.

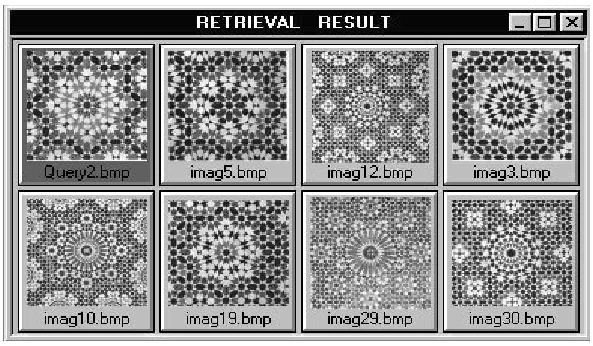

Figure 6: Retrieval result

VI. – CONCLUSION

A method that can be used to index and retrieve images of decorative mosaics has been proposed. A new unsupervised color-based segmentation procedure is combined with classical moment invariants to identify the different small pieces constituting the mosaics. This low-level description of the images is used to extract their skeletons, which are characterized by Fourier descriptors. They appear to be relevant index vectors for the image content and they can be effectively used for retrieval.

VII. - REFERENCES

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