Pattern Recognition Letters 68 (2015) 111–117

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

A rotation symmetry group detection technique for the characterization of Islamic Rosette Patterns☆

Aziza El ouaazizi[a,*], Abdelbar Nasri[b], Rachid Benslimane[b]

[a] Laboratory of Engineering Sciences, Sidi Mohamad Ben Abdallah University, FP Taza, BP.1223 Taza Gare, Morocco
[b] Laboratory of Data Transmission and Processing, Sidi Mohamad Ben Abdallah University, EST, Route d'Imouzzer BP.2427, Fès, Morocco

ARTICLE INFO

Article history:
Received 14 March 2015
Available online 16 September 2015

Keywords:
Islamic Rosette Pattern
Rotational symmetry
Symmetry group
Frieze-Expansion
Genetic algorithm

ABSTRACT

The purpose of this paper is to detect and characterize geometric rosettes which are among many different star-like motifs used in the most common Islamic Geometric Patterns. Based on symmetry group theory, a geometric rosette can be characterized by its center; order and group of symmetry. It is easy to observe that a rosette is formed by a central star surrounded by two types of shapes (mid-cells and outer-cells) called "*furmah*" by Moroccan artisans. The center of symmetry is the center of the concentric circles circum-circling respectively the central star, mid-cells and outer-cells. The order of the rosette is connected with the number of mid-cells.

To detect the center of symmetry in a rosette image, we propose an original method based on genetic algorithm that extracts the circle passing by the maximum pixels belonging to the binary rosette image. The center and the radius of the detected circle correspond respectively to the symmetry center of the rosette and the radius of its supporting concentric region. To determine the type and the order of symmetry, Frequency analysis using Discrete Fourier Transform is applied to the Frieze-expansion pattern. This later is obtained by applying the Frieze-Expansion technique to the extracted supporting concentric region. Experimental results prove that the proposed algorithm for rotational symmetry detection is rather successful because it manages to localize the real center of symmetry of any rosette pattern. The key point of this algorithm lies at the same time in its simplicity and its efficiency.

1. Introduction

The symmetry is a natural phenomenon exploited and used in most part of sciences: mathematical, physics, architecture, etc. It also plays a very important role in the field of computer vision. Indeed, symmetry can be used for the generation of artificial object and motifs as it can be also used to characterize and detect objects stemming from the real world.

The automatic detection of symmetry has drawn the attention of several researchers during the latter decades [2,10,12,13]. Indeed, in the image processing (restoration, segmentation, indexation), a symmetric object can be characterized efficiently by its symmetry group, leading to a vector of this object [18,19,24]. The methods of rotational symmetries detection can be grouped in two main categories: local and global methods.

The local methods are based on the local features such as edge, corner and boundary [2,13]. For example in [2], the SIFT, Harris-affine and Hessian-affine feature detectors are used to detect rotational symmetry under affine projection. Each feature pair hypothesizes a set of centers of rotation for different tilts and orientations and the centers of rotation that are close to each other are grouped together to find the dominant rotational symmetries in the image. This algorithm relies on features that require texture, which limits the method to object with rotational symmetric texture. The method proposed in [13] simultaneously considers symmetries over all locations, scales and orientations, and has shown to reliably detect both bilaterally and rotationally symmetric figures in complex backgrounds, and handle multiple occurrences of symmetry in a single image. The method relies on the robust matching of feature points generated by modern feature techniques such as SIFT [14]. However, these local features are not always optimal for rotational symmetry detection.

The global methods [7,9,22], search for either the entire image or the whole parameter space. For example in [7], a polar Fast Fourier Transform (FFT) is used on the pseudo polar grid to find signal repetition over angular direction for rotation symmetry detection. However, their polar FFT investigates pre-selection local areas and can't distinguish cyclic from dihedral symmetry. Yip [22] introduces an algorithm of detection and analysis of the rotational symmetries, based

☆ This paper has been recommended for acceptance by Dr. D. Coeurjolly.

* Corresponding author. Tel.: +212 5 35 211976; fax: +212 5 35 211978.
E-mail address: aziza.elouaazizi@usmba.ac.ma (A. El ouaazizi).

http://dx.doi.org/10.1016/j.patrec.2015.08.021
0167-8655/

on its Hough transform. This algorithm is suitable for our application because it gives information about the center of rotation, the angle of projection, the order of rotation and an estimation of the positions of the points of the image made sound effects. The main disadvantages of using HT are its large data storage requirements and its expensive time computation. Both the storage and computation time grow exponentially with the number of parameters. Moreover, to detect a rotational symmetry center with a higher accuracy, the parameters space must be partitioned into smaller cells. The two factors together may lead to a large accumulator array even for a small number of parameters. In [9] a Frieze-Expansion method is used to transform the rotational symmetry group detection into a simple translation symmetry detection problem. They define and construct a dense Rotation Symmetry Strength (RSS) map from a given image, and search for potential rotational symmetry centers automatically. Frequency analysis, using Discrete Fourier Transform (DFT), is applied to the Frieze-Expansion patterns to uncover the types and the cardinality of multiple rotation symmetry groups in an image. This technique is also very suitable for the Islamic Rosette Patterns characterization but the rotational symmetry center detection part of the corresponding algorithm takes several steps and it acted as follows:

- Reduce gradually the size of the original input image.
- Compute the RSS score for expanded Frieze-Expansion patterns around each pixel of the reduced image to build a dense RSS map.
- Enlarge the RSS map gradually using linear interpolation to reach the original image resolution.
- Adopt the inhibition-of-return method to extract local maxima (rotational center candidates). The radius supporting the region of the symmetry group for each potential rotation center is taken to be the maximum inside the given image.

To overcome this drawback, we propose a new rotational symmetry detection algorithm that provides, just in two steps, the true center of symmetry of the rosette pattern and the radius of the circular band (supporting concentric region) that becomes translational symmetry by the Frieze-Expansion technique and we adopted the second part of this method to detect the group and the order of symmetry the Islamic Rosette Patterns because it's very efficient as shown in [9].

The remainder of this paper is organized as follows: Section 2 gives an overview over the characteristics of Islamic Rosette Patterns; Section 3 presents our approach to extract the geometric rosette characteristics (center, order and group of symmetry); Section 3.2 presents our proposed method for symmetry center detection; Section 3.3 describes different steps used for the determination the order and the group of the symmetry of the rosette. Experimental results and conclusion are finally given in Sections 4 and 5.

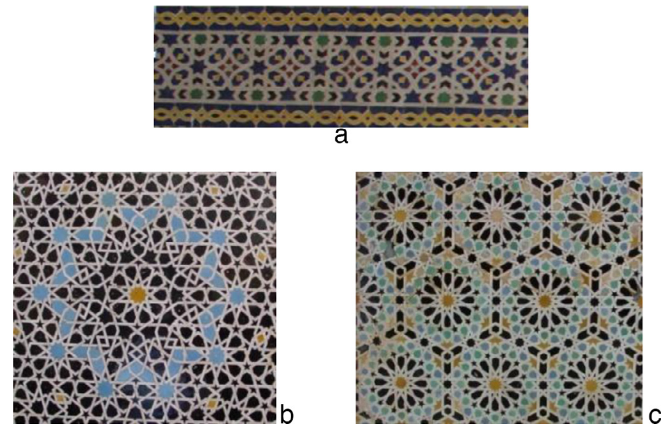

Fig. 1. Types of Islamic Geometric Patterns: (a) Frieze group (b) Point group, (c) Wallpaper group *Photos R. Benslimane (a/ Kasbat of Talouit, b/c/ Medersat Attarine, Fez-Morocco.*

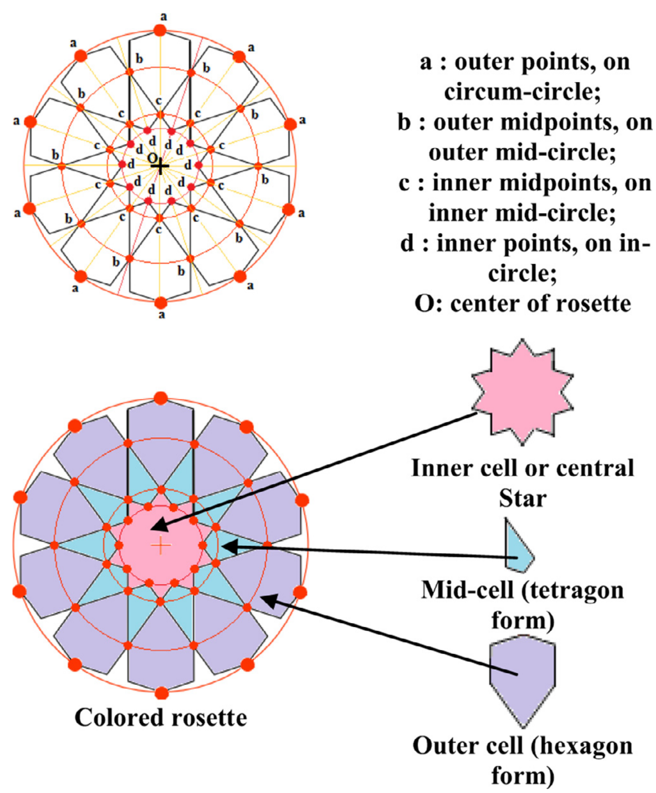

Fig. 2. An example of geometric synthetic rosette and its nomenclature according to Lee [8].

2. Characteristics of Islamic Rosette Patterns

Geometrical patterns have been popular with Islamic artists and designers in all parts of the world, for decorating almost every surface, walls, floors, pots, lamps, book covers or textiles.

By analyzing Islamic Geometric Patterns, it's obvious to see that the majority of the Geometric Islamic Patterns often take the form of a division of the plane into star-shaped regions (Fig. 1). This category of patterns is simply called "Islamic Star Patterns". The geometric rosette is among the many different star-like motifs used which distinguish to be "Islamic" [6]. As it is shown in Fig. 2, it is easy to observe that an Islamic Rosette is formed by a central star surrounded by two types of shapes or *furmah* (mid-cells and outer cells) [8]. As shown in Fig. 3, a rosette can also be surrounded by several types of outer cells that preserve its concentric form. The center of symmetry is the center of concentric circles encircling respectively the central star, mid-cells and different outer-cells. The order of the rosette is connected with the number of mid-cells (see Fig. 3).

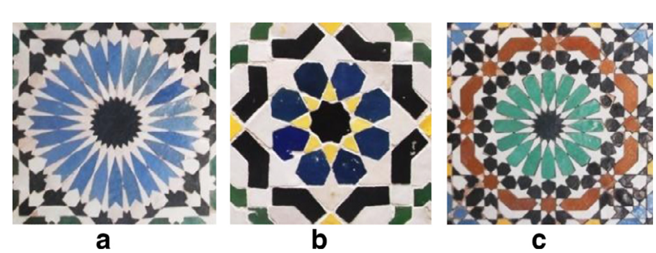

Fig. 3. Examples of geometric rosette with different order from Fez city (Morocco): (a) Rosette with 24 folds, (b) Rosette with 8 folds, (c) Rosette with 16 folds.