Illumination Invariant Recognition of Color Texture Using Correlation and Covariance Functions

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Abstract. In this paper, we derive a complete set of Zernike moment correlation functions used to capture spatial structure of a color texture. The set of moment correlation functions is grouped into moment correlation matrices to be used in illumination invariant recognition of color texture. For any change in the illumination, the moment correlation matrices are related by a linear transformation. Circular and non-circular correlations are discussed and comparisons with a previously suggested color covariance functions have been carried out using about 600 different illuminations and rotations textured images. Using moment correlation matrices in the invariant recognition of color texture, the process can promise in high computation efficiency as well as recognition accuracy. The derived correlation invariants is proposed as a general formalism that can be used directly with other kinds of complex moments, e.g. Fourier Mellin, pseudo Zernike, disc-harmonic coefficients, and wavelet moments, to obtain moment correlation based invariants.

1. Introduction

Early image recognition algorithms were based on computing (geometric) invariant features for gray-level intensity images. The goal was to detect an object or classify a textured image from an image database (gray-level and binary image recognition is still dominant in computer vision and pattern recognition applications). Despite of the increase in dimensionality, the use of colors is unavoidable in recent recognition applications. In fact, using color images may give a better recognition performance than gray-level images due the capability of capturing local and global image features within and between color bands. Moreover, it is not possible to perform illumination invariant recognition without using color properties of an image.

Many techniques had been suggested to investigate the use of multi bands of a color image to achieve geometry, illumination, or illumination-geometry invariant recognition. First, the work of Swain and Ballard [1] in which they showed that color distributions can be used directly for recognition without even paying attention to the spatial structure of the image. Their method, however, fails if the illumination spectral is changed or the spatial structure of the image is high (it is possible for regions with significantly different spatial structure to have similar color distributions). A Color Indexing color constancy algorithm [2] was developed to remove the dependency of color distributions on illumination changes. The algorithm performs well for an object
recognition task but with less success when the image is highly structured as in textures. The other group of color image recognition algorithms deals with computing spatial structure based features, some of the methods are Gabor filters [3], color distributions of spatially filtered images [4], Markov random field models [5] & [6], and spatial covariance functions [7]. Moment invariants of color covariance functions [7] (or as the authors called them color correlation functions but see Rosenfield [8] for the exact terminology which copes with the one we claim in this paper) within and between bands of a color image had been used to recognize three-dimensional textures. The same color covariance functions had been used successfully in a series of illumination recognition experiments of 2-D color texture [9]-[11]. Jain [10] used color covariance functions to recognize multispectral satellite images. In [11], Zernike moment invariants were computed for color covariance functions, the derived Zernike moment invariants, however, were not complete. In this paper a complete set of Zernike moment correlation and covariance matrices is derived. Different color correlations are introduced, circular and non-circular. Experimental results using about 600 different illumination-rotation images are used to compare the proposed model to the previously suggested color covariance functions.

2. Spatial Interaction within and between Color Bands

To be able to recognize the texture of a color image, the interaction within and between its bands is considered in this paper. The spatial covariance family functions forms one of the most reliable schemes used to model the color texture. In this paper we will discuss four different measures of these covariance functions.

2.1 Spatial Covariance Functions

Over the image region defining the texture, each band \( I_i(\alpha, \beta) \) is assumed wide-sense stationary and each pair of bands is assumed jointly wide-sense stationary. The set of covariance functions within and between sensor bands \( 1 \leq i, j \leq N \) is defined as

\[
C_{ij}(x, y) = E\{[I_i(\alpha, \beta) - \bar{I}_i][\bar{I}_j(\alpha + x, \beta + y) - \bar{I}_j]\}
\]

where \( \bar{I}_i \) and \( \bar{I}_j \) denote spatial means and \( E \) denotes the expected value. For the trichromatic case \( N = 3 \) we observe the following properties:

- The definition given in (1) will lead to nine covariance functions that include three autocovariance functions and six crosscovariance functions. All the nine spatial covariance functions have the following property \( C_{ij}(x, y) = C_{ji}(-x, -y) \) in which only the autocovariance functions are symmetric about the origin. Therefore, we can make use of this symmetry to reduce computations.

- The crosscovariance functions are not symmetric; however, only three should be computed i.e. \( (C_{12}, C_{13}, C_{23}) \), the other three \( (C_{21}, C_{31}, C_{32}) \) can be obtained