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Color image retrieval using statistical model and radial basis function neural network

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Abstract This paper proposes a new and effective framework for color image retrieval based on Full Range Autoregressive Model (FRAR). Bayesian approach (BA) is used to estimate the parameters of the FRAR model. The color autocorrelogram, a new version of edge histogram descriptor (EHD) and micro-texture (MT) features are extracted using a common framework based on the FRAR model with BA. The extracted features are combined to form a feature vector, which is normalized and stored in image feature vector database. The feature vector database is categorized according to the nature of the images using the radial basis function neural network (RBFNN) and *k*-means clustering algorithm. The proposed system adopted Manhattan distance measure of order one to measure the similarity between the query and target images in the categorized and indexed feature vector database. The query refinement approach of short-term learning based relevance feedback mechanism is adopted to reduce the semantic gap. The experimental results, based on precision and recall method are reported. It demonstrates the performance of the improved EHD, effectiveness and efficiency achieved by the proposed framework.

1. Introduction

Rapid development in the multimedia and its related fields drastically increases the size of the image repositories in diverse fields such as medicine, media, commerce, engineering, and entertainment. Simultaneously, the significant increase in the use of images for training, education and research in diverse fields greatly demands for effective and efficient system for storing and retrieving the images in/from the huge repositories, which is very difficult and most challenging task than ever before for a research community.

The traditional image retrieval techniques rely on manually annotated textual keywords [1]. With the large-scale image repositories, the results of textual keyword based retrieval systems are not completely reliable due to the usage of limited number of textual keywords, being subjective, laborious, time-consuming and tedious. The content based image retrieval (CBIR) system overcomes the shortcomings of textual keyword based image retrieval systems and it is an effective and

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efficient solution to deal with the large-scale image repositories. Thus, many effective CBIR systems have been presented in the literature [2–10] since 1990s with varying degree of reliability, capability and automation. The images in the CBIR systems are represented by a set of visual contents such as color, texture, spatial, and shape.

Since, color is one of the most prominent perceptual features of an image, several approaches such as color histogram, color moments, color correlogram, color autocorrelogram and MPEG-7 based scalable color descriptor (SCD), dominant color descriptor (DCD), color layout descriptor (CLD) and color structure descriptor (CSD) have been used in the literature [5,11] to represent the color information of an image.

Texture feature explores the structural arrangement of surfaces and its relationship in the images. Hence, many researchers [5,11–14] conducted studies on texture features extracted using the Markov random field, Hidden Markov random field, Autoregressive, Multiresolution Gaussian Autoregressive, Gibbs field, Homogeneous texture descriptor (HTD), BDIP and BVLC, wavelet transform based techniques and so on.

Shape features also provide potential information of an image. Many research efforts have been taken to describe the shape features [15–19] based on region and edge information. However, region based approach may not be easy and reliable for a diverse collection of images due to the unavailability of fully automated generalized approach [20]. Hence, most of the researchers employed the edge based techniques [21–25] for CBIR system.

In the same line, many researchers performed semantic based image retrieval [26–29]. But, they are not able to establish a robust map between automatically annotated textual keywords and visual contents for a wide range of visual concepts. Hence, it affects the desired level of generalization and accuracy. Moreover, creating a dictionary of textual keywords is difficult due to the semantic gap problem and it also requires manual verification process, which is tedious and time consuming. Recently, a few numbers of studies have been conducted to construct composite feature descriptors [21,23,30], namely joint composite descriptor (JCD) and micro-structure descriptor (MSD).

JCD is a combination of color and edge directivity descriptor (CEDD) and fuzzy color and texture histogram (FCTH). The JCD describes color, texture and shape information. For color information, JCD uses 24-bin color histogram produced by the 24-bin fuzzy-linking system, for texture information it uses energy in high frequency bands of Haar wavelet transform and for shape information it exploits MPEG-7 based edge histogram descriptor (EHD). The MSD extracts and describes the color, texture and shape information using the edge orientation similarity with the underlying colors.

Although, a number of techniques have been developed by the researchers, the retrieval accuracy of the existing CBIR systems is still limited and unsatisfactory. Thus, there is a need of an increased attention for extracting compact and more balanced visual characteristics of an image. Moreover, most of the early studies extract various visual characteristics (color, texture, shape, etc.) of an image using various kinds of techniques, which is a cumbersome process due to the complementariness of techniques.

The main objective of the proposed work is developing an efficient and effective CBIR system, which extracts all kinds of visual features (color, texture, spatial and shape) of color images in HSV color space using a framework based on Full Range Autoregressive (FRAR) model with Bayesian approach (BA) [12,13,31]. In the proposed system, the effectiveness of FRAR model with BA in capturing the edge and texture features of gray-scale images is successfully incorporated into color images in HSV color space and the same framework is used to extract the color features of an image. The extracted features are combined, normalized and stored in a separate feature vector database. The feature vectors in the feature vector database are indexed [32].

Artificial neural network techniques provide a potential solution for categorization task [33]. Recently, radial basis function neural network (RBFNN) [34] has attracted much attention due to its simple architecture, very efficient in learning, function approximation [35] and categorization tasks [36], and ability to escape from the local minima [37]. Hence, the present paper exploits the potential of RBFNN for image categorization. In RBFNN, the k-means algorithm [38] has been incorporated to determine the number of cluster centers. Correspondingly, several researchers reported that CBIR systems have been successfully applied the relevance feedback (RF) mechanism [39–41] to reduce the semantic gap and it considerably improves the retrieval performance of CBIR systems. Thus, this paper constructs a CBIR system with RF mechanism in short term learning. Manhattan distance measure [42,43] of order one is used to measure the similarity between the query and target images in the categorized and indexed feature vector space. Precision and recall method [42] is used to measure the performance of the proposed system.

The rest of the paper is organized as follows. The FRAR model is described in Section 2, while the feature extraction method is discussed in Section 3. Section 4 explains the RBFNN. The measure of similarity and performance is provided in Section 5. The proposed retrieval system is explained in Section 6. Section 7 provides experiments and results. Finally, conclusion is formulated in Section 8.

2. FRAR model

Recent literature reports that a framework based on FRAR model [12,13,31] outperforms the existing methods in terms of capturing the edge and texture features of gray-scale images. In the proposed system, a framework based on FRAR model with BA is used for extracting color and its spatial information, shape information and micro-textures of color images in HSV color space.

Let X be a random variable that represents the intensity value of a pixel at location (k, l) in an image of size $L \times L$. The FRAR model is expressed in Eq. (1).

$$X(k,l) = \sum_{\substack{p=-M \\ p=q\neq 0}}^{M} \sum_{q=-M}^{M} \Gamma_r X(k+p, l+q) + \varepsilon(k,l) \tag{1}$$

where $\Gamma_r = \frac{K \sin(r\theta)\cos(r\varphi)}{\alpha^r}$ and $r = |p| + |q| + M(M-1)/2$.

The initial assumption about the parameters are $K \in R$; $\alpha > 1$; θ, $\phi \in [0, 2\pi]$ and $n \in \{1,2,\ldots\}$. In Eq. (1), $X(k+p, l+q)$ is the spatial variation due to image properties and $\varepsilon(k, l)$ is the spatial variation due to additive noise and FRAR model coefficients Γ_r, $(r = 1, 2)$ is the variation among the low-level primitives in the sub-image region of size $M \times M$,