A NEW NON-SEGMENTATION SHAPE-BASED IMAGE INDEXING METHOD

Fariborz Mahmoudi [a], Jamshid Shanbehzadeh [b],
Amir-Masoud Eftekhari-Moghadam [a], and Hamid Soltanian-Zadeh [c,d]

[a] Iran Telecommunication Research Center, Tehran, Iran
[b] Department of Computer Eng., Teacher Training University, Teheran, Iran
[c] Department of Electrical and Computer Eng., Teheran University, Teheran, Iran
[d] Department of Radiology, Henry Ford Health System, Detroit, Michigan, USA

[a]{mahmoudi, eftekhari}@itrc.ac.ir, [b]jamshid@saba.tmu.ac.ir, [d]hamids@rad.hfh.edu

ABSTRACT

This paper proposes a new feature vector for non-segmentation shape-based image indexing and retrieval. This feature considers correlation between neighboring edges. Hence it includes information of continuous edges and lines of images and describes major shape properties of images. This scheme is effective and robustly tolerates translation, scaling, color, illumination, and small viewing position variations. Experimental results show superiority of proposed scheme over several other indexing methods. Averages of precision and recall rates of this new indexing scheme for retrieval as compared with edge direction histogram are 1.26 and 1.04 times, respectively.

1. INTRODUCTION

Shape-based image retrieval is a major category in content-based image retrieval (CBIR) systems [1]. This scheme is retrieval based on the shape similarity of images and requires achieving some information related to approximate shape of the objects in images. This information is the basis of feature vector generation. We can divide the shape-based algorithms from segmentation point of view; segmentation and non-segmentation based methods. The segmentation-based methods [2,3,4,5,6] detect the homogeneous regions of images, and then compute the feature vector with some region information like surface, contours, corners, curvature, etc. These methods are effective and compatible with human perception. However, they suffer from three following difficulties: 1) segmentation is never perfect; 2) they are unable to identify high frequency images; and 3) they have high computational overhead. These difficulties constrain segmentation-based methods to some special domains, for example, face identification.

The non-segmentation based methods extract shape factors of an image and generate feature vector without image segmentation [7,8,9,10,11,12,13]. For example, Zheng and Leung [8] presented a method using approximate segmentation, in order to avoid complete segmentation computational overhead. This method converted the image into a binary image, extracted twelve shape factors, and employed them as a feature vector. Since a binary image cannot detect homogeneous regions perfectly and regions merge together, this method is ineffective particularly in large image databases. Jain and Vailaya [10] introduced edge direction histogram (EDH). This method finds the image edges, and with grouping them on the quantized edge directions, generates the EDH. This method is relatively effective and performs retrieval independent of translation, scaling, and small viewing position variations. Since this method uses the edges individually and ignores correlation between neighboring edges, its effectiveness is limited.

This paper proposes a new non-segmentation shape-based image retrieval method called the *edge orientation autocorrelogram* (EOAC). The highlights of this approach are: 1) it includes the correlation between neighboring edges in a window around the kernel edge; 2) it describes the global distribution of local correlation of edges; 3) it describes shape aspects of an image and thus it is not sensitive to color and illumination variation; 4) it acts independent of translation, scaling, and small rotation; and 5) it is easy to compute. Our experiments show that this new feature outperforms non-segmentation based methods in retrieval by shape similarity.

The organization of the rest of paper is as follows. Section 2 introduces the edge orientation autocorrelogram algorithm. Section 3 describes the retrieval evaluation test-bed, and illustrates the superiority of the new scheme over other similar methods. The final section presents the conclusions.

2. EDGE ORIENTATION AUTOCORRELOGRAM

Correlogram is a proper tool to express the correlation between image elements [14]. This paper introduces a new approach to Correlogram called edge orientation autocorrelogram (EOAC) for image retrieval. The EOAC

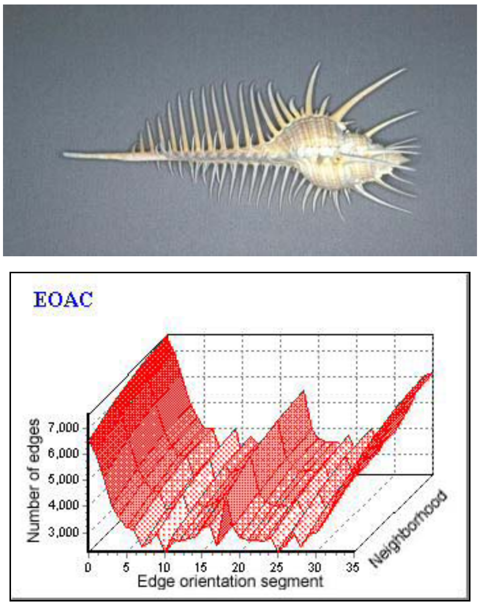

Figure 1- EOAC graph for an image sample.

classifies edges based on their orientations and correlation between neighboring edges, hence it contains major shape properties of the image. The algorithm of generating EOAC consists of six steps as follows:

1) Edge detection: The *Sobel* operator is less sensitive to noise than other edge detectors [15]. Therefore it has been used for edge detection and making the gradient image. This operator generates two edge components, G_x and G_y. The amplitude and edge orientation is computed as follows:

$$|G| = \sqrt{G_x^2 + G_y^2} \quad (1)$$

$$\angle G = tg^{-1}(G_y / G_x) \quad (2)$$

2) Finding prominent edges: This step extracts the prominent edges of the gradient image. The prominent edges are extracted by comparing all the edge amplitudes with a threshold value T_1. We have chosen $T_1 = 25$, which is approximately 10% of the maximum intensity value in the 8-bit original images [15].

3) Edge orientation quantization: This step quantizes the edges uniformly into n segments $\angle G_1, \angle G_2, \angle G_3, \ldots, \angle G_n$, and each segment is equal to five degrees.

4) Determining distance set: This step constructs a distance set (*D*), which shows the distances from the current edge that is used in calculating correlation. It is clear that near edges have high correlation together, thus the number and value of members of *D* must be low. In our algorithm we have chosen a set with four members as shown below:

$$D=\{1, 3, 5, 7\} \text{ and } d=|D|=4 \quad (3)$$

There is no need to consider the pixels with even numbers, because most of their information is in their adjacent pixels with odd numbers. For example, the correlation information associated with 2 pixels apart can be extracted from 1 and 3 pixels apart.

5) Computing elements of EOAC: In this stage, the edge orientation autocorrelogram is constructed. This correlogram is a two-dimensional array (a matrix), consisting of *n* rows and *d* columns. The $\langle j,k \rangle$ element of this matrix $(1 \le j \le n \ , \ k \in D)$ indicates the number of similar edges with the orientation $\angle G_j$, which are *k* pixel distances apart. Two edges with *k* pixel distances apart are said to be similar if the absolute values of their orientations and amplitudes differences are less than an angle and an amplitude threshold value, respectively [15].

6) Normalization of feature vector: Some variations on images such as scale, color and illumination changing affect the total number of prominent edges and consequently change the feature vectors. This step performs some modifications on the EOAC to make it invariant with respect to the three mentioned factors. Whereas, these variations have no effect on edge orientations, the populations of EOAC's elements are changed with a constant ratio. Therefore, feature vector normalization against scaling variation can be simply performed by dividing the population of each EOAC's element by the sum of the populations of all EOAC's elements.

Figure 1 illustrates the EOAC matrixes for a sample image as 3D graph. We have used this 3D EOAC as a feature vector for describing shape content of an image and as an index for shape-based image retrieval.

3. EXPERIMENTAL RESULTS

This section consists of three subsections as follows: The first subsection describes the image retrieval process. The second subsection presents the specification of the test-bed for retrieval evaluation. The final subsection evaluates the accuracy of the retrieval scheme.

3.1. IMAGE RETRIEVAL PROCESS

The EOAC matrixes are precomputed for the entire of the images of the database and stored in a feature database. This reduces the retrieval search time. At retrieval time, query image feature vector is computed in the initial step. Then a linear search is accomplished in the entire feature database and by comparing feature vectors, 12/24 similar images are retrieved in rank order. We used *L1* distance as comparison measures with the following formula:

$$L1(X,Y) = \sum_{i=1}^{n} |x_i - y_i| \quad (4)$$

3.2. RETRIEVAL EVALUATION TEST-BED

Since there is no standard test-bed for evaluating the performance of image retrieval methods, we have setup a prototype image retrieval evaluation system. We have evaluated EOAC performance and compare it with other schemes by using the evaluation system. The prototype system consists of an image database, a set of benchmark queries, a set of relevant images, and a set of evaluation metrics as described below.

a) Image Database: We used 10,000 photos package from Greenstreet (www.gstsoft.com) as an image database. This collection includes 10,000 JPEG color images with different sizes from heterogeneous classes.

b) Benchmark Queries and Relevant Images: For the purpose of performance evaluation, we have chosen 65 images from different classes as query images. For each query image, we have considered a set of relevant images and added them to image database. The relevant images are very similar to their query image with some differences on color, illumination, scaling, translation, and viewing position variation. Ideally, when a query is performed all of its relevant images should be retrieved in lower ranks.

c) Performance Evaluation Metrics: This paper has analyzed the performance in terms of *retrieval accuracy.* This term is concerned with effectiveness of image retrieval. For this purpose, many researchers have computed *precision* and *recall rates* as two accuracy metrics. There is no standard definition for these metrics. Based on the general concepts, different researchers have presented different formulas [16,17,18]. Semantically, recall rate evaluates accuracy of the system by the number of retrieved relevant images and precision rate acts based on the ranks of retrieved relevant images. In the following, by considering formulas introduced in [16], we have employed some formulas for these two metrics. Our metrics are normalized so that they are independent of the number of relevant images. Therefore, the ranges of values for precision and recall rates are between 0 and 1 in all of the cases, and their ideal value of them is 1. The precision and recall rates are computed as follows:

$$Y(Q) = \left| \{ I_i \mid Rank(I_i) \le k, I_i \in A \} \right| \quad (5)$$

$$R(Q) = \frac{Y(Q)}{|A|} \quad (6)$$

$$P(Q) = \frac{\sum_{i=1}^{Y(Q)} fib(Rank(I_i))}{\sum_{i=1}^{|A|} fib(i)} \quad (7)$$

$$\begin{cases} fib(i) = fib(i+1) + fib(i+2) & if \quad 1 \le i \le k-2 \\ fib(k-1) = 2 & \\ fib(k) = 1 & \\ fib(i) = 0 & else \end{cases} \quad (8)$$

Where parameters used in above formulas are:
Q – A sample query image.
P(Q) – Precision rate of Q.
R(Q) – Recall rate of Q.

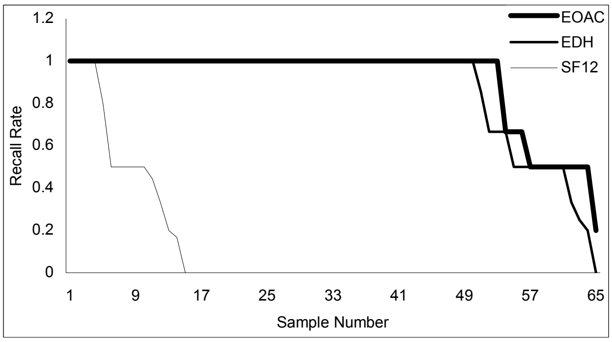

Figure 2- Comparison of recall rates of SF12, EDH and EOAC .

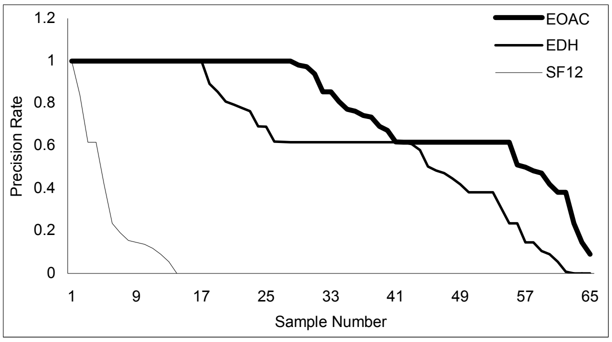

Figure 3- Comparison of precision rates of SF12, EDH and EOAC.

A – The set of relevant images of *Q*.
I_i – The i[th] relevant image of *Q*.
k – The number of retrieved images *(k=24).*
Y(Q) – The number of retrieved relevant images of *Q*.
Fib – The fibonacci function that emphasizes on images retrieved in lower ranks.

3.3. ACCURACY EVALUATION

For the purpose of accuracy evaluation, we have measured the averages of precision and recall rates for all 65 benchmark queries. We have also implemented the twelve shape factors (SF12) [8], the edge direction histogram (EDH) [10] in our prototype test-bed and measured same metrics for them. The experimental results presented in figures 2 and 3.

These diagrams show precision or recall rates for all the benchmark queries sorted by their values. In other words, if *n* is considered as a point on the horizontal axis and *f(n)* as its function value on the vertical axis, *n* is the total number of images that their precision or recall rates are greater than or equal to *f(n)*. In these diagrams, areas under the curves are proportional to, the accuracy of methods. Whereas, the area under EOAC's curves is greater than the area of other methods, this indicates the superiority of our scheme. Figure 4 shows some example of image retrieval via EOAC.

a-1- Query image

a-2- Image retrieved in rank 1

b-1- Query image

b-2- Image retrieved in rank 1

Figure 4 – Two samples of retrieval via EOAC

4. CONCLUSIONS

This paper presented a new image feature called the edge orientation autocorrelogram (EOAC). This feature is used for non-segmentation shape-based image indexing and retrieval. The EOAC is independent of color and illumination, therefore images with these variations are appropriately retrieved. The EOAC is also appropriate for retrieving images with continuous and clear edges particularly images with direct lines, because it extracts proper information from correlation between edges on a border. Despite this effectiveness, the EOAC is not appropriate for retrieving texture-based images and images with unclear edges. The main reason for the superiority of EOAC is further use of correlation between edges in feature vector generation.

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