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Novel Shape Description for CBIR in Medical Application

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Abstract. Image Retrieval for Medical Applications (IRMA) has received a significant research interest over the past decade as a promising approach to address the data management challenges posed by the rapidly increasing volume of medical image data collections in use and also to aid clinical medicine, research, and education relying on visual content in the data. The research presented in this paper was aimed to improve the retrieval performance of an images retrieval system in medical applications based on shape features. In general, the work consists of two phases: (1) enrollment phase, which consist of feature extraction based on developed method to extract the shape features, (2) retrieving phase, which use the Euclidian distance measure. The conducted tests were carried on 350 medical images from four types (i.e., abdominal CT scan, MRI, ultrasonic, X-ray) and give good precision and recall rates (94,89).

Keywords: Content Based Image Retrieval (CBIR), shape, sobel filter.

1. Introduction

Shape of the objects represented in images is one of the most significant properties used in CBIR and in recognition tasks. This is particularly due to the fact that shape is perceptually very relevant in order to recognize objects. In some circumstances shape contains more intrinsic information about the represented object than color, texture or other features. From a geometric point of view, shape can be informally defined as the result of removing color, texture, and effects due to affine transformations such as scale, translation and rotation from a representation of an object in an image [1].

Various techniques used for shape description. These techniques can be broadly categorized into two types: (1) boundary based and (2) region based. Boundary based methods use only the contour or border of the object shape and completely ignore its interior. Hence, these methods are also called external methods. The region based techniques take into account internal details (like holes) besides the boundary details. Recognition of a shape by its boundary is the process of comparing and recognizing shapes by analyzing the shapes boundaries; but the local structural organization is always hard to describe [2].

The shape of an object is a very important character in human's perception, recognition, and comprehension. Because geometric shape represents the essential characteristic of an object the recognition of shapes in images is an important problem in computer vision. A fast recognition of contours provides an efficient and robust way of accelerating the search. The similarity measures for such shape matching must be robust to various transformations and modest occlusions [3].

This paper proposes a new method for shape features extraction which intends to describe 2D shapes in images. Many studies have applied the concepts of shape feature extraction and similarity measurement to analyze and retrieve medical images for example, Choras [4], Presented an approach for shape based image retrieval using the moments invariants and some shape descriptors. The proposed approach has three modules: image preprocessing, shape descriptor, and retrieval. The retrieval module is based on the Euclidean distance that compares an image query feature vector with a feature vector of the database contain 120 greyscale images of isolated objects with arbitrary orientation. Nunes, et al [1], proposed the use of a reduced set of features to describe 2D shapes in images. The design of the proposed technique aims to result in a short and simple to extract shape description. For the retrieval experiment the achieved bull's eye performance is about 60%. Recognition was tested with three different classifiers: decision trees (DT), k-nearest neighbor (kNN) and support vector machines (SVM). Estimated mean accuracies range from 69% to

86% (using 10- fold cross validation). The SVM classifier presents the best performance, followed by the simple kNN classifier. Kalpana, et al [5], presented a new idea of using Walsh transform to generate the feature vector for content based image retrieval. The proposed algorithm is worked over database of 270 images spread over 11 different classes. The Euclidean distance is used as similarity measure. Average precision and recall is calculated for the performance evaluation. The overall average of cross over points of precision and recall is above 50%. Joseph, and Govindan [6], presented a novel approach for sketch based image retrieval (SBIR) using Contourlet edge detection. Test results carried out on a database of 1240 images provide the precision rate as 0.8 and the recall rate as 0.5.

This paper is organized as follows. In Section 2 the basic concepts and used methods are described, Section 3, the tests of the proposed method are presented. In the last section contains the conclusions of the proposed work.

2. Concepts and Methods

2.1. Content Based Image Retrieval

The picture may worth thousands of words. Humans have often used drawings to convey information. The cave men have told us about their dangerous hunting trips through the illustrations on the stone walls. The Pharaohs have illustrated their customs of praying on the walls of their temples. Nowadays, visual information can be found in most (if not all) areas of life. As the impact of computers on our lives is becoming more and more significant, much of the information, including pictures, is being digitized. Digital imagery is getting more popular in many perspectives. Private photo collections, medical imaging, and geographical information systems are only some to mention. As the computation power is growing and the cost of storage media is decreasing, the size of digital image collections is increasing rapidly. There is a need for techniques that enables us to access and retrieve the huge amount of information embedded in these collections, methods that can present us the information efficiently and conveniently. Simple manual browsing is getting cumbersome even with private collections. Automatic image retrieval is inevitable [7].

In 1992, the National Science Foundation of the United States organized a workshop on visual information management systems in order to identify new directions in image database management systems. At this conference, Kato [8] introduced the term Content-Based Image Retrieval (CBIR) to describe automatic retrieval of images from a database. He emphasized the use of color and shape as the criteria for the automatic image retrieval process. Since then, the term CBIR has been adopted to describe an image-retrieving process that is used for large collections of images and that is based on features that can be automatically extracted from the images themselves. The visual contents of the images are extracted and described by feature vectors that form a feature database. During the retrieval stage, the users provide the retrieval system with a sample image (query image) or a sketched figure. The system then changes this query into feature vectors. In the matching stage, the system calculates the similarities between the feature vectors of the query sample or sketch and those of the images in the database, and then performs the retrieval accordingly [9].

Content Based Image Retrieval is a set of techniques for retrieving semantically-relevant images from an image database based on automatically-derived image features. The main goal of CBIR is efficiency during image indexing and retrieval, thereby reducing the need for human intervention in the indexing process. The computer must be able to retrieve images from a database without any human assumption on specific domain. One of the main tasks for CBIR systems is similarity comparison, extracting feature signatures of every image based on its pixel values and defining rules for comparing images. These features are considered as the image representation structure which used for measuring it degree of similarity with other images registered in the database. Images are compared by calculating the difference of its feature components with the corresponding features of other image [3]. CBIR draws many of its methods from the field of image processing and computer vision. Image processing covers a much wider field, including image enhancement, compression, transmission, and interpretation. While there are gray areas (such as object recognition by feature analysis), the distinction between mainstream image analysis and CBIR is usually fairly clear-cut [10].

2.2. Sobel Filter

Edge detection is an important first stage in the determination of existing orientations in images. Edges correspond to local intensity discontinuities of an image. Edge detection can be used for feature extraction and object or boundary description.

Sobel operator is applied in this work to evaluate the strength of existing edges and to produce a new image with edge information. This new edge image will be utilized to compute moments as indicators for shape feature. Sobel operator uses the convolution concept, where a set of two 3 x 3 convolution kernels will be used. One of the kernels is used to detect the brightness changes in the horizontal direction (Gx), and the other one used to detect the brightness changes in the vertical (Gy) direction. Figure (1), illustrates to the kernel of Sobel filter.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Fig. 1: Sobel operators

Then, the gradient magnitude (i.e., edge strength) can be calculated from the following equation:

$$|G| = \sqrt{Gx^2 + Gy^2} \tag{1}$$

The new |G| is considered as the edge strength of the tested pixel. A new edge image will be created once all the |G| values over the entire coordinates are collected. An example of the input image before and after edge detection process is shown in Figure (2).

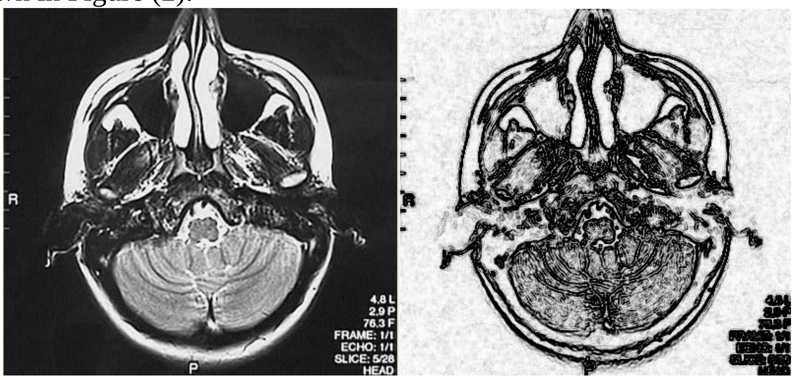

Fig. 2: The input before edge detection and the output after edge detection

2.3. Distance Measure

In this work the similarity measure between a pair of images Q and T having feature vectors Qi and Ti is computed using Euclidean distance metric. The uniformity assumption of the feature space implies that the perceptual distances between points in the space correspond to the Euclidean metric. The similarity measure is therefore:

$$d(Q,T) = \sum_{i=0}^{N-1} |Q_i - T_i| \tag{2}$$

Where Q = {Q0, Q1, … QN-1} and T = {T0, T1, …, TN-1} are the query and target feature vectors respectively, d(Q, T) is the Euclidean distance, N values which represent feature vector length.

The distance between two identical images is zero, (i.e., d(Q, T)=0). Smaller values of distance d() indicate more similarity between images and vice-versa. For similarity retrieval of images, the Euclidean distance d(Q, T), can be computed between the query image and all the database images. Then the thresholds value will be used to determine images to be retrieved.

2.4. Proposed method

The shape or form of the object is an attribute that must significantly change when the original object is submitted to a certain set of affine geometric transformations. A 2-D shape descriptor should be invariant to translation, scale changes (uniform in both the X-coordinate and the Y-coordinate) and rotations. Since shapes in medical images are usually complicated, and the process of isolating objects from background in medical images is too complicated and requires high computational complexity, so in order to get an applicable retrieval system that requires a reasonable computational potential a combination of edge detection using Sobel operator and high order moments for the edge image is proposed and used.

The operation of any typical image retrieval system passes through two main phases (enrollment and retrieving similar images). In the first phase the whole set of databases images are passed through the feature extraction module to extract the features vectors and then stored in feature vector databases. The collection of samples consists of 250 images stored in image database, and same number of feature vectors have been registered and saved in a dedicated database called feature vector database.

In the second phase of system operation (i.e., retrieving phase), a set of test samples had been used to investigate the efficiency of the established retrieval system. In this phase, the tested image sample (i.e., 100) is passed through the feature extraction module to extract its feature vector and match this extracted feature vector with stored vectors in feature vector database. Finally, a list of similar images to a given sample is retrieved from image database. For purpose of performance evaluation some of the retrieval results for the conducted tests were used to determine the precision and recall rates of the proposed system. The block diagram for the proposed system is shown in Figure (3).

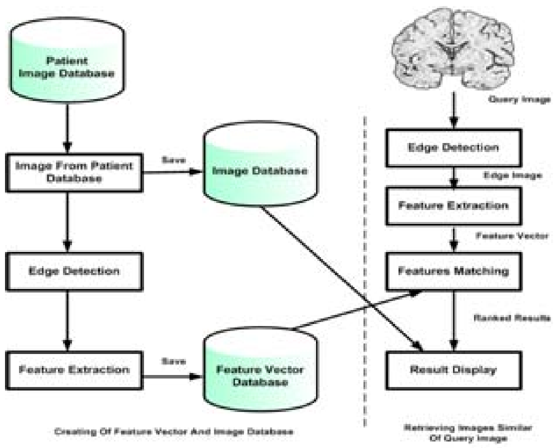

Fig. 3: The proposed shape image retrieval system

In both system operation phases (i.e., enrollment and retrieval), the same image loading module is included and also the same edge detection, and feature extraction module is applied.

The edge detection process is to identify the edges of the existing objects in an image and to create a new image file which contains the edge information which in turn is good signs for the geometrical behavior of the existing objects. The medical image will be processing by passing Sobel operator on it to produce its edge image. Then the produced edge image is partitioned in to overlapped blocks have same size (L*L), the moments are determined for these blocks, separately and the histogram for these moments are determined, and then a set of moments are determined using the histograms.

The implementation of shape feature extraction stage implies the following steps:

- Partition the edge image into overlapped blocks, each block has size LxL, where L is the block length. In this work, the values L=4, 6, 8, 10, 12 or 14 where tested. Also, different values for distance between the overlapped blocks (i.e., jump step value) are tested (i.e., 2, 4, 6, 8, 10, or 12). The Usefulness behind using the overlapped horizontal and vertical blocks is to improve the relationship among the adjacent pixels to overcome the scale and orientation problem. An example of partitioning the image in to overlapped blocks is shown in figure (4) below.

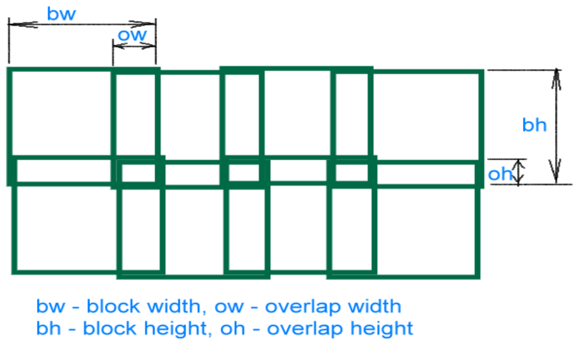

Fig. 4: Representation of the overlapped blocks method

- Calculate the number of overlapped blocks within image, where the horizontal number of blocks (i.e., image width-block length)/jump step), and the vertical number of blocks (i.e., image height-block length)/jump step).
- For every block extracted from the edge image do the following:
    - For each block calculate the local edge density ($\overline{D}$) and standard deviation (σ_D) value within this block using the following equations:

$$D = \frac{1}{Blocksize} \sum_{i=0}^{blocklength-1} \sum_{j=0}^{blocklength-1} feat(x, y) \tag{3}$$

$$\sigma^2{}_D = \frac{\sum_{i=0}^{blocklength-1} \sum_{j=0}^{blocklength-1} feat(x, y)^2}{Blocksize} - D^2 \tag{4}$$

Where feat(x,y) is the edge feature

- Determine the mean for the calculated density and standard deviation values over all blocks.

Extract set of 6-order moments for the edge density distribution. This set will be used as shape feature vectors.

3. Results and Discussion

The main stages of the established system are: feature extraction and retrieving using similarity measurement. The feature extraction unit has two parameters, namely; block length and jump step. The parameters of this stage have considerable effects on the discriminating power of extracted feature vector. In the retrieval unit the threshold value have important role to acceptable precision and recall rates.

Two metrics for retrieval effectiveness were used; they are recall and precision. Recall signifies the relevant images in the database that are retrieved in response to a query. Precision is the proportion of the retrieved images that are relevant to the query. They defined as follows:-

(1) Percentage of precision

$$\text{Precision} = \frac{\text{Retrieved related images}}{\text{Total retrieved images}} * 100\% \tag{5}$$

(2) Percentage of recall

$$\text{Recall} = \frac{\text{Retrieved related images}}{\text{Total related images}} * 100\% \tag{6}$$

The number of medical images samples used in the below sets of tests are more than 100 samples, also 250 samples of sizes (400x320), (400x400) and (500x330) stored in the database, from multiple sources contain abdominal CT scan, MRI, Ultrasonic and X ray images. Also, 6000 features stored in features vectors database (i.e., each image have 24 features). Figure (5) presents the main window of the developed image retrieval system based on shape feature extraction, an example image is presented to the system and the user makes a query for images that are similar to the given example. Performance of CBIR systems is highly dependent on the properties of the example image.

Fig 5: The proposed system interface

A. The Effect of Block Length and Jump Step

In this set of tests the system performance was tested using different blocks sizes and jump steps to estimate the image shape features. Table (1) shows the effect of using different block sizes and jump steps, when the value of threshold is set to (23).

TABLE (1) THE EFFECT OF BLOCK LENGTH AND JUMP STEP ON SHAPE IMAGE RETRIEVAL PRECISION AND RECALL

Block length	**Jump step**	**Precision**	**Recall**
4	**2**	**90%**	**75%**
6	**4**	**88%**	**75%**
8	**6**	**92%**	**80%**
10	**8**	**94%**	**89%**
12	**10**	**85%**	**78%**
14	**12**	**65%**	**65%**

As shown in Figure (6), the most suitable values for block length and jump step are (10) and (8), respectively, they lead to good precision and recall values.

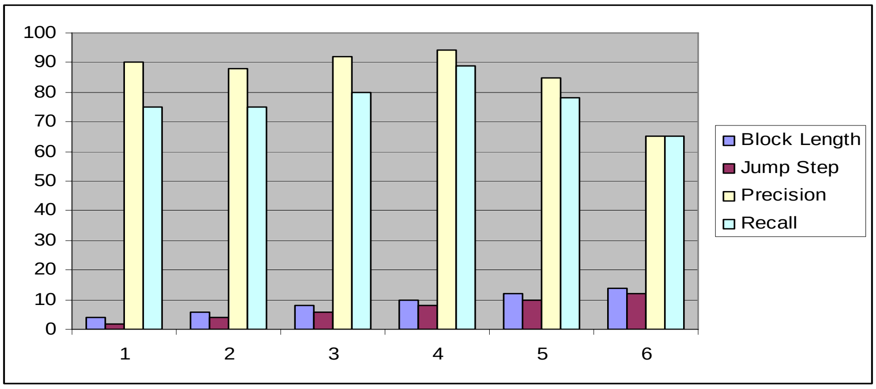

Fig. 6: The effect of block length and jump step on shape image retrieval precision and recall

B. The Effect of Threshold Value

The test aimed to investigate the effect of using different threshold values on system precision and recall, when the values of block length and jump step set to (10) and (8), respectively. Table (2) presents the result of this test.

TABLE (2) THE EFFECT OF THRESHOLD VALUE ON SHAPE IMAGE RETRIEVAL PRECISION AND RECALL

Threshold	Precision	Recall
15	**100%**	**65%**
19	**100%**	**75%**
20	**98%**	**83%**
23	**94%**	**89%**
30	**91%**	**91%**
32	**85%**	**93%**
39	**65%**	**95%**

In the experiment as shown in figure (7), the most suitable value for threshold is the (23) which give the good precision and recall values.

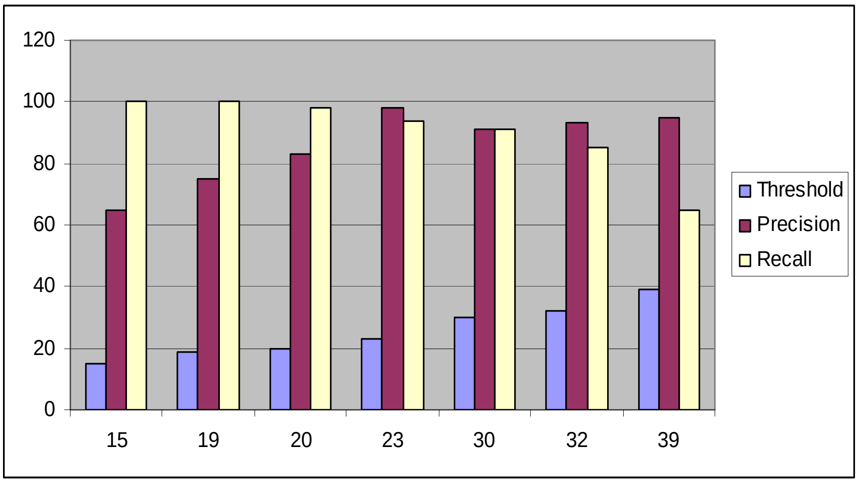

Fig 7: The effect of threshold value on shape image retrieval precision and recall

4. Conclusion

The use of 24 features extracted from edge describers and high order moments can be utilized to describe the shape content of abdominal CT scan, MRI, ultrasonic and X-ray images.

For shape feature extraction the idea of "edge density histogram" is introduced; then the moments (up to 6th order) of this histogram is used to describe the feature. The edge density is determined after prtitioning the image into overlapped blocks.

Testing the effect of using different block length and overlap ratio helps to find the suitable values which lead to best retrieval results for shape medical images.

The established shape image retrieval system gave better precision and recall rate (94, 89), when the block length is taken 10, jump step taken 8 (i.e., overlap ratio=%20), and threshold value less than or equal (23).

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