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Application of Edge Histogram Descriptor and Region Shape Descriptor to MRIs

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Abstract. Medical images have a crucial place in the medical diagnosis. As a specific part of medicine, Magnetic Resonance Imaging (MRI) has become a useful modality since it provides plentiful information and high sensitivity. The rapid growth of MRI technology results in increasingly amount of MRIs which have to be efficiently stored, analyzed and described. By improving these processes, the decision making process for the clinicians is getting easier.
In this paper we apply the Edge Histogram and the Region-based Shape descriptors standardized by MPEG-7 standard to MRIs. We have used 13917 MRIs provided by ImageCLEF 2008. Experimental results showed the Edge Histogram Descriptor achieves higher precision. We have also combined both descriptors by averaging their output ranks. Analysis showed that averaging the output ranks leads to higher precision. However, the obtained results and the fact that MRIs have specific characteristics suggest that additional image processing techniques have to be used.

Keywords: Magnetic Resonance Imaging (MRI), Content Based Image Retrieval (CBIR), MPEG-7, Edge Histogram Descriptor, Region-based Shape Descriptor.

1 Introduction

The already large and continuously increasing amount of medical images indicates the necessity for developing system characterized by efficient and precise storing, indexing and retrieval capabilities.

CBIR systems can be used for searching and retrieving different kinds of images from large databases on the bases of the visual content of the images. Thus the precise retrieval from the large images collections can be accomplished by indexing or feature extraction, namely, by describing the images according to their content.

Medical images and especially digital medical images used for diagnostic, therapy and research purposes are very significant for the medicine field. Thus, Digital Imaging and COmmunication in Medicine (DICOM) standard [1], [2] is provided by the National Electrical Manufacturers Association (NEMA) [3] to enable a stable communication between imaging systems and other healthcare information systems with a wide variety of different kind of equipment in an efficient way which ensures a high level of compatibility.

Moreover, developing Picture-Archiving and Communication Systems (PACS) [2], [4], provides techniques for high resolution image acquisition and storage, high speed networking, standardized transmission format support and a consistent way for image representation in different and often distributed nodes.

Developing content based image retrieval systems for medical purposes improves the process of storing, indexing an analyzing medical image content. Moreover, refining the efficiency and precision of medical CBIRs helps the decision making process which is often very difficult and specific.

CBIR systems for medical purposes are categorized into two categories: those that retrieve the entire anatomic structure and those that retrieve abnormalities or pathologies within an anatomical structure [5]. The second type of CBIRs is more complex than the first, but more precise and specific as well.

CBIR systems for medical purposes have been continuously developing. One such system is Automatic Search and Selection Engine with Retrieval Tools (ASSERT) [6]. This system uses images by High Resolution Computed Tomography (HRCT) of lung and includes two main phases of operation: the image archiving and the image retrieval phase.

One medical CBIR system is CasImage [7], developed at the University Hospital in Geneva, Switzerland. The image database in CasImage contains medical images obtained from different modalities such as MRI, CT, radiographs. The system is integrated into a Picture Archiving and Communication System (PACS) environment and includes a teaching and reference database. To retrieve medical images different combinations of visual characteristics of the image content and textual labels are used.

Another system developed as a platform for content-based medical image retrieval is IRMA system. The process behind IRMA includes categorization, registration, feature extraction, feature selection, indexing, identification and retrieval [8], [9].

The paper is organized as follows. Section 2 provides a brief overview on existing content based image retrieval systems used for MRIs, while Section 3 depicts the main concept of the feature extraction process by using the Edge Histogram Descriptor and the Region-based Shape Descriptor and the appropriate similarity measurements specified by MPEG-7 standard that will be use in the later retrieval process. Section 4 presents the application of the Edge Histogram Descriptor and Region-Based Shape Descriptor on the MRIs. Also, some experimental results are presented in section 4. Section 5 concludes the paper.

2 Related Work

Medical Content Based Image Retrieval (CBIR) systems intended for the domain of MRI requires a specific design basically because of the very particular features of MRIs. In fact, the phase of making appropriate description of the image content and applying the appropriate image processing techniques is very important to achieve accurate, efficient and correct retrieval process.

The CasImage system, mentioned in the previous section, is not basically aimed for MR Images, but besides CT images and radiographs, also contains and works with MRIs.

Another CBIR platform based on two-level architecture is designed especially for the domain of brain MRI image retrieval. To obtain flexibility in MRI analysis one level or a combination of the two levels can be used. In the first level, the main goal is to make non-specific description of MR image. At the second level specific regions of interest are being analyzed [10]. Thus, the system consists of two main functional stages: the import stage and the retrieval stage. In the first stage occurs the process of continuously searching for images and importing images in the database by the application specific agent (brain MRI in this case). Then, follow the feature extraction and storage. In the next stage, the retrieval stage, the user request is followed by the feature extraction from the Query Image, the access to the DB and feature comparison, then to the voting stage, and finally the presentation of the results to the user. The retrieval result is updated as more images from the DB are analyzed, until the user is satisfied or all the DB images are compared to the query [10].

Each agent [11] has its own database used for extracting, retrieving and storing information. Summarizing the results from the asynchronous parallel processes for retrieval decision task is made by the selected voting scheme.

Another CBIR system for automatically extracting image content features is proposed in [12] where combination of registration, segmentation and natural language processing is made. This system is tested with MRIs of the brain of 9 patients. The capabilities of this system should be additionally tested with bigger dataset. However, with the information for 9 patients stored in the system, it gives correct identification result.

3 Content Based Retrieval Using Edge Histogram Descriptor and Region Based Shape Descriptor

According to [13] visual features of the images can be classified into:

- Primitive features – color or shape, for example
- Logical features – identity of objects shown
- Abstract features – significance of scenes depicted.

On the other hand, primitive features can be used from the view point of a global image level or of a local level on the particular parts of images [14] if, for example, blocks of fixed size and location, or image partitioning is obtained.

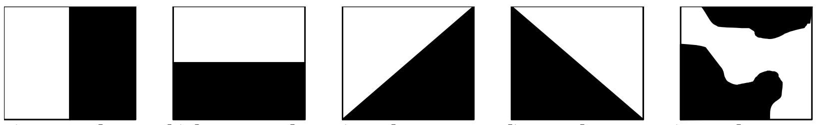
The medical images, in general, do not contain color or are taken under controlled conditions. According to [14], the color features are not the features of interest when the research of medical image content, and especially MR Image content, is obtained. For that reason, in this paper texture and region based descriptors are analyzed and a comparison between one of each type is provided.

MPEG-7 visual standard [15] provides descriptors on the bases of visual content of streamed or stored images or videos. The MPEG-7 descriptors can be categorized into two main categories: General visual descriptors (include color, texture, shape and motion features) and Domain-specific visual descriptors (e.g. face-recognition descriptor).

In this paper, Edge Histogram descriptor and Region-based Shape descriptor provided by MPEG-7 standard are used for feature extraction.

3.1 Edge Histogram Descriptor

The edge histogram descriptor (EHD) represents the local edge distribution by dividing image space into 4×4 subimages and representing the local distribution of each subimage by a histogram. The fact that the EHD consists of the local-edge histograms only, makes it very flexible. In the sense of generating histograms, edges in all subimages are categorized into five types shown on Fig. 1: vertical, horizontal, diagonal and nondirectional edges (namely edges with no particular directionality), resulting in a total of 5×16 = 80 histogram bins. Each subimage is further divided into nonoverlapping square image blocks with particular size which depends on the image resolution. Each of the image blocks is then classified into one of the five mentioned edge categories or as a nonedge block [15].



a) vertical b) horizontal c)45 degree d) 135 degree e)non-directional

Fig. 1. Five types of edges in the Edge Histogram descriptor.

However, the local-edge histograms alone may not be sufficient for an effective image matching. Instead, some global-edge distributions as well as the local ones are used. Specifically, edge distribution information for the whole image space and some horizontal and vertical semiglobal-edge distributions as well as local ones are required [15] in order to improve the matching performances.

In the retrieval process where Edge Histogram Descriptor is used, we have used expression (1) as an appropriate similarity distance measure:

$$D(d,q) = \sum_{0}^{79} \left| h_d(i) - h_q(i) \right| + 5 \times \sum_{0}^{4} \left| h_d^g(i) - h_q^g(i) \right| + \sum_{0}^{64} \left| h_d^S(i) - h_q^S(i) \right| \qquad (1)$$

where $h_d(i)$ and $h_q(i)$ represent the normalized histogram bin values of image *d* from the database and the query image *q*, respectively; $h_d^g(i)$ and $h_q^g(i)$ represent the normalized histogram bin values for the global edge histogram of image *d* from the database and the query image *q*, respectively obtained from the corresponding local edge histograms $h_d(i)$ and $h_q(i)$; and $h_d^S(i)$ and $h_q^S(i)$ represent the histogram bin values for the semiglobal-edge histogram of image *d* and image *q*, respectively [15]. Since the number of bins of the global histograms is relatively smaller than that of local and semiglobal histograms, a weighting factor 5 is applied, as defined by the MPEG-7 standard [15].

3.2 Region Based Shape Descriptor

The region-based shape descriptor includes both the boundary and interior pixels, in fact, all pixels belongs to the shape. This descriptor can be applied to the object consisting of a single connected region or multiple regions, possibly with wholes. The main concept behind the region-based descriptor is decomposing the shape into a number of orthogonal 2D basis functions, defined by the Angular Radial Transform (ART). The ART coefficients are defined by:

$$F_{nm} = \langle V_{nm}(\rho,\theta), f(\rho,\theta)\rangle = \int_0^{2\pi}\int_0^{1} V_{nm}^{*}(\rho,\theta), f(\rho,\theta)\rho d\rho d\theta \tag{2}$$

where F_{nm} is an ART coefficient of order n and m, $f(\rho,\theta)$ is an image function in polar coordinates and $V_{nm}(\rho,\theta)$ is the ART basis function that are separable along the angular and radial directions defined by (3).

$$V_{nm}(\rho,\theta) = A_m(\theta)R_n(\rho) \tag{3}$$

In order to achieve rotation invariance, an exponential function is used for the angular basis function A_m. The radial basis function $R_n(\rho)$ is defined by a cosine function.

$$A_m(\theta) = \frac{1}{2\pi}exp(jm\theta) \qquad R_n(\rho) = \begin{cases} 1 & n = 0 \\ 2\cos(\pi n\rho) & n \neq 0 \end{cases} \tag{4}$$

After applying this kind of transform, the normalized and quantized magnitudes of coefficients are used as a description of the particular shape [15]. The description process using region-based descriptor is characterized by twelve angular and three radial functions, and the quantization method is used to keep the descriptor size to a minimum.

The similarity distance that is the most appropriate using this descriptor is given with expression (5) and uses the L_1 norm, by summing up the absolute differences between ART coefficients of equivalent order:

$$D(d,q) = \sum_i \left\| M_d[i] - M_q[i] \right\| \tag{5}$$

In expression (5) the subscript d and q depicts the image in the database and the query image, respectively, and M is the array of ART descriptor values [15].

3.3 Averaging output ranks

Magnetic Resonance Imaging, as a specific technique for medical diagnosis, needs as precise as possible computer analysis support. Thus, every improvement in the effectiveness of the retrieval process for magnetic resonance imaging is of very high importance for medical analysis.

In this paper we made a combination by averaging the output ranks provided by the retrieval process using both descriptors, Edge Histogram Descriptor and Region-based Shape Descriptor for feature extraction. Using a combination of the outputs may reduce the risk of an inappropriate feature extraction of a poorly performing descriptor and may or may not emphasize and combine the advantages of both descriptors.

4 Evaluation Results

The main goal of this paper is to apply the edge histogram descriptor and the region-based shape descriptor to a set of magnetic resonance images. We have used 13917 MRIs provided by ImageCLEF 2008 (Cross Language Evaluation Forum) [16].

Fig.2 shows the first 5 closest result images provided by the retrieval process when the image located on the top of Fig.2 is used as a query image if the database images and the query image are described by using edge histogram descriptor. As a similarity measure expression (1) is used. Similarly, Fig.3 depicts the first 5 closest matches if the region-based shape descriptor is used for feature extraction. In the second case, the appropriate similarity measure given by (5) is used.

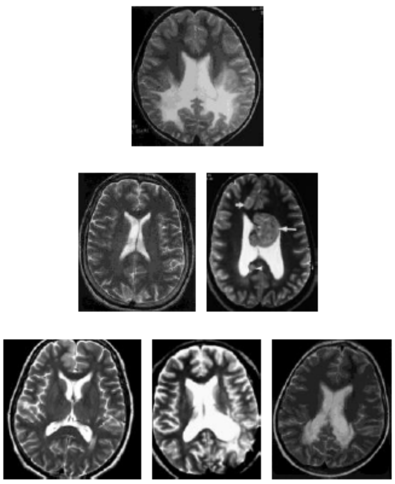


Fig. 2. Retrieval results by using Edge Histogram Descriptor.

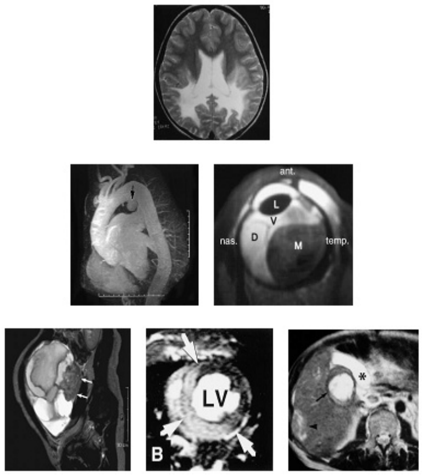


Fig. 3. Retrieval results by using by using Region-based Shape Descriptor.

As it can be seen from Fig.2 and Fig.3, the edge histograms descriptor retrieves much similar images than the region-based shape descriptor.

Evaluation of both descriptors is obtained. A dataset consists of 13917 MRIs. We have used 10% of the dataset (1392 MRIs) as a test dataset.

The evaluation of the retrieval effectiveness is provided by calculating the precision and recall [17]. Let n_t denote the number of training images in class t. For each of the feature vectors of the testing images we find the n_r nearest neighbors of training images. The precision rates, defined by (6) as in [17] and [18] are calculated from the ranked retrieval result denoted as r. A function $rank(r, i)$ returns the rank of the i-th training image from class t, in r.

$$Precision = \frac{\sum_{i=1}^{min(n_r, n_t)} i / rank(r,i)}{min(n_r, n_t)} \tag{6}$$

Precision rates are reported to evaluate the retrieval accuracy based on recall rates from 10% up to 100% with step 10%. Each recall rate shows the fraction of relevant training images that have been retrieved. A training image is considered to be relevant if it has the same class label as the testing image.

Precision recall diagrams of descriptors are depicted on Fig.4. According to the retrieval, we can conclude that the edge histogram descriptor gives higher precision than the region-based shape descriptor.

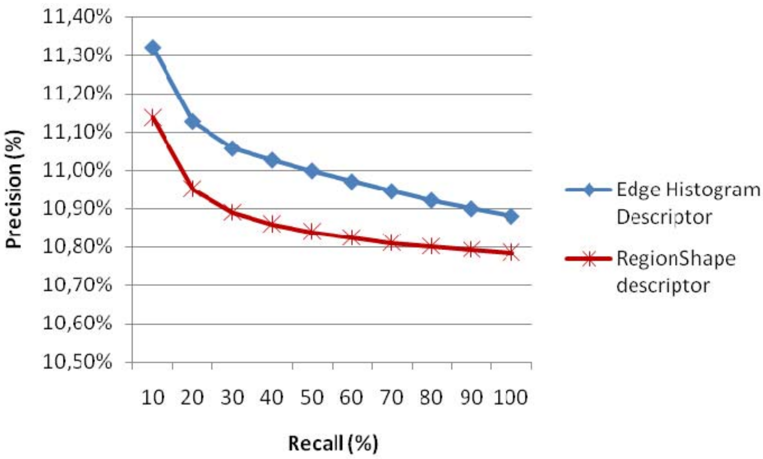


Fig. 4. Precision-recall diagrams.

We evaluated the results obtained from the combination technique which averages the output ranks of both descriptors. The appropriate precision – recall diagram is depicted on Fig. 5.

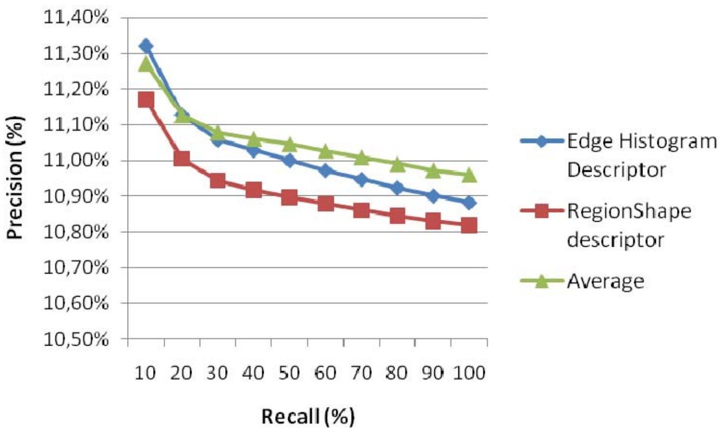


Fig. 5. Precision-recall diagrams.

According to Fig. 5, we can conclude that the precision of the retrieval process at some levels of the recall (recall>20%) is better using the averaging process of the output ranks obtained in the retrieval process in both cases, feature extraction phase by using Edge Histogram Descriptor and feature extraction phase by using Region-based Shape Descriptor. Also, it is worth to mention that the curve by averaging output ranks decreases more mildly than the rest. So, if the dataset was bigger, the difference would be even more remarkable.

However, additional image processing techniques should be applied in the field of MRIs to obtain higher precision, because of their specific characteristics and complexity.

5 Conclusion

The significance and usability of CBIR system for automated image analysis and retrieval, especially in the domain of Magnetic Resonance Imaging (MRI) according to the new approaches and innovations in MRI technology, is continuously increasing.

In this paper, texture-based and shape-based descriptors, namely Edge Histogram Descriptor and Region-based Shape Descriptor defined by MPEG-7 standard, were used for MRIs retrieval. Dataset consist of 13917 MRI images provided by ImageCLEF 2008. According to the analysis, we can conclude that the Edge Histogram Descriptor achieves higher precision. Moreover, the analysis provided in this paper shows higher precision results if averaging of output ranks obtained from both cases, feature extraction with Edge Histogram Descriptor and Region-based Shape Descriptor.

The fact that MRIs have specific characteristics and the results obtained from this research suggest that we have to use additional image processing techniques in order to provide higher precision. Our future work will be concentrated on increasing the efficiency of the descriptors by incorporating some additional features.

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