A Novel Image Retrieval System Using an Effective Region Based Shape Representation Technique

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Abstract

With recent improvements in methods for the acquisition and rendering of shapes, the need for retrieval of shapes from large repositories of shapes has gained prominence. A variety of methods have been proposed that enable the efficient querying of shape repositories for a desired shape or image. Many of these methods use a sample shape as a query and attempt to retrieve shapes from the database that have a similar shape. This paper introduces a novel and efficient shape matching approach for the automatic identification of real world objects. The identification process is applied on isolated objects and requires the segmentation of the image into separate objects, followed by the extraction of representative shape signatures and the similarity estimation of pairs of objects considering the information extracted from the segmentation process and shape signature. We compute a 1D shape signature function from a region shape and use it for region shape representation and retrieval through similarity estimation. The proposed region shape feature is much more efficient to compute than other region shape techniques invariant to image transformation.

Keywords: Shape representation, Image retrieval, shapes signature, enhancement, segmentation

1. INTRODUCTION

An image retrieval system is a computer system for browsing, searching and retrieving images from large repositories_of digital images. The increase in social web applications and the semantic web have inspired the development of several web-based image annotation tools[1]. The processing semantics of the images is an open research area, as a support for a series of complex operations in the field of processing images and videos, such as recognizing shapes and objects, understanding video and detect potential risk events in video surveillance, etc. For semantic retrieval based on image content, it is important to have existing metadata such as an annotation for images. For each domain of application, where image retrieval is desired, semantic relationship needs to be established between the objects (the structure of the working object) present in the images[2,3]. Image search is a specialized data search used to find images. To search for images, a user may provide query terms such as keyword, image file/link, or click on some image, and the system will return images "similar" to the query[4]. Here we propose a system in which query is an image and the output of it is images related to that query i.e. images that contains input image.

In this paper, we propose a novel retrieval system using contour based method for region based shape representation and retrieval [7]. Conventional shape methods use grid sampling to acquire shape information. The shape representation derived this way is usually not translation, rotation and scaling invariant. Extra normalization is therefore required. Goshtasby proposes the use of shape matrix which is derived from a circular raster sampling technique [8]. The idea is similar to normal raster sampling. However, rather than overlaying the normal square grid on a shape image, a circular sampling of concentric circles and radial lines is overlaid at the centre of mass of the shape. The binary value of the shape is sampled at the intersections of the circles and radial lines. The shape matrix is formed so that the circles correspond to the matrix columns and the radial lines correspond to the matrix rows. The result matrix representation is invariant to translation, rotation, and scaling.

Specifically, we compute a one dimensional signature function from a region shape and use it for region shape representation and retrieval [9]. We call it circular raster sampling signature or CRSS for short. We show that the proposed technique is robust and outperforms the widely used shape methods in literature.

2. RELATED WORKS

Conventional information retrieval is based solely on text, and these approaches to textual information retrieval have been transplanted into image retrieval in a variety of ways, including the representation of an image as a vector of feature values. Wilkins et al propose a technique that uses text based IR methods for indexing MPEG- 7 visual features to perform rapid subset selection within large image collections [10]. Barrios et al present an image retrieval system based on a combined search of text and content. The idea is to use the text present in title, description, and tags of the images for improving the results obtained with a standard content-based search [13]. To provide text descriptions or annotations, two approaches can be applied. The first approach acquires descriptions/annotations manually by human annotators. The second approach is to automatically annotate images using machine-learning techniques that learn the correlation between image features and textual words from the examples of annotated images [14, 15].

However, “a picture is worth a thousand words.” Image contents are much more versatile compared with text, and the amount of visual data is already enormous and still expanding very rapidly. Hoping to cope with these special characteristics of visual data, content-based image retrieval methods have been introduced. It has been widely recognized that the family of image retrieval techniques should become an integration of both low-level visual features, addressing the more detailed perceptual aspects, and high-level semantic features underlying the more general conceptual aspects of visual data. Neither of these two types of features is sufficient to retrieve or manage visual data in an effective or efficient way. Although efforts have been devoted to combining these two aspects of visual data, the gap between them is still a huge barrier in front of researchers. Intuitive and heuristic approaches do not provide us with satisfactory performance. Therefore, there is an urgent need of finding and managing the latent correlation between low-level features and high-level concepts. How to bridge this gap between visual features and semantic features has been a major challenge in this research field.

3. APPROACH OVERVIEW

The system proposed is an efficient content based image retrieval system. This basically has three sections: Signature Generation, Image Storage and Image Retrieval. First, signatures are generated for the enhanced and segmented image, by applying the circular grid. Then, we store the set of signatures of the basic image patterns in our reference table. Finally, we input a query image to the system and find its corresponding set of signatures and search with the stored set of signature in reference table. If we get signatures which are matching, then the system outputs all the images that are mapped with matching reference signature. And if not, it will be added to the reference table.

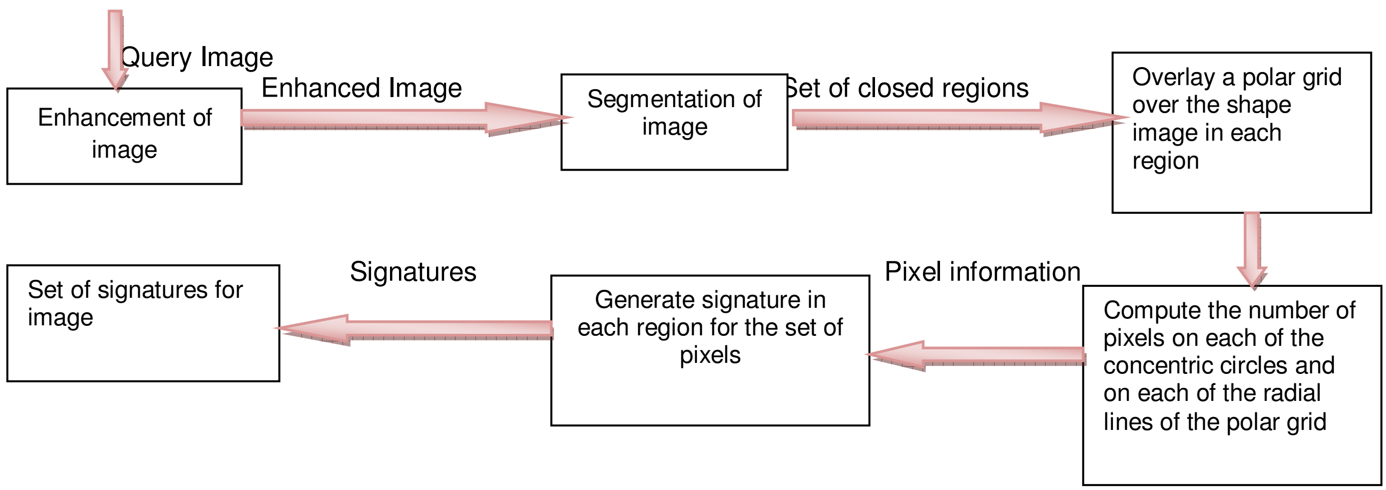
Steps for Signature Generation based on CRSS Algorithm

Step 1. Input image
Step 2. Enhancement of image to reduce noise and increase its image quality.
Step 3. Segment the image into different closed regions.
Step 4. For each image do following

- 4.a Determine the centroid of image.
- 4.b Overlay polar grid over shape image to compute number of shape pixels on intersection of concentric circles and radial lines for each region
- 4.c Collect pixel information – pixel position of these pixels
- 4.d. Generate signature from the set of shape pixels.

Figure 1 describes the bock diagram of the proposed retrieval system.

Signature Generation



Storing Image to the Database

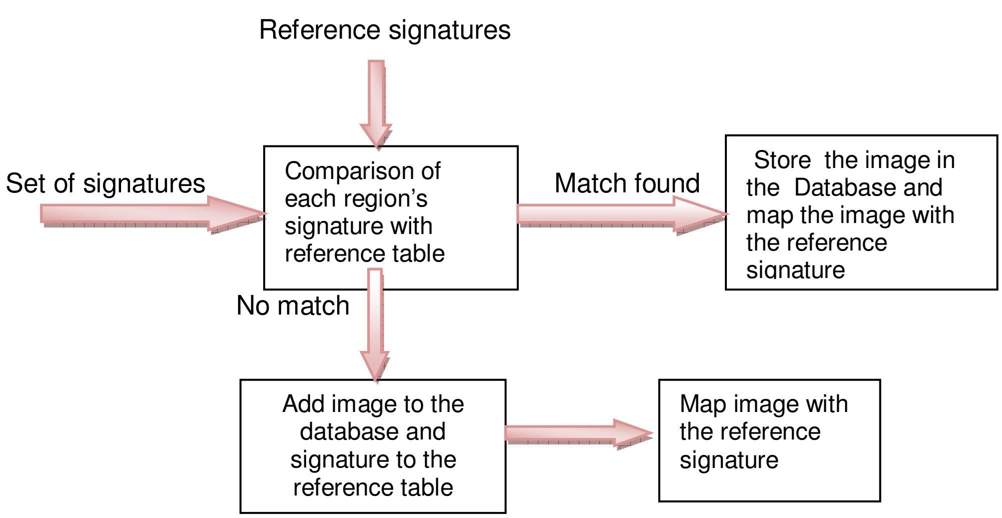
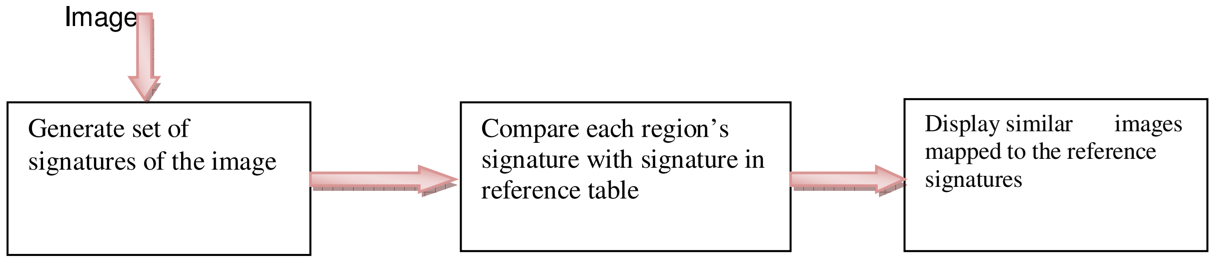


Image Retrieval



4. IMAGE ENHANCEMENT

Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine . Meanwhile, the term image enhancement is mean as the improvement of an image appearance by increasing dominance of some features or by decreasing ambiguity between different regions of the image. Contrast stretching is the image enhancement technique that is commonly used . To date, contrast stretching process plays an important role in enhancing the quality and contrast of images. There are 4 steps involved in applying image enhancement process. a) The first step is image capturing b) Then, save the images under .bmp extension. c) The third step is to select picture with 3 different types which is normal image, bright image and dark image. Three images are selected for each different type. d) The last step is applying the identified Partial Contrast stretching technique to the selected images.

Partial contrast stretching is an auto scaling method. It is a linear mapping function that is usually used to increase the contrast level and brightness level of the image. This technique will be based on the original brightness and contrast level of the images to do the adjustment. The mapping function is as follows [11,12]:

$$P_k = ((max - min)/(f_{max} - f_{min})) *(q_k - f_{min}) + min$$

Where,
Pk: : color level of the output pixel *qk* : color level of the input pixel
f max :maximum color level values in the input image *f min* :minimum color level values in the input image *max & min* :desired maximum and minimum color levels that determines color range of the output image, respectively
Before the mapping process start, the system will find the range of where the majority of the input pixels converge for each colour space. Since the input images are the RGB model, so it is necessary to find the range for the red, blue and green intensities. After that, the average will be calculated for these upper and lower colour values of the range of three colour space by using the following formula [12]:

maxTH = (maxRed + maxBlue + maxGreen)/3
minTH = (minRed + minBlue + minGreen)/3

maxRed, maxBlue and maxGreen are the maximum colour level for each red, blue and green colour palettes, respectively. minRed, minBlue and minGreen are the minimum value for each colour palette, respectively. maxTH and minTH are the average number of these maximum and minimum colour levels for each colour space. The maxTH and minTH will be used as the desired colour ranges for all the three colour palettes. The purpose of the three colour palette to have the same threshold value is to avoid the colour level to be placed out side of a valid colour level. After that, the mapping process will start [12]. The function in Equation 4 will be used for the pixels transformation, which is based on the concept of the linear mapping function in Equation .

$$out(x,y) = \begin{cases} \frac{in(x,y)}{minTH} * NminTH & for \quad in(x,y) > minTH \\ \left[\frac{NMaxTH - NMinTH}{maxTH - minTH} * (in(x,y) - fmin)\right] + \min & for\ minTH < in(x,y) < maxTH \\ \frac{in(x,y)}{maxTH} * NmaxTH & for \quad in(x,y) < maxTH \end{cases}$$

where, *in(x,y)* : colour level for the input pixel
out(x,y) : colour level for the output pixel
minTH : lower threshold value
maxTH : upper threshold value
NminTH : new lower stretching value
NmaxTH : new upper stretching value

The pixel within the range of minTH and maxTH will be stretched to the desire range of NmaxTH to NminTH, whereas the remaining pixels will experience compression. By this stretching and compressing processes, the pixels of the image can be mapped to a wider range and brighter intensities; as a result the contrast and the brightness level of the raw images are increased. Figure 1 illustrates the compression and stretching processes for partial contrast method. The value of 80 and 200 were used as an example of lower and upper threshold value while 20 to 230 as the desired range of the colour level for the output image. The original range of the input image will be stretched to the range from 20 to 230. The colour level below 80 will be compressed to the range of 0 to 20 and the colour level more than 200 will be compressed to the range of 230 to 255.

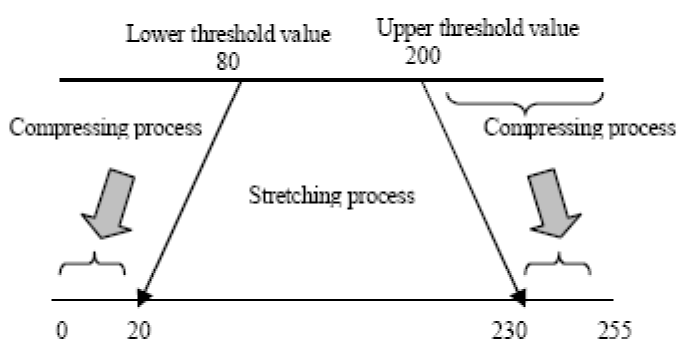


Figure 2 Partial Contrast Stretching Method

5. IMAGE SEGMENTATON

Segmentation, i.e. the partitioning of image data into related sections or regions, is a key first step in a number of approaches to data analysis and compression. In image analysis, the group of image data points contained in each region provides a statistical sampling of image data values for more reliable labeling based on image feature values[16]. In addition, the region shape can be analyzed as an additional clue for the appropriate labeling of the region. In data compression, the regions form a basis for compact representation of the image data. The quality of the prerequisite image segmentation is a key factor in determining the level of performance of most of these image analysis and data compression approaches. Region growing approaches to segmentation are preferred here because region growing exploits spatial information and Guarantees the formation of closed, connected regions [5].

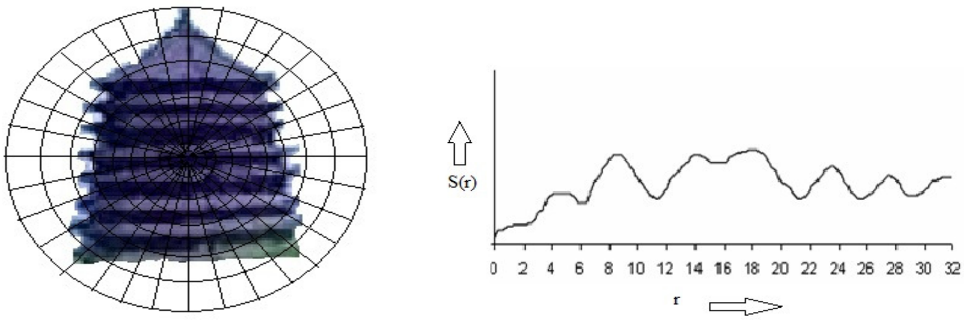
A less commonly used approach to region growing image segmentation is the Hierarchical Stepwise Optimization algorithm of Beaulieu and Goldberg [6]. HSWO is best defined iteratively: Start with an image and a segmentation of that image into *N* regions in which (i) every picture element (pixel) is in a region, (ii) and each region is connected, (*i.e.* composed of contiguous image pixels). Then compare all spatially adjacent regions with each other (*e.g.*, compute a vector norm between the region means of the spatially adjacent regions). Merge the most similar pair of spatially adjacent regions. Continue to compare spatially adjacent regions and merge the most similar pair of spatially adjacent regions until either a specified number of regions are reached or the dissimilarity between the most similar pair of spatially adjacent regions reaches a specified threshold.
The initial partition may assign each image pixel to a separate region. Any other initial partition may be used, such as an over-segmented result from region growing based on the classic definition given above (*i.e.*, classic region growing segmentation with a low threshold value). Here we make use of the recursive region growing approach utilized by the hierarchical image segmentation (RHSEG) algorithm described by James Tilton[5]. It is identical to that employed by Beaulieu and Goldberg's HSWO algorithm except that HSEG optionally alternates spectral clustering iterations with region growing iterations. In the spectral clustering iterations, non-adjacent regions are merged. In fact, in their paper on HSWO, Beaulieu and Goldberg [6] provide the theoretical basis for the HSEG algorithm in their theoretical analysis of HSWO. They show that the HSWO algorithm produces the globally optimal segmentation result if each iteration is statistically independent. Even though each iteration will generally not be statistically independent for natural images, the HSWO approach still produces excellent results. Beaulieu and Goldberg also point out that the sequence of partitions generated by this iterative approach reflect the hierarchical structure of the imagery data: the partitions obtained in the early iterations preserve the small details and objects in the image, while the partitions obtained in the latter iterations preserve only the most important components of the image. They further note that these hierarchical partitions may carry information that help in identifying the objects in the imagery data.

Input Image For Segmentation   Final Segmented Image

FIGURE 3: Image Segmentation using RHSEG

6. CICULAR RASTER SAMPLING SIGNATURE

In this section, we introduce the basic idea of the shape representation technique named as *circular raster sampling signature(CRSS)*, and describe its implementation details.The shape matrix technique captures local shape information well, however, it suffers from noise and high dimension matching drawbacks. The area-ratio technique is robust to noise, however, it does not capture local shape information, as the result, it is not accurate[17]. In this context, we propose a polar raster sampling signature technique which computes a signature function of the sampled points. Specifically, we overlay a polar raster grid over the shape image, and compute the number of shape pixels on each of the concentric circles and on each of the diameters of the polar sampling grid. Then the shape pixels are filtered to avoid noise. This is done by calculating the intensity of the pixel and comparing with a threshold value. The number of pixels is a function of the radius and the angle, the function is called circular raster sampling signature, or CRSS for short. In the following, we describe the proposed technique in details.



(a) (b)

FIGURE 4: (a) polar sampling of a shape (b) *S*(*r*) component of the CRSS of (a)

6.1 Implementation

To implement PRS, a shape image needs to be converted from Cartesian space to polar space. Given an shape image in Cartesian space: $I = \{f(x, y); 0 \le x \le M, 0 \le y \le N\}$, it can be represented in polar space as $Ip = \{f(r,\theta); 0 \le r \le R, 0 \le \theta \le 2\pi\}$, where R is the maximum radius of the shape. The origin of the polar space, set to be the centroid of the shape, is initialised to 0.

Step 1: Find the centroid (x_c, y_c) of the region, which is given by

$$x_c = \frac{1}{M} \sum_{x=0}^{N-1} x, \quad y_c = \frac{1}{N} \sum_{y=0}^{M-1} y$$

Step 2: Calculation of pixels position (x, y) of each shape pixel on each of the concentric circles and radial lines.(for each region)

Step 3: Find (r,θ) is given by:

$r = \sqrt{(x - x_c)^2 + (y - y_c)^2}$, $\theta = arctan\frac{y - y_c}{x - x_c}$

Step 4: The *PRS* signature function consists of two components: $S(r)$ and $S(\theta)$, which are given by

$$S(r) = \sum_x \sum_y f(x, y)\,\delta\left[r - \sqrt{(x - x_c)^2 + (y - y_c)^2}\right]$$

$$S(\theta) = \sum_x \sum_y f(x, y)\,\delta\left[\theta - arctan\frac{y - y_c}{x - x_c}\right]$$

Where $0 \le r \le R$, $0 \le \theta \le \pi$. $f(x, y)$ is the binary value of image pixel at (x, y), $\delta(x)$ is the Dirac delta function:

$$\delta(x) = \begin{cases} 1 & if\ x = 0 \\ 0 & if\ x \neq 0 \end{cases}$$

In our case, r is quantized by 32, and θ is quantized by 30. An example shape and its first component of CRSS signature are shown in Figure 4.

7. CONSLUSION & FUTURE WORK

In this paper, we have proposed an efficient and robust content based image retrieval system using the region based shape representation technique named *circular raster shape signature (CRSS).* The novel approach uses contour shape method to compute a concentric circular sampling signature from a region shape which may not have a continuous boundary. It overcomes several drawbacks in existing techniques, like noise sensitivity, loss of local information and computational complexity. The proposed shape descriptor has better performance compared with well known shape representation techniques and will be useful in retrieval of similar image from large repositories of images.

The semantic interpretation of the image and the spacing of the concentric circles in the circular grid can further be studied to improve the storage and retrieval performance of the CRSS based image retrieval System.

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