IMAGE RETRIEVAL WITH RANDOM BUBBLES

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ABSTRACT

In this work we propose an algorithm for content based image retrieval based on random selection of circular bubbles on the reference image. More specifically, an image fingerprint vector is extracted from the image, the components of which are simple statistical parameters associated to the luminance values in some selected circular areas of the image. The positions and radius of these bubbles result from a random selection, with characteristics defined by the user. In this way, the extracted fingerprint is very robust with respect to linear and nonlinear distortion of the image. Experiments based on the detection of various linearly and nonlinearly distorted versions of a test image in a large database have shown very promising results.

1. INTRODUCTION

The content of a multimedia document refers to its main perceptual characteristics. Content hashing consists in efficiently extracting the content information from a multimedia document, and then representing it in a sintetic way by means of a fingerprint.
These techniques are recently riemerged as a feasible solution to a wide variety of multimedia applications, such as database indexing and retrieval, author authentication and data integrity checking.
The various methods of content hashing can be distinguished on the base of the feature being extracted; depending on the application, this feature has to be robust against different types of data manipulation. For example, it should tolerate a slight noise addiction but not a severe cropping in a retrieval environment.
Audio hashing algorithms include use of frame-based subband energy correlation [1] and generation of a masking curve based on the psycho-acoustic model of human auditory system [2].
Greater attention has been dedicated to the field of image processing; methods based on color histograms [3], edge extraction [4], DCT [5], and wavelets transform [6][7][8] have been recently proposed.
Video hashing can be thought as some sort of extension of image or audio hashing, as proposed in [5] ,[9] ,[10].

In this paper we present a fingerprint extraction scheme based on local statistics estimated in random circular areas of the image, and we demonstrate its usefulness in a retrieval application. In this field, there are many novel retrieval techniques based on content hashing; a brief description of the state of the art can be found in [11][12].

The rest of the paper is organized as follows. In Section 2 the proposed algorithm for fingerprint extraction is introduced and described. In Section 3 some experimental results obtained using the proposed fingerprint in the context of content based image retrieval are reported and compared with a simple method based on color histogram. Finally, concluding remarks are drawn in Section 4.

2. THE IMAGE FINGERPRINT

In this work a very simple statistical property of the image is used to generate a fingerprint of the reference image.
In particular, the extracted feature is a real-valued vector composed of a predefined number of components. Each component represents the variance of pixels luminance within a randomly selected circular areas of the image (bubble). The positions and radius of these bubbles result from a random selection, with characteristics defined by the user.

The image regions are selected randomly for different reasons. First of all, the random selection guarantee in some way that some significant part of the image is likely to be taken into account, with the result that the extracted fingerprint describes the image effectively.
Also the fact of having bubbles with random radius is important. In fact, in this way both small and more large areas of the image are considered, and the structural characteristics of the image can be captured more efficiently.
Moreover, the process of fingerprint extraction could be reiterated obtaining a more robust description of the considered image.

In more detail, as a first step of the processing, the bubbles radius is randomly extracted according to a probability distribution function selected a priori by the user. This radius has to be not too small nor too large for the variance estimation make sense; values ranging from 5 to 14 have proven to be acceptable and could be optionally set depending on image dimensions.
The position of each bubble in the image is then selected by randomly extracting the coordinates of its centre. The bubble is prevented from exceeding the boundaries of the image by properly bounding this latter extraction.

Apixel is said to belong to the bubble if its distance from the bubble centre is less than the ball radius; the variance of the pixels belonging to the ball is then computed and stored, together with the ball radius and position.
A variety of parameters in this process can be modified by the user, mainly the number of components of the vector (i.e., the number of bubbles to be considered), the probability distribution function of the radius of the bubbles, and whether or not the bubbles could overlap.
Figure 1 shows an example of bubbles extraction on a reference image. In the following figure, 100 overlapping bubbles were selected. The radius of the bubbles in this example is a random variable uniformly distributed between 4 and 15.

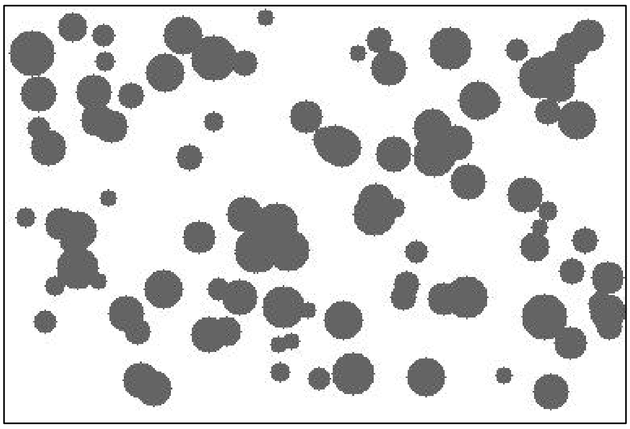

Figure 1: An example of random bubbles selection.

The vector containing the positions and radius of the bubbles, and the estimated variances represents the desired fingerprint of the image.
A conceptual schematic of the steps involved in the fingerprint generation is shown in Figure 2.

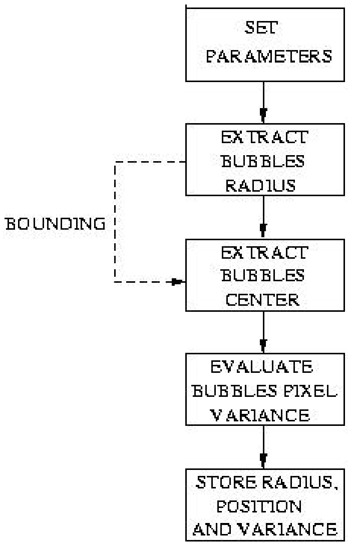

Figure 2: The procedure for fingerprint extraction.

The obtained fingerprint has then been used for content-based image retrieval, using the standard euclidean distance as similarity metric between the extracted features.
The retrieval process consists in the ordering of the images in a database on the basis of their similarity with an assigned queue image.
In our case, the program extracts from the signature of the queue image the characteristics of every bubble, and applies them to compute the feature vector of every candidate image. The squared magnitude of the difference vector is then used by the Quick Sort algorithm as the criterium for the final ordering.

3. EXPERIMENTAL RESULTS

The database consisted of 233 images. One of them was selected as the queue image and six different distorted versions of the original image were generated and added to the database. The processed images were obtained applying respectively 2 and 4 iterations of blurring, light and heavy addition of gaussian noise, and two distinct grades of sharpening.
Several signatures were then generated, varying the parameters of the extraction process. In particular, the selected radius probability distribution functions were: uniform distribution between 5 adiacent values, gaussian distribution with a deviation standard of 2, and unit step distribution, chosen so as to have always the same value.
The mean value can assume 4 different values: 6, 8, 10 and 12. For each one of these 12 radius probability distribution function, signatures of various lenghts were generated, namely 60, 80, 100, 120, 140 and 160. Furthermore, 5 iterations of every signature type were generated to demonstrate the indipendence of the fingerprint with respect of the particular realization being used.
Therefore a grand total of 360 signatures of the original image were obtained and compared with the signatures of the same type of the images in the database.
Some experimental results are plotted in Figure 3 in histogram form; black bins represents the distorted versions of the original and white ones the other images. The x-axis represents the distance (each unit corresponds to 10^6) , that is to say the squared magnitude of the difference vector.
Although it can be noted some form of clustering of the dark bins towards the origin, it is clear that the separation between the two subsets is indeed small or nonexistent; again, the distance value for the version with exasperate sharpening diverges.
Therefore we included a moderate low pass filtering of the image prior to its fingerprinting.
The results are reported in Figure 4. Substantial improvements can be observed. All the distorted versions of the reference image cluster towards the origin and the others images appear more distant. Moreover, as expected, a further performance improvement is achieved by increasing the total number of bubbles.

For comparison with existing retrieval methods, we have implemented a classical approach based on color histograms.

Again, we have resized every image to the standard size of 512*512 pixels prior to the feature extraction.
Then we have partitioned the image into blocks of 32*32 pixels and computed the mean value of the luminance histogram; the feature vector was then generated by concatenating these values.
The same tests applied to our method have been carried out. Experimental results indicate inferior performance.
Although the 6 processed versions of the query image were retrieved into the first 15 images, no separation was obtained between the two subsets; indeed, there were a significant number of false positives. Some minor improvements have been observed using RGB color histograms.

The fingerprint extraction described so far have proven to be robust against some basic form of filtering and resizing, but it doesn't take into account other geometric transformation like, for example, the rotation of the image.
In order to consider these types of manipulation, we have to readapt our algorithm. Suppose that we stretch horizontally our query image by 10%, and then crop it to his original dimensions. In this case the previous method will fail to retrieve this image because there is clearly a mismatch between the bubbles centres. It is possible to overcome this problem if we suppose to know a priori what types of geometric manipulations could be applied to the database images (not a too strict constraint). In this case, we modify the bubbles into ellipses that have the centres moved and horizontal dimension scaled by some percentage, and repeat the retrieval process for a certain number of times, each one with a different percentage of stretching.
Obviously, we lose some precision because every bubble that moves out of the image boundary has to be discarded, and the correspondent signature vector component ignored, reducing this way the number of bubbles considered.
This improvement of the proposed algorithm is in progress.

4. CONCLUSION

In this paper we have presented an algorithm for image retrieval based on a fingerprint associated to a random selection of circular bubbles on the reference image. The positions and radius of these bubbles result from a random selection, whose parameters are user-defined. In this way, the extracted fingerprint is very robust with respect to linear and nonlinear distortion of the image. The reliability and the effectiveness of this scheme has been proven through very good results obtained in an application of image retrieval.

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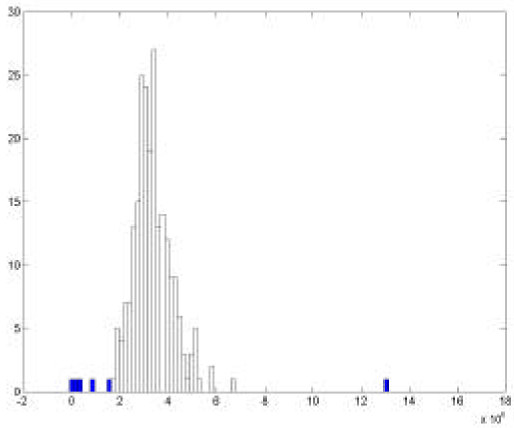

Figure 3a. Histogram of the distances of the database images (mean value = 6; 80 bubbles).

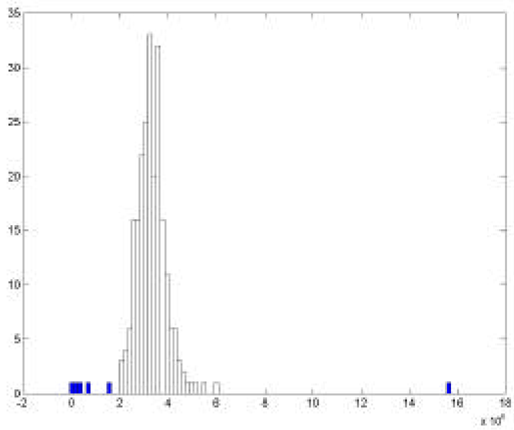

Figure 3b. Histogram of the distances of the database images (mean value = 6; 120 bubbles).

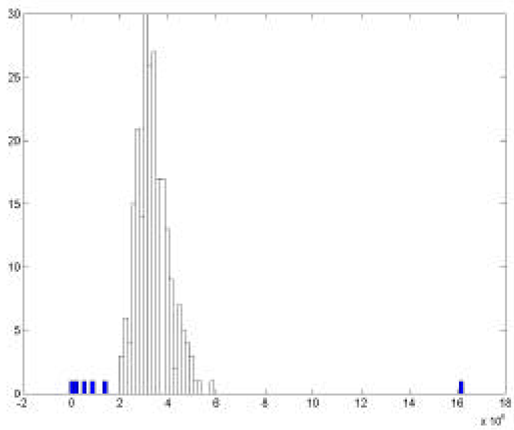

Figure 3c. Histogram of the distances of the database images (mean value = 6; 160 bubbles).

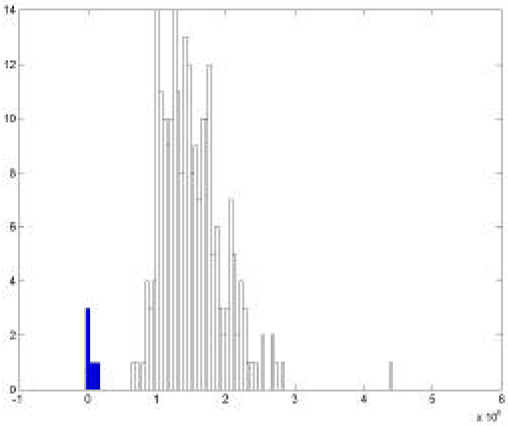

Figure 4a. Histogram of the distances of the database images (mean value = 8; 80 bubbles; low-pass filtered images).

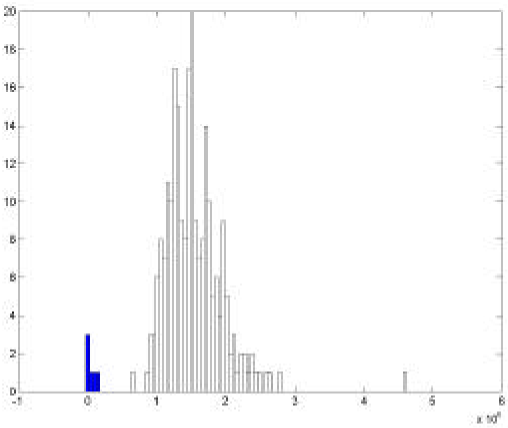

Figure 4b. Histogram of the distances of the database images (mean value = 8; 120 bubbles; low-pass filtered images).

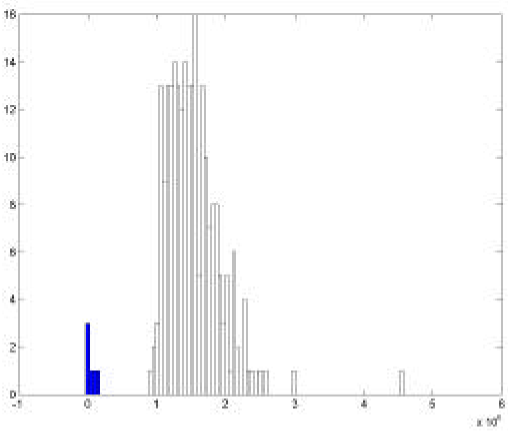

Figure 4c. Histogram of the distances of the database images (mean value = 8; 160 bubbles; low-pass filtered images).

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