EFFECTIVE IMAGE FINGERPRINT EXTRACTION BASED ON RANDOM BUBBLE SAMPLING

S. Benini, F. Guerrini, R. Leonardi, P. Migliorati

DEA University of Brescia, Italy

ABSTRACT

In this paper we propose an algorithm for image fingerprint extraction based on random selection of circular bubbles on the considered image. In more detail, a fingerprint vector is associated to the image, the components of which are the variances of pixel luminance values in randomly selected circular zones of the image. The positions and radius of these bubbles result from a random selection, whose parameters are user-defined. The obtained fingerprint has then been used for content-based image retrieval, using the standard euclidean distance as similarity metric between the extracted features. Experiments based on the detection of various linearly and nonlinearly distorted versions of a test image in a large database show very promising results.

1. INTRODUCTION

Content hashing is recently riemerged as a feasible solution to a variety of multimedia applications, ranging from database indexing and retrieval to author authentication and data integrity checking.

The basic idea of content hashing is the extraction of main perceptual characteristics of the multimedia data and then represent in an efficient and sintetic way this perceptual content by means of a fingerprint.

The feature extraction has to be robust against various types of data manipulation depending on the application; for example it might tolerate a moderate compression, but not a severe cropping in an authentication environment.

Many algorithms have been recently proposed. Beyond to multimedia being hashed, the feature extraction is in the end what distinguishes the various methods of content hashing. In the field of image processing, the use of color histograms [1], edges [2], DCT coefficients [3], and wavelets transform coefficients [4][5][6] have been recently proposed. Audio hashing algorithms include use of frame-based sub-band energy correlation [7] and generation of a masking curve based on the psycho-acoustic model of human auditory system [8].

Video hashing can be thought as some sort of extension of image or audio hashing, like the schemes presented in [3] and [9]. As a desirable option, extracted features can be MPEG-7 compatible [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 context. In this field, there are many novel retrieval techniques based on content hashing, and some of them can be found in [11][12].

The paper is organized as follows. In Section 2 the proposed algorithm for image 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 discussed. Finally, concluding remarks are drawn in Section 4.

2. IMAGE FINGERPRINT EXTRACTION BASED ON BUBBLE RANDOM SAMPLING

In our approach a very simple structural property of the image, namely the variances of the pixels luminance, is used to generate a fingerprint of the reference image.

In detail, the extracted feature is a real-valued vector made of a certain fixed number of components. Each component represents the variance of pixels within a randomly selected circular areas of the image.

As a first step, the bubbles radius is randomly extracted from a known a priori probability distribution function. This radius has to be not too small nor too large for the variance to 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.

A pixel 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.

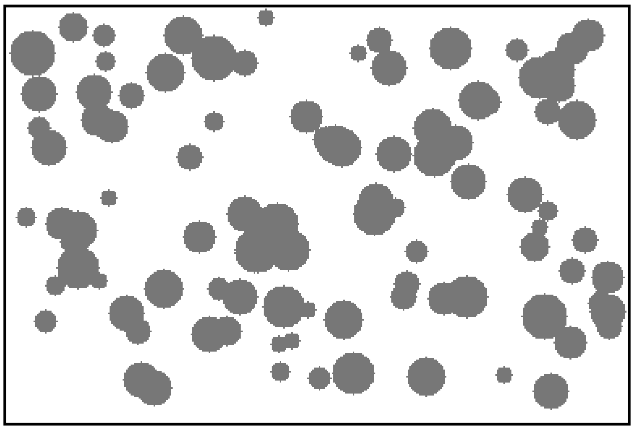

Figure 1. An example of random bubbles selection.

The vector containing the positions and radius of the bubbles, and the estimated variances represents the desired signature of the image. For the sake of simplicity, an header containing the original image dimensions is added, and the first implementation of the proposed algorithm considers only images of the same size. A conceptual schematic of the steps involved in the fingerprint generation is shown in Figure 2.

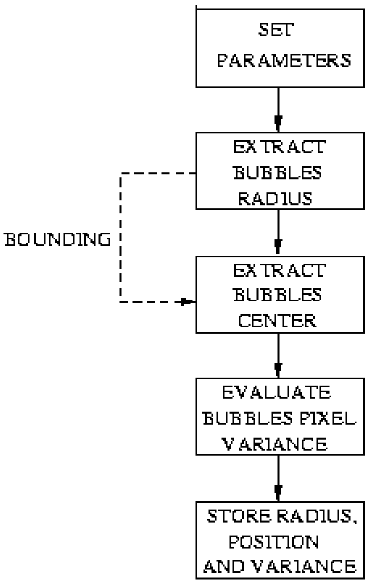

Figure 2. Procedure for fingerprint extraction.

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, 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.

4. CONCLUSIONS

In this paper we present an innovative image fingerprint extraction technique based on a unique bubbles random selection approach.
In more detail, a fingerprint vector is associated to the considered image, the components of which are the variances of pixel luminance values in randomly selected circular zones of the image. The positions and radius of these bubbles result from a random selection, whose parameters are user-defined.
The reliability and the effectiveness of this scheme has been proven through very good results obtained in an application of image retrieval.
Further work on the optimization of the parameters involved in the extraction process and on robustness against geometric transformations, for example by means of prior image rescaling to a standard size and/or selective changes in bubbles position and shape, is underway.

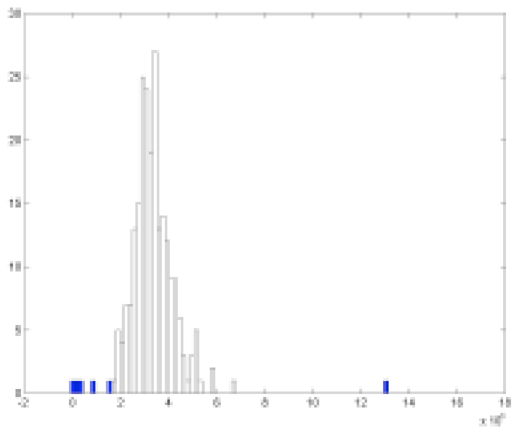

Figure 4a. Histogram of the distances of the database images (mean value = 6; 80 bubbles).

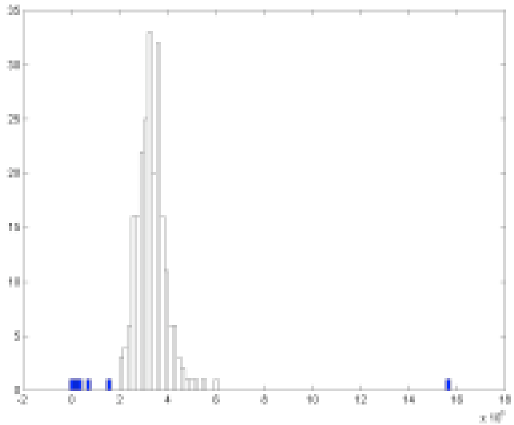

Figure 3b. Histogram of the distances of the database images (mean value = 6; 120 bubbles).

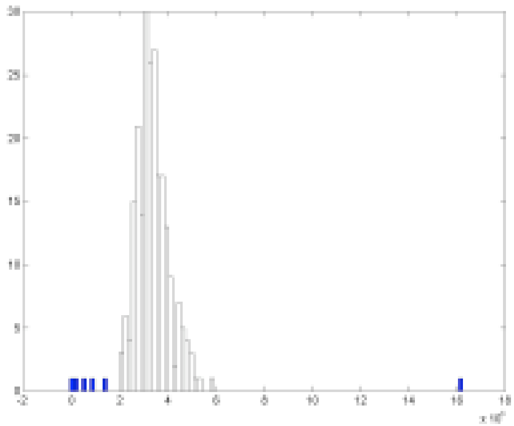

Figure 3c. Histogram of the distances of the database images (mean value = 6; 160 bubbles).

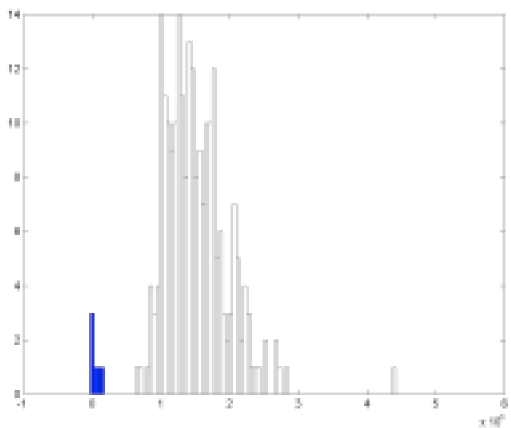

Figure 4a. Histogram of the distances of the database images (mean value = 8; 80 bubbles; low-pass filtered images).

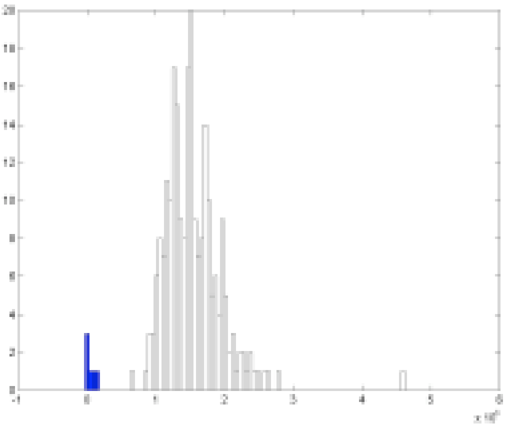

Figure 4b. Histogram of the distances of the database images (mean value = 8; 120 bubbles; low-pass filtered images).

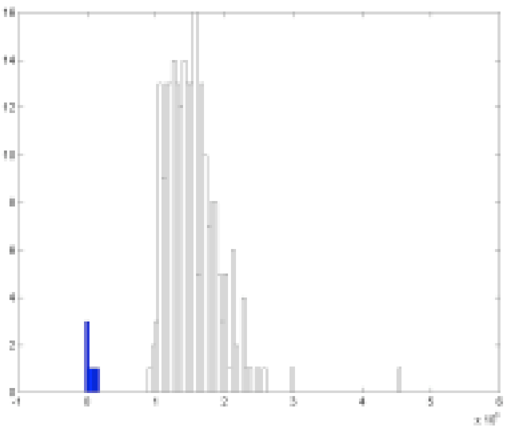

Figure 4c. Histogram of the distances of the database images (mean value = 8; 160 bubbles; low-pass filtered images).

ACKNOWLEDGMENTS

This material is based upon work partially supported by the IST programme of the EU in the project IST-2001-32795 SCHEMA.

5. REFERENCES

[1] M. Schneider, S.-F. Chang, "A Robust Content Based Digital Signature for Image Authentication", Proc. of the IEEE ICIP'96, Lausanne, Switzerland, September 1996.

[2] M. P. Queluz, "Towards Robust, Content Based Techniques for Image Authentication", Proc. of the IEEE 1998 Workshop on Multimedia Signal Processing, Los Angeles, California, USA, December 1998.

[3] C.-Y. Lin, S.-F. Chang, "Generating Robust Digital Signature for Image/Video Authentication", Proc. of the Multimedia and Security Workshop at ACM Multimedia '98, Bristol, UK, September 1998.

[4] S. Bhattacharjee, M. Kutter, "Compression Tolerant Image Authentication", Proc. of the IEEE ICIP'98, Volume 1, Chicago, Illinois, USA, October 1998.

[5] R. Venkatesen, S.-M. Koon, M. Jakubowski, P. Moulin, "Robust Image Hashing", Proc. of the IEEE International Conference on Image Processing, Vancouver, Canada, September 2000.

[6] C.-S. Li, H.-Y. M. Liao, "Structural Digital Signature for Image Authentication: An Incidental Distorsion Resistant Scheme", Proc. of the 2000 ACM Workshop on Multimedia, Los Angeles, California, USA, November 2000.

[7] J. A. Haitsma, J. C. Oostven, A. A. C. Kalker, "Robust Audio Hashing for Content Identification", Proc. of the 2001 Content Based Multimedia Indexing, Brescia, Italia, September 2001.

[8] R. Radhakrishnan, N. Memon, "Audio Content Authentication Based on Psycho-Acoustic Model", Proc. of the SPIE Security and Watermarking Contents, San Jose, California, USA, February 2002.

[9] J. C. Oostven, A. A. C. Kalker, J. A. Haitsma, "Visual Hashing of Digital Video: Applications and Techniques", Proc. of the SPIE Applications of Digital Image Processing XXIV, San Diego, California, USA, July 2001.

[10] B. S. Manjunath, P. Salembier, T. Sikora, "Introduction to MPEG-7", Wiley, 2002.

[11] G. Schaefer, "Compressed Domain Image Retrieval by Comparing Vector Quantization Codebooks", Proc. Of the Visual Communications and Image Processing 2002, San Jose, California, USA, January 2002.

[12] G. Ciocca, R. Schettini, "Image Retrieval Using Dynamic Spatial Chromatic Histograms", Proc. Of the Visual Communications and Image Processing 2003, San Jose, California, USA, July 2002.