BROWSING IMAGE DATABASES BY 2D IMAGE SIMILARITY SCATTER PLOTS: UPDATES TO THE IRIS SYSTEM

C. VERTAN[1,2], M. CIUC[1], C. FERNANDEZ-MALOIGNE[2], V. BUZULOIU[1]

Abstract *: In the context of multimedia information mining growth, image retrieval has an important place. The content-based image retrieval paradigm consists of computing image similarities by distances between image descriptors; important research efforts have been deployed by now for improving the description procedures. Still, the visualization of the similarity relations between images and the current displaying of images relevant to a given query image is far less studied. In this paper we propose some new, fast, two-dimensional image-similarity-preserving displays.*

Keywords *: content-based image retrieval, image similarity, human-computer interaction*

I. IMAGE DATABASE QUERYING AND BROWSING

The growing demand for fast and accurate access and information retrieval has extended to visual information as well. The multimedia revolution of the last years imposed ever more demanding image handling requirements in displaying, storing, searching and analyzing visual information. The Internet and the World Wide Web are certainly part of this evolution. The recent emphasis on image retrieval systems, by visual and content similarity, strongly illustrates the need for the development of effective image description schemes.

In the context of retrieval, the descriptor is used to search in a database for images that are similar to the given image. Image description involves extracting relevant features from images within the database, such that a mathematically-computed distance between feature vectors corresponds to the visual distance (or visual similarity) between the images. Since the introduction of the first image retrieval systems [1], [5], [6] important research efforts have been deployed for improving the image description procedures. Still, the visualization of the similarity relations between images and the current displaying of images relevant to a given query image is far less studied.

[1] LAPI, Dept. of Applied Electronics and Information Engineering, Bucharest Politehnica University, {cvertan, mciuc, buzuloiu}@alpha.imag.pub.ro
[2] ACTIOM, IRCOM-SIC, University of Poitiers, France, fernandez@sic.sp2mi.univ-poitiers.fr

The remainder of the paper is organized as follows : section II will focus on the description of the IRIS indexing and retrieval system and section III will present the proposed two-dimensional retrieved image displays. The paper ends with some concluding remarks.

II. THE IRIS SYSTEM

IRIS (Image Retrieval and Indexing System) is a prototype software toolbox for image database browsing and management [9]. The IRIS system consists of a Matlab function set, which allows querying image databases according to image query examples, in order to retrieve images that are visually similar to the query. The query image can be internal or external to the indexed image database and is considered as a global query. Like most indexing systems, IRIS performs database indexing off-line, by computing the content descriptor vectors for all the images within the specified image database. The image content descriptors are stored into an Image Database Descriptor (IDD) file, in a simple matrix form and linked to an Image Database Content (IDC) file, which lists the image filenames and locations. The similarity between images is inferred according to simple distances (such as Euclidean or city-block) between the corresponding image content description vectors. The query results are ranked according to their distance to the query image. The graphical user interface of the IRIS system (see figure 1) is an image database browsing tool, which allows the user to visualize the content of a selected image database according to some pre-defined orders: the usual IDC-file order (alphabetical order of image filenames), a randomized selection order (a shuffle of the previous order) and the query-induced similarity order. All the aforementioned browsing types produce a linear image plot (see figure 1).

The IRIS system currently implements several basic image descriptors, based on statistical measures (moments and distributions) of relevant image features. The image description is done according to the classical color-texture-shape paradigm [1], [6], accounting for image colors (represented in *RGB* or *Lab* color spaces), energetic and run-length textural features and edge strengths.

III. SIMILARITY-PRESERVING IMAGE DISPLAYS

There are two main approaches in constructing scatter-plots of images with respect to their relative similarities. The usual approach [1], [5], [8] is to show images in the order of their similarity ranks, in a linear structure (figure 1); this approach is inexpensive but reduces the overall perception of image similarity relations. Improvements have been proposed, by using visual effects (fish-eye lens deformation of the entire image display) or special, fractal-type shapes for the image grid [1], [6]. Although the effects create some enhanced perception of the set of images, it should be noted that this approach is not taking into account the specific similarity between the displayed images.

A second approach is based on statistical tools that allow to reduce the dimensionality of the image description vector to two components, further viewed as Cartesian coordinates for a subsequent image plot. At each resulting point a thumbnail of the original image is displayed. The dimensionality reduction is usually done by a principal component analysis (PCA) or Karhunen-Loeve (KL) expansion of the set of image description vectors, or by a multidimensional scaling (MDS) [7], [3], [4], based on the distances between the image descriptors.

Both methods require a lot of computations: the PCA implies computing the covariance matrix and its eigenvalues and eigenvectors; the MDS (in its classical, metric form) uses a singular value decomposition (SVD) of a matrix. The MDS is preferred with respect to the PCA, since the PCA is intrinsically adapted to hyper-ellipsoidal shaped image descriptor distributions (which is not always the case). If the techniques are used for the entire database, they are performed off-line [4].

A computational simplification of the MDS has been proposed as the FastMap algorithm [2]. The FastMap algorithm is based on geometrical considerations and uses vector projections and distance updates, by iteratively finding the direction of the strongest component variation. We propose to further simplify the idea behind FastMap.

We will use a simplified model of the dimensionality reduction, based on the angular distances between the image descriptors of the images belonging to a selection of relevant images. Since the final image display must preserve the image similarity information (represented by the current distance between the image descriptors) the relative spatial spread of the image descriptors with respect to the query descriptor could be used. We propose to measure this spatial spread by the angle between the query descriptor and each descriptor of the retrieved images, or the difference vector between the query descriptor and each descriptor of the retrieved images. If we denote by $\mathbf{x}_q$ the query descriptor and by $\mathbf{x}_i$ the descriptor of the *i*-th retrieved image, the relative angles q_i are computed as:

$$q_i = \arccos\frac{\langle \mathbf{x}_q, \mathbf{x}_i \rangle}{\|\mathbf{x}_q\|\|\mathbf{x}_i\|} \text{ or } q_i = \arccos\frac{\langle \mathbf{x}_q, \mathbf{x}_q - \mathbf{x}_i \rangle}{\|\mathbf{x}_q\|\|\mathbf{x}_q - \mathbf{x}_i\|}.$$

In the equations above, $\langle \ \rangle$ is the scalar product of the image descriptor vectors and $\| \ \|$ is the Euclidean vector norm. This procedure is computationally inexpensive and produces visually significant results (see figure 2).

The IRIS browsing interface was updated in order to accommodate image scatter-plot (two-dimensional) displays based on the various presented methods (PCA, MDS, angular).

IV. CONCLUSIONS

In this paper we briefly presented a fast method for the computation of plane coordinates for two-dimensional image displays, to be used with content-based image retrieval systems. Such displays provide an enhanced perception of the image database content and of the similarity between the selected images. In the same time, the display is richer than the classical matrix-based display, since more image thumbnails can be viewed simultaneously.

Further developments of this display techniques may include the improvement of the computational complexity of the dimensionality reduction scheme for any of the presented methods and the further embeding of human visual system characteristics (focus of attention, peripheral vision, visual scan path).

V. REFERENCES

[1] A. del Bimbo, *Visual Information Retrieval,* Morgan Kaufmann: San Francisco, CA, 1999.

[2] C. Faloutsos, K. I. D. Lin : FastMap : A fast algorithm for indexing, data-mining and visualization of traditional and multimedia datasets, *Proc. of SIGMOD* 1995.

[3] K. Rodden, W. Basalaj, D. Sinclair, K. Wood: A comparison of measures for visualising image similarity, *Proc. of The Challenge of Image Retrieval CIR 2000*, Brighton, May 2000.

[4] Y. Rubner, C. Tomasi, L. J. Guibas: A Metric for Distributions with Applications to Image Databases, *Proc. of IEEE ICCV 1998*, Bombay, India.

[5] W. Niblack, R. Barber, W. Equitz, M. Flickner, E. Glassman, D. Petkovic: QBIC project: querying images by content using colour, texture and shape, *Storage and Retrieval for Still Image and Video Databases I*, vol. SPIE 1908, 1993.

[6] A.W.M. Smeulders, M. Worring, S. Santini, A. Gupta, R. Jain: Content Based Image Retrieval at the End of the Early Years, *IEEE Trans on PAMI*, vol. 22, no. 12, 1349-1380, Dec. 2000.

[7] M. Steyvers : Multidimensional Scaling, *Macmillan Encyclopedia of Cognitive Sciences*, 2002.
[8] C. Vertan, N. Boujemaa: Upgrading Color Distributions for Image Retrieval: Can we do better?, *Advances in Visual Information Systems*, Ed. R. Laurini, vol. LNCS 1929, Springer, pp. 178-188, 2000.
[9] C. Vertan, M. Ciuc, C. Fernandez-Maloigne, V. Buzuloiu: IRIS - color texture indexing and recognition toolbox, *Proc. of 8th Intl. Conf. on Optimization and Electronic Equipment OPTIM '02*, Brasov, May 2002, 757-762.

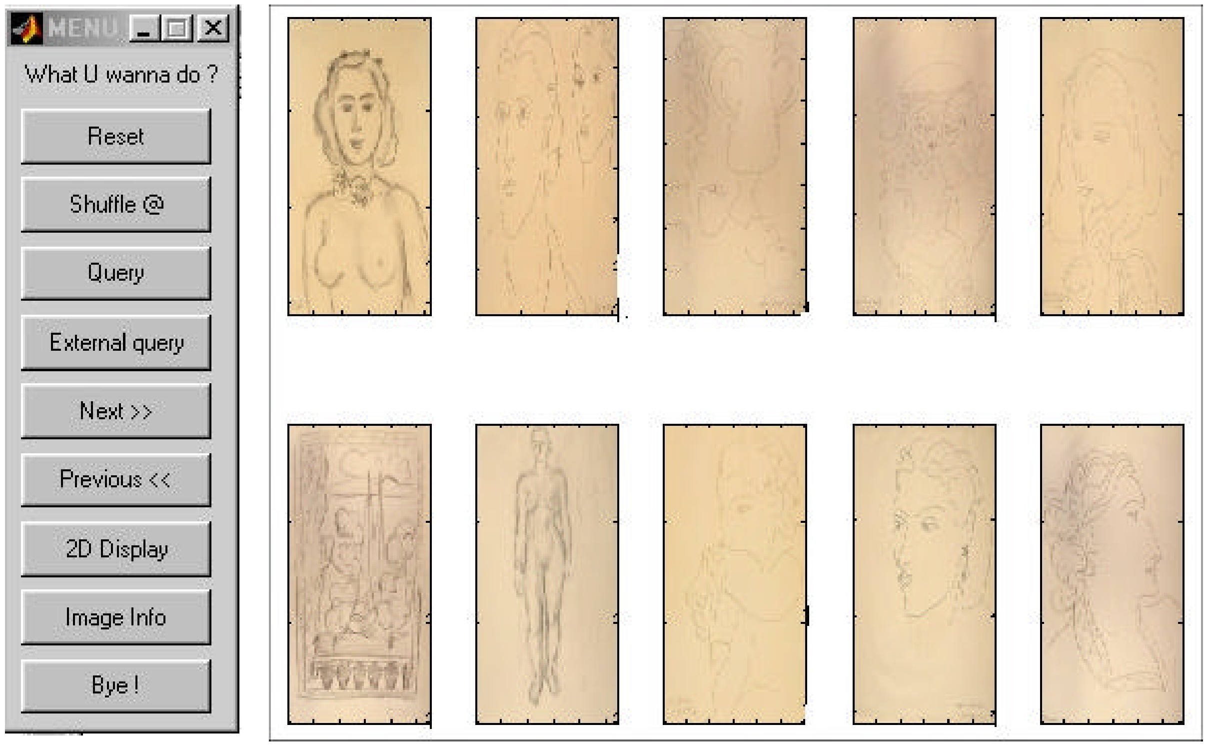

Fig. 1: Command window (at left) and image database browsing window of the IRIS system. The image database used is Hermitage paintings, consisting of 140 paintings from www.hermitage.org. The image database browsing was performed according to the visual similarity with respect to the top-left image; the visualization effect is poorer than the visualization using two-dimensional similarity representation (presented in figure 2). The two-dimensional displays accommodate twice the number of image thumbnails on almost the same area as the current matrix display.

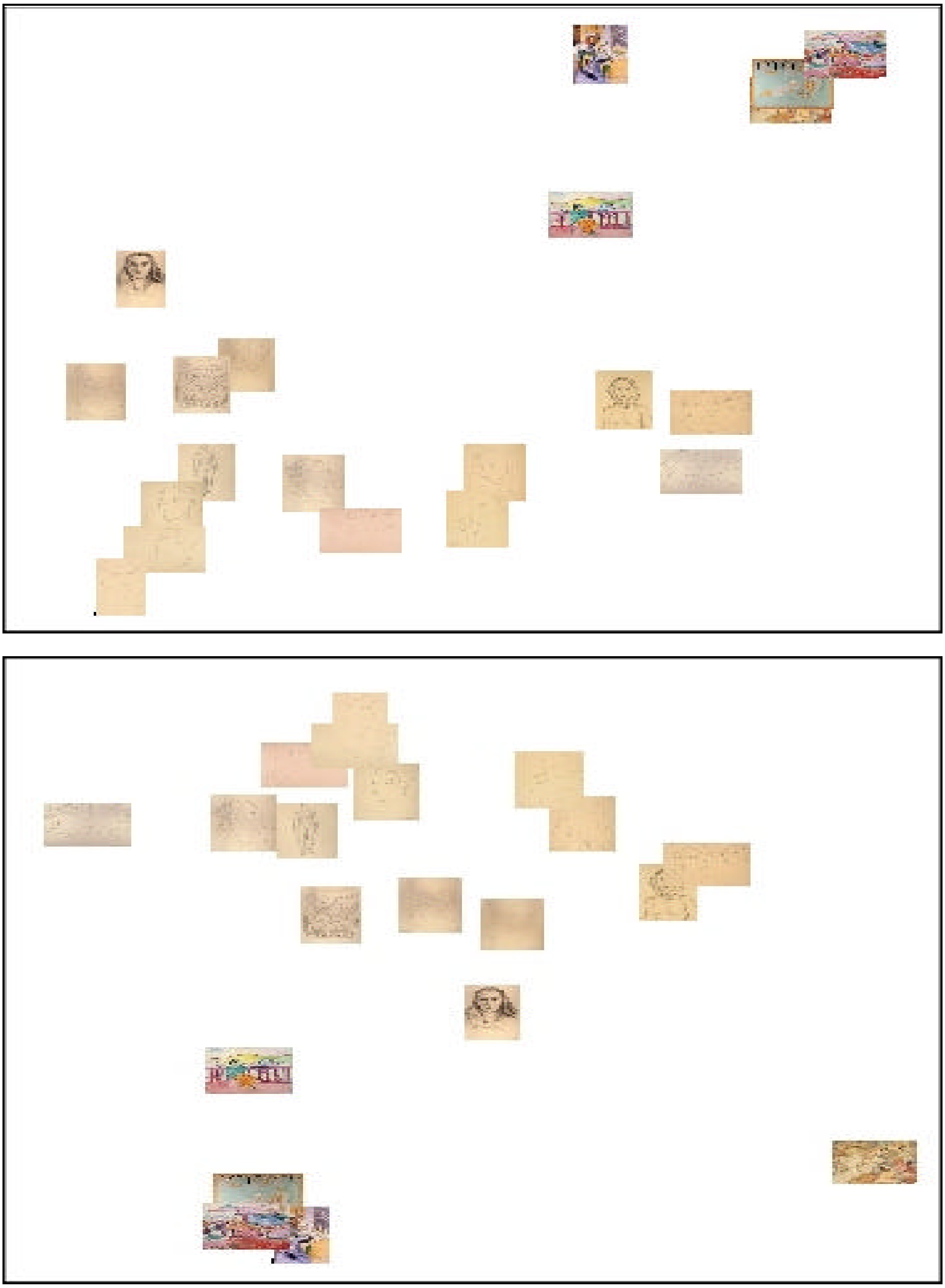

Fig. 2: Two-dimensional image scatter-plot of images within the database, according to the similarity relations between the images (same query image as in figure 1). The distances within the image locations are proportional to the image similarity. The two-dimensional scatter is performed according to the angle between the image signatures and their corresponding distances (upper image) and according to the FastMap algorithm (lower image).