Wavelet-Based Multi-level Object Retrieval In Contour Images

Azhar Quddus, Faouzi Alaya Cheikh and Moncef Gabbouj
Tampere University of Technology (TUT),
Signal Processing Laboratory,
P.O. Box 553, FIN-33101
Tampere, Finland
{azhar, faouzi, moncef}@cs.tut.fi

Abstract

In this paper we present a novel approach to shape similarity estimation. The target application is content-based indexing and retrieval over large image databases. The technique is based on wavelet decomposition and uses polygon approximation over several scales. This technique uses simple features (aspect ratio, angles, distances from the centroid, distance ratios and relative positions) extracted at high curvature points. These points are detected at each level of the wavelet decomposition as wavelet transform modulus maxima. The experimental results and comparisons show the performance of the proposed technique. This technique is also suitable to be extended to the retrieval of 3-D objects.

Introduction

Since the early 1990s, content-based indexing and retrieval (CBIR) of digital images became a very active area of research. Both industrial and academic systems for image retrieval have been built. Most of these systems (e.g. *QBIC* [9] from IBM, *Netra* from UCSB, *Virage* from Virage Inc., *MUVIS* [10, 11] from TUT) support one or more of the following options: browsing, searching by example, search based on a single or a combination of low level features such as color, shape, texture, spatial layout of objects in the scene and keywords.

In the case of shape, high curvature points are robust features in the sense that they are invariant under translation, rotation and scale change [1,2]. Moreover, they provide reliable clues regarding objects even under occlusion and varying background levels [3]. Corner-based representation of objects reduces significantly the size of the feature vector representing the object-contour, while still keeping mach of the boundary information essential to object recognition [7]. Therefore, object recognition techniques based on corner point matching have been used in machine vision applications [3, 4]. It can be seen that complexity of the algorithms proposed in [3, 4] increases exponentially as the number of candidate objects increases. Therefore, these techniques are not suitable for large image databases where thousands of images are involved.

In this context we propose a robust wavelet-based matching algorithm, which is suitable for contour-based object matching. Moreover, it is not very sensitive to noise and is invariant to rotation, flipping and scale change. The algorithm uses both local and global features and produces a scalar measure for the degree of similarity between two shapes. In this proposal the performance of our approach is evaluated for estimating the similarity of natural objects. The retrieved images with the proposed approach are compared to those retrieved with the contour scale-space (CSS) base technique [8] and to a set of images retrieved by humans.

Wavelet-based feature extraction and matching

Wavelet decomposition provides natural setting for the multi-level image contour analysis. Since wavelet transform modulus maxima (WTMM) provide useful information for curvature analysis [6,12], we propose to use it here for fast feature extraction. It has been shown in [5, 12] that biquadratic wavelets, proposed by Mallat and Zhong [13], perform better than other wavelets for corner detection applications.

First the boundary is tracked and its orientation profile is computed as in [14]. Wavelet transform of the orientation profile is computed for dyadic scales from 2^1 to 2^6. WTMM is then computed and scaled with the global maxima at the same scale. Only those WTMMs greater than a certain threshold are taken as valid candidates. These events are tracked in the lower successive levels to find their exact locations. This procedure is repeated from level six to two.

Fast schemes for narrowing the search space are becoming essential in content-based retrieval systems due to the size of databases. Here we used the aspect ratio γ to reduce the search space. Images with error on γ larger than a fixed threshold is discarded. The remaining candidates go through the second step of the retrieval process, where a set of low-level features are extracted and compared to those of the query image. These low-level features are the angles subtended (at the corners), distances from the centroid (of the contour), distance ratios and the locations of the corner points.

Algorithm:

1. Select candidate objects with similar aspect ratios as the query object,
2. Locate the important high curvature points based on WTMM, for each level of the wavelet decomposition,
3. Extract a set of low-level features for each of the selected high curvature point,
4. Compute a similarity score, at each level, between the query image and the image in the database,
5. The final similarity score is computed as the mean of the scores at each level.

At each wavelet decomposition level l, we characterize the query image contour with four vectors, ϕ_l^q, D_l^q, R_l^q and L_l^q, where, $\phi_l^q = [\theta_{l1}^q \quad \theta_{l2}^q \quad \cdots \quad \theta_{lm}^q]$ is the vector containing the angles at the contour points corresponding to detected modulus maxima, $D_l^q = [d_{l1}^q \quad d_{l2}^q \quad \cdots \quad d_{lm}^q]$ is the vector containing the distances of these points from the centroid of the contour, $R_l^q = [r_{l1}^q \quad r_{l2}^q \quad \cdots \quad r_{lm}^q]$ distance ratios and $L_l^q = [p_{l1}^q \quad p_{l2}^q \quad \cdots \quad p_{lm}^q]$ are the locations of the points on the normalized contour. Similarly we characterize the candidate image contour with four vectors, ϕ_l^c, D_l^c, R_l^c and L_l^c of length n each.

Let K be the number of valid matches for the high curvature point P_i at level l in the query object contour. A valid match is a point with corresponding errors under certain thresholds $\theta_{err} < T_\theta, D_{err} < T_D, R_{err} < T_R, L_{err} < T_L$. The similarity score at level l, for $l = 2, \quad \cdots, \quad 6$, is computed as:

$$s_l = \left(\frac{2K}{(m+n)} \times 100 \right) - \xi \text{, where } \xi = \alpha[mean(\theta_{err}, D_{err}, R_{err})] + \beta L_{err} \qquad (1)$$

where $\theta_{err}, D_{err}, R_{err}$ are relative percentage errors on the angle, distance and distance ratio, while L_{err} is the absolute error on the location. The first term in the similarity score indicates the amount of points matched, while the second part of it provides information on how good is the match.

Level one is not considered in the matching process in order to reduce the noise effect. The overall similarity score is $S = \frac{1}{5} \times \sum_{l=2}^{6} s_l$.

To initialize the algorithm, we consider the five most prominent points of the WTMM from each of the query image and the target image. And we find the best matching pair of points using the same similarity score as in Equation (1). These are used as starting points for the matching process.

Experimental results

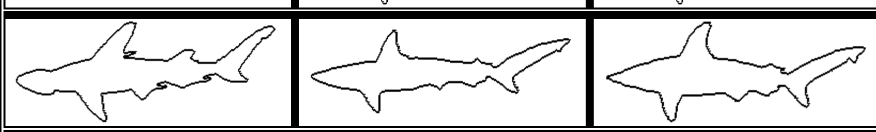
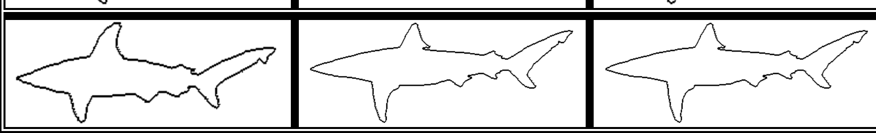
In these experiments we used 1130 fish contour images, (see acknowledgment). In Table 1 and Table 2 we present the query image in the top raw first column of each table, and the five most similar images retrieved using the CSS algorithm, the proposed algorithm and the matching results of human users. We found the threshold values $T_\theta = 35, T_D = 25, T_R = 20$ and $T_L = 0.065$ acceptable. For computation of scores (according to Eq. 1) we selected $\alpha = 0.2$ and $\beta = 100$. These values are selected so that the maximum value of ξ does not exceed 14, so it would not have too much effect on the overall similarity score.

The CSS results were obtained from the web-based demo available at: "http://www.ee.surrey.ac.uk/Research/VSSP/imagedb/dbase2.html".

Table 1

CSS	Human	Proposed algorithm	Similarity Scores with proposed algo.
			100
			96
			87
			82
			77

Table 2

CSS	Human	Proposed algorithm	Similarity Scores with proposed algo.
			100
			90
			84
			80
			77

From the above tables, one can easily see that the proposed algorithm often produces results, which are very close to those produced by human users. The produced results are clearly better than those obtained by CSS.

Conclusions

In this paper we proposed a fast and robust retrieval algorithm for contour images. This technique is invariant to rotation, scale change and noise corruption. Moreover, it is simple and thus suitable for large databases. We have compared this algorithm with scale–space based technique called “CSS” [8] and against results produced by human users. Tables 1 and 2 show that the results are encouraging.

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References

[1] Attneave, F. ‘Some informational aspects of visual perception’, *Psychological Rev*., 61, (3), pp. 183-193, 1954.

[2] Teh, C.H. and Chin, R. T., “On the detection of dominant points on digital curves”, *IEEE Trans. PAMI*, vol. 11, pp. 859-872, 1989.

[3] Han, M. H. and Jang, D., “The use of maximum curvature points for the recognition of partially occluded objects”, *Pattern Recognition*, vol. 23, pp. 21-23, 1990.

[4] Koch, M. W. and Kashyap, R.L., “ Using polygon to recognize and locate partially occluded objects”, *IEEE Trans. PAMI*, vol. 9, pp. 483-494, 1987.

[5] Quddus, A. and Fahmy, M. M., “Corner detection using various wavelets”, accepted for the ICICS'99, December 1999, Singapore.

[6] Quddus, A. and Fahmy, M. M., “Fast wavelet-based corner detection technique”, *Electronics Letters*, Vol. 35, pp. 287-288, Feb. 1999.

[7] Russ, J. C., “The Image Processing Handbook”, 3rd edition, *CRC, Springer and IEEE Press inc.*, 1995.

[8] Abbasi, S., F. Mokhtarian, and J. Kittler, “Curvature Scale Space image in Shape Similarity Retrieval,” *Springer Journal of MultiMedia Systems*, 1999.

[9] Niblack, W. et al, “The QBIC project; querying images by content using color, texture and shape”, *SPIE*, Vol. 1908, 1993.

[10] Alaya Cheikh, F., Cramariuc, B. and Gabbouj, M., "MUVIS: A System for Content-Based Indexing and Retrieval in Large Image Databases," in *Proc. of the VLBV98 workshop*, pp.41-44, Urbana, IL, USA, October 8-9, 1998.

[11] Alaya Cheikh, F., Cramariuc, B., Reynaud, C., Quinghong, M., Dragos-Adrian, B., Hnich, B., Gabbouj, M., Kerminen, P., Mäkinen, T. and Jaakkola, H., "MUVIS: A System for Content-Based Indexing and Retrieval in Large Image Databases," *Proceedings of the SPIE/EI'99 Conference on Storage and Retrieval for Image and Video Databases VII*, Vol. 3656, pp.98-106, San Jose, California, 26-29 January 1999.

[12] Quddus, A., “Curvature analysis using multi-resolution techniques”, *Ph.D. Thesis, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*, 1998.

[13] Mallat, S.,G. and Zhong, S., “Characterization of signals from multiscale edges”, *IEEE Trans. on PAMI*, Vol. 14, pp. 710-732, 1992.

[14] Lee, J. S., Sun, Y. N. and Chen, C. H., “Multiscale corner detection by wavelet transform”, *IEEE Trans. on Image Processing*, Vol. 4, pp. 100-104, 1995.