Content-based Object Retrieval Using Maximum Curvature Points In Contour Images

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ABSTRACT

In this paper we present a technique for shape similarity estimation and apply it to content-based indexing and retrieval over large image databases. This technique is based on wavelet decomposition and uses polygonal approximation. It uses simple features (aspect ratio, angles, distances from the centroid, distance ratios and relative positions) extracted at high curvature points. 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.

Keywords: Contour matching, object retrieval, indexing, image database, content, boundary, high curvature points, similarity measure, wavelet.

INTRODUCTION

Since the early 1990s, content-based indexing and retrieval (CBIR) of digital imagery became a very active area of research. Traditional methods for image indexing by keywords associated with each image are inadequate in terms of effective description of image contents, since they are subjective (relative to the person indexing the images) and are not even possible in some applications due to the fast growth of the digital material collections.

Both industrial and academic systems for image retrieval have been built. Most of these systems (e.g. QBIC from IBM, *Netra* from UCSB, *Virage* from Virage Inc., MUVIS[14, 15] 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 colour, shape, texture, spatial layout of objects in the scene and keywords.

Generally shape representation can be based on its outer boundary or on the regions it contains. Characterising the shape of an object by its boundary meets the way humans perceive objects. Since the human visual system itself concentrates on edges and ignores uniform regions[13]. This capability is hard-wired into our retinas. Connected directly to the rods and cones of the retina are two layers of the neurones that perform an operation similar to the Laplacian. This operation is called local inhibition and helps us to extract boundaries and edges[10].

An object shape however, will have an intrinsic intraclass variation (in the experimental parts of this paper we show several different fish contours for similar fishes). Moreover, object boundary deformation is expected in most imaging applications due to the varying imaging conditions, sensor noise, occlusion and imperfect segmentation. Deformable models may be a promising approach for solving this problem due to their flexibility in object modeling. On the other hand, they are computationally very expensive to be used in a real time application, or even in a retrieval application where the user expects to have a response few seconds after he puts his query. Therefore, simpler shape features have been used in several CBIR systems, e.g. QBIC[12].

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Corners and high curvature points give important clues for shape representation and analysis[1]. Since dominant information regarding shape is usually available at the corners, they provide important features for various applications e.g. object recognition, shape representation, image interpretation [2, 3] and motion analysis[4]. Corners are robust features in the sense that they are invariant under translation, rotation and scale change[5]. Moreover, they provide reliable clues regarding objects even under occlusion and varying background levels[6].

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 matching. Therefore, they are very useful in developing efficient algorithms for content-based indexing and retrieval in large image databases.

Object recognition techniques based on corner points matching have been used in machine vision applications[7, 8]. It can be seen that complexity increases exponentially as the number of candidate objects increases. Therefore, these techniques are suitable when the set of objects is small. Hence these are not suitable for large databases where thousand of images are involved.

The authors have proposed a multilevel wavelet-based technique for content-based object retrieval[16]. There, the similarity is estimated at each level of the wavelet decomposition. In this paper, we propose a robust matching algorithm, which does not require computing similarity measure at each level. This approach is robust in the sense that it is suitable for both natural and industrial objects. Moreover, it is invariant to both rotation and scale change. It gives similarity measure on the scale of 100 and is based on both global and local feature extraction and matching. In this proposal the performance of our approach is evaluated for estimating the similarity of natural objects, which is a more difficult problem than man-made objects similarity estimation. The retrieved images with the proposed approach are compared to those retrieved with the contour scale-space (CSS) based technique[11] and to a set of images retrieved by human users.

FEATURE EXTRACTION AND MATCHING

Corner point can be extracted using several techniques proposed in the literature. However, multiresultion decomposition provides natural setting for the image contour analysis. Hence, a recent and fast wavelet-based corner detection technique[9] is used here.

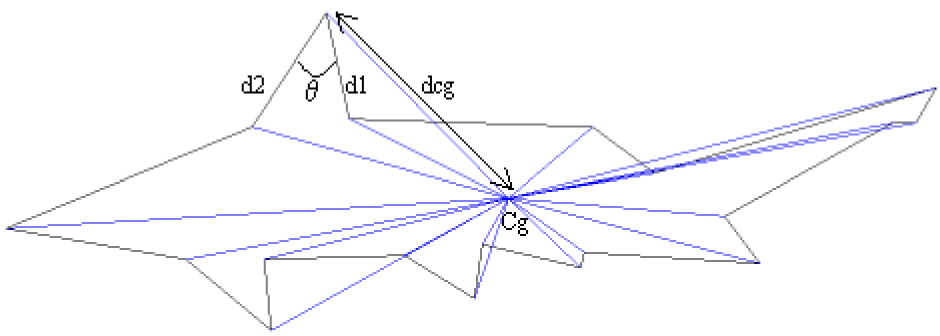
An effective way of speeding up the search while minimizing the risk of skipping good candidates, is to first narrow the search space and than to search in the set of remaining images. Global features are very important in this task since they are usually easy to extract and manipulate. In the proposed algorithm we use the aspect ratio denoted γ to reduce the search space. Images with error on γ larger than a fixed threshold, are discarded. The remaining candidates go through the second step of the retrieval process, where a set of other low- level features are extracted and compared to those of the query image. These low-level features are the angles subtended at the corner points, distances from the centroid, distance ratios of the adjacent sides and their locations on the boundary.

Algorithm

1. Select candidate objects with similar aspect ratios as the query object,
2. locate the important high curvature points based on WTMM using the approach in[9],
3. extract a set of low-level features from the polygonal approximation of the contour,
4. compute a similarity score using the extracted features from the query and candidate object.

In the following, we characterize the query image contour with four vectors, ϕ^q, D^q, R^q and L^q, where, $\phi^q = [\theta_1^q \quad \theta_2^q \quad \cdots \quad \theta_m^q]$ is the vector containing the angles at the contour points corresponding to detected modulus maxima, $D^q = [d_1^q \quad d_2^q \quad \cdots \quad d_m^q]$ is the vector containing the distances of these points from the centroid of the contour, $R^q = \left[r_1^q \quad r_2^q \quad \cdots \quad r_m^q \right]$ distance ratios and $L^q = \left[p_1^q \quad p_2^q \quad \cdots \quad p_m^q \right]$ are the locations of the points on the normalized contour. Similarly we characterize the candidate image contour with four vectors, ϕ^c, D^c, R^c and L^c of length n each.

(a)



(b)

Figure 1. (a) Original contour image, **(b)** its polygonal approximation

Let K be the number of valid matches of the high curvature points, between query and the candidate objects. 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 is computed as:

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

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.

In order to get robust and rotation insensitive results, the matching is done as follows:

1. The entries in the feature vector of the query image are arranged starting from the *smallest* angle.

2. The entries in the feature vector of the target image are also arranged starting from the *smallest* angle. And score computed using equation (1).
3. The entries in the feature vector of the target image are rearranged by a circular shift in order to start from the *next smallest* angle. And again the score is computed using equation (1).

Step 3 is repeated four times and the maximum score is considered.

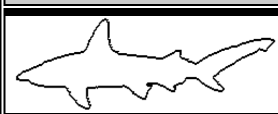
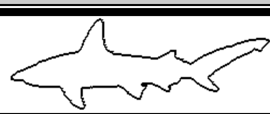
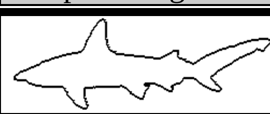
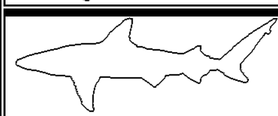
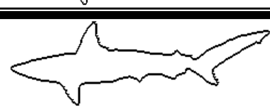
EXPERIMENTAL RESULTS

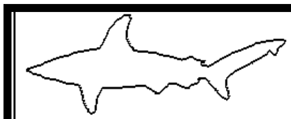
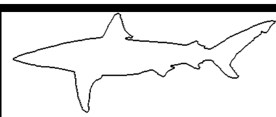
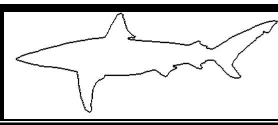
In these experiments we used 1130 fish contour images, (see acknowledgment). In Figure 2 and Figure 4 we present the query images. And in Table1 and Table 2, the obtained results with the proposed algorithm are compared to images retrieved using the CSS algorithm and human users. We found the threshold values $T_\theta = 30, T_D = 25, T_R = 50$ and $T_L = 0.04$ acceptable. For the score computation (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".

Figure 2. Query image

Table 1

CSS	Human	Proposed algorithm	Similarity Scores
			100
			95
			89
			88

			86

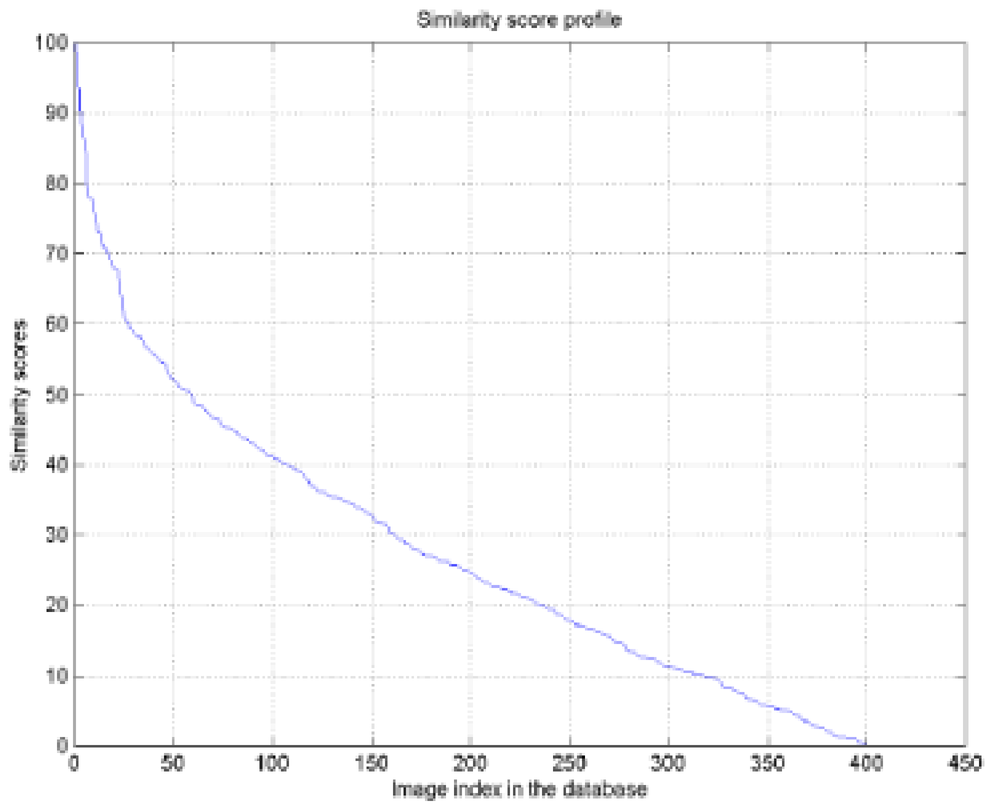


Figure 3. Similarity scores profile for the query image in Figure 2.

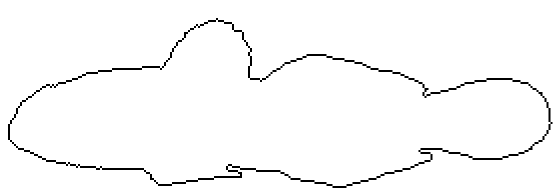
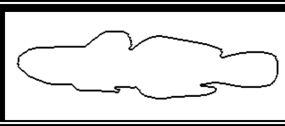
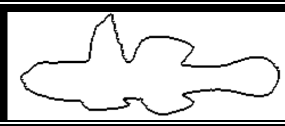


Figure 4. Query image

Table 2

CSS	Human	Proposed algorithm	Similarity Scores
			100
			98
			85
			81
			75

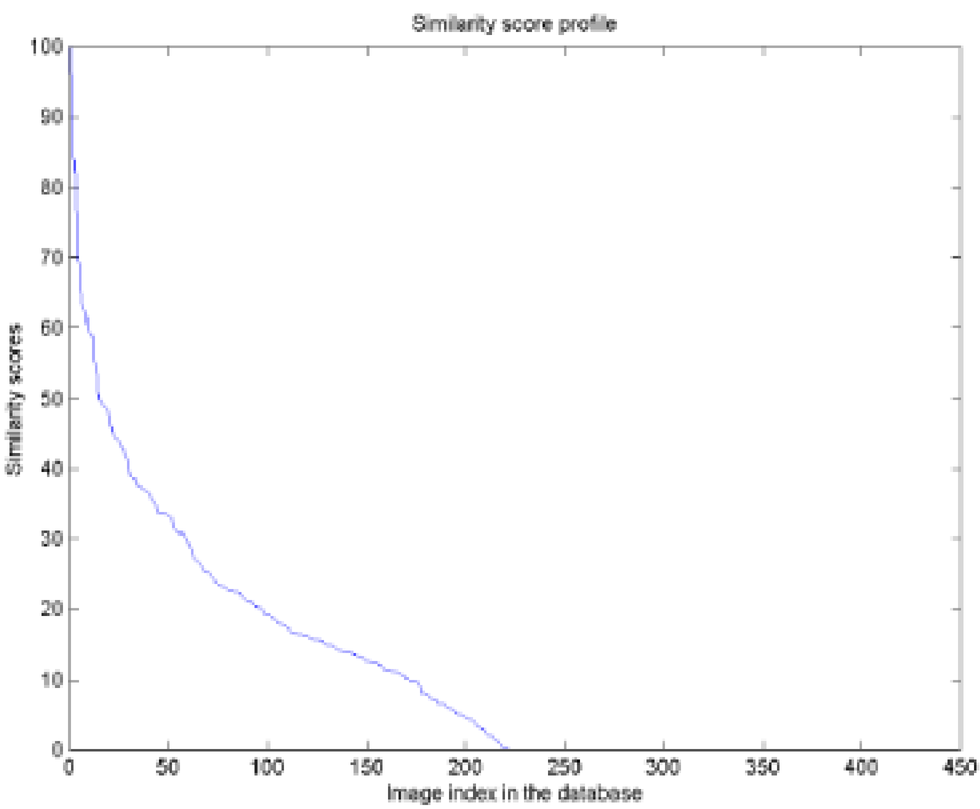


Figure 5. Similarity scores profile for the query image in Figure 4.

The approach we presented in this paper can be easily extended to 3-D object retrieval. In this case the several projections of the 3-D silhouette may be used. Each projection represents a 2-D closed contour, which can be processed with the proposed algorithm. And the set of scores obtained for different projections will provide an estimate of the 3-D shapes similarity.

CONCLUSIONS

In this paper we presented a fast retrieval algorithm for contour images. This technique is simple and suitable for large databases. We have compared this algorithm with scale–space based technique called “CSS”. The results are encouraging. This is a part of ongoing project called “MUVIS”. More results and comparisons will be provided in the full manuscript.

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