A Convexity Measure for Open and Closed Contours

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Object recognition represents an extremely powerful capability of the Human Visual System (HVS). It has been shown that shape is the single most important feature used by the HVS to recognize objects. Many general shape descriptors exist, such as Fourier descriptors and moments, which provide a feature vector of high dimensionality capable of accurately describing shape. Alternatively many shape descriptors exist which measure a single characteristic of shape. Such characteristics include circularity, rectangularity, triangularity, rectilinearity and convexity [3]. In machine vision research object contours are commonly extracted from images using an edge detection and linking strategy. Due to occlusion, scene complexity and image noise, contour extraction techniques do not necessarily always return a closed object contour. Instead, in many cases, a set of open contours corresponding to object parts are returned. This does not represent an obstacle to recognition in the HVS as psychophysical studies have shown that recognition can be successfully achieved by partial contours alone. As such, many methods exist to accurately describe the shape of open contours so that inference regarding object class can be determine. From the above discussion it should be clear that in order to perform contour based object recognition one must be able to accurately describe the shape of both open and closed contours.

In this paper we focus exclusively on the shape characteristic of convexity. Convexity represents an important descriptor of shape for many reasons. It is generally accepted that the parts of an object's contour which exhibit high convexity generally correspond to object parts. Convexity is also a nonaccidential property which can distinguish structures from noise in real images. In this paper we propose a new perimeter based convexity measure called *SC* which determines convexity by determining the shape similarity between the open contour in question and its corresponding open convex hull. The computation of *SC* requires three steps which we now briefly describe. Firstly the convex hull of the open contour is computed and from this two open hulls, entitled *CW* and *CCW*, are extracted.

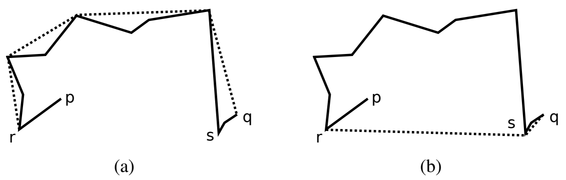

Figure 1: A open contour (solid lines) and its corresponding CW and CCW hulls (dotted lines) are displayed in (a) and (b) respectively.

Next the shape similarity between both open hulls and the original contour is determined. In order to determine shape similarity between a contour and its corresponding hulls, the turning-function representation of Arkin et al. [1] was used. This function is denoted $\Theta(s)$ and measures the angle of the counter-clockwise tangent as a function of arclength s. $\Theta(s)$ accumulates the turning which takes place; increasing with left-hand turns and decreasing with right hand-turns. The contour is rescaled such that the total perimeter is 1; $\Theta(s)$ is therefore a function from $[0,1]$ in $\mathbb{R}$. The similarity of two contours A and B is determined by Equation 1 [2]. The variable θ represents a rotation of B and the value which minimizes this integral can be calculated by Lemma 3 in [1].

$$D(A,B) = \min_{\theta \in R} \int_0^1 \left(\Theta_A(s) - \Theta_B(s) + \theta\right)^2 ds \tag{1}$$

Finally the minimum of these values, DH, is normalized using Equation 2 to give a measure of convexity. *SC* can be applied to a closed contour by representing the contour as an open contour where the first and last vertices are equal.

$$SC(W) = \frac{1}{1+DH} \tag{2}$$

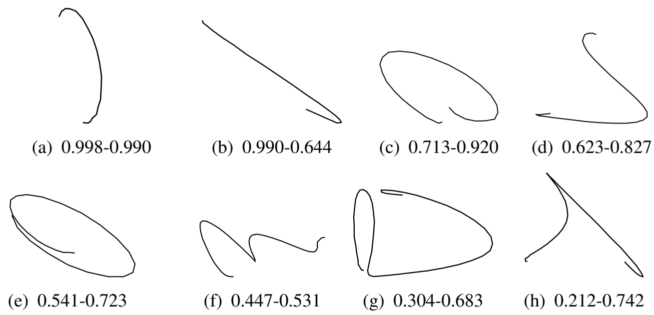

Figure 2: The convexity measures are listed in the order SC-M under each contour. The measure M is a benchmark method.

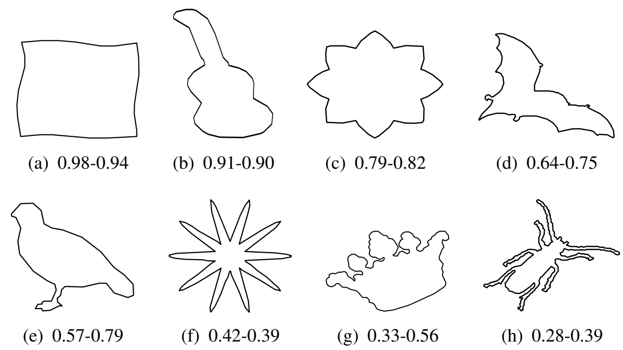

Figure 3: The convexity measures are listed in the order SC-CP under each contour. The measure CP is a benchmark method.

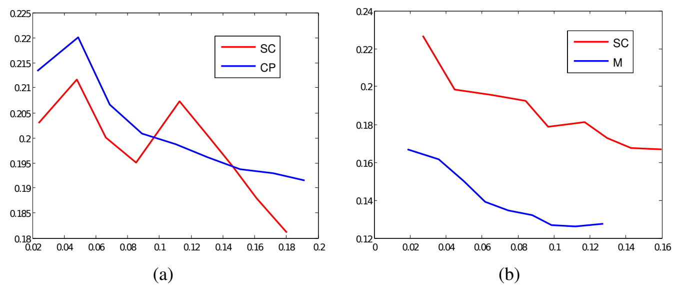

Figure 4: PR curves showing retrieval performance relative to two benchmark methods on open contours (a) and closed contours (b).

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