Contour-based Shape Recognition using Perceptual Turning Points

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Introduction
This work is about using shape-based feature for object recognition. The proposed shape feature is based on psychological and biological research.

Psychological and Physiological Evidence
It is known that the V4 area is sensitive to curvature (Pasupathy & Connor, 2001).

The points along the contour where curvature reaches (curvature extrema) a local maximum contains the most information about the curve (Attneave, 1957).

Hoffman and Singh (1997) proposed that the change of the normal angle from the two sides of a curve, called the turning angle, as a determinant of saliency.

De Winter and Wageman (2008) concluded that the turning angle between the two flanking lines on both sides of the curve (Figure 1) is an important factor for perceptual saliency.

Based on Information Theory, Feldman and Singh (2005) developed a mathematical formulation of turning angle. We used this as a basis for object recognition. Based on Shannon theory of information (1948), information content is dependent to the negative logarithm of the probability.

\[ u(M) = -\log[p(M)] \]

The quantity \( u(M) \) is also called the surprisal of M. The information content is the expected value of the surprisal.

\[ I(M) = -\sum_{M} p(M) \log[p(M)] \]

1. We used Canny edge detection to extract edges, and separate out the lines by breaking the branchings

2. To obtain the turning points (TP), we first find the local neighbourhood peaks of the surprisal and measure the normal angles adjoining two points on either side of the central point (Figure 2). The peak surprisal within a window that exceeds a certain threshold is marked as our TPs.

3. Over a small local neighborhood, we mark the peak surprisal with local turning angle that exceeds a threshold within that window. If there are many equal maximum values, we pick the one point in the middle of the window as the turning point.

Object Recognition
1. To detect the object, we slide multiple sizes window across the image.
2. Then we count the number of features that matches.
3. The window with the largest total of matches is the location of the object.

Results

Fig 1. Turning points of an object is strongly suggestive of its shape.

Fig 2. Turning angle measured as the difference of normal angle (arrowed line) between straight line segments connecting to two neighbouring salient points (dark circles).

Fig 3. Unbranching edges.

Fig 4. Location and magnitude of surprisals.

Fig 5. Turning points as calculated

Fig 6. Feature matching.