I-034

# Study of Detecting Primitive Shapes by Local Optimization Method

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## 1. Introduction

Feature extraction is one of the most important issues among computer vision and pattern recognition. As a kind of feature, shape of natural objects is often adopted as description both computer and our human being. In diverse areas of computer vision, such as medical imaging, scene understanding, intelligent transportation system and etc, we may find benefit from the detection of shape primitives. Recent years, ellipse detection from image becomes an attractive issue. However, the accuracy as well as the robustness against noise is a challenging issue for this topic. It is well known that ellipse detection from parametric methods, typically Hough Transform [1], and Randomized Hough Transform (RHT), require random selection of five pixels from edge image to compute a set of ellipse parameters. For the sake of random selection process, these methods suffer heavy computation load and inaccuracy against noise in the edge images. Alternative methods, including the variations of RHT [2], resolve the speed problem by decrease the dimension of equation parameter space, which is achieved by using the symmetrical characteristic of ellipse. Nevertheless, the efficiency is obtained by paying the cost of some functionality, such as capability of partial ellipse detection.

In this paper, we propose a local feature based ellipse detection method to improve the accuracy against complex edge image. Our method extract ellipse by observe the edge pixels appearance, when edge curve "looks like" an ellipse; we treat it as a candidate of detection result. Obviously, to reach this goal, we have to firstly recognize which part or parts have the greater probability to be classified within the same primitive shape feature. This is one of the major focuses in the algorithm design, which is achieved by computing the local features, including curvature of an edge curve in a chain code format, as well as the local color intensity. As demonstrated in Fig.1, we perform elliptical shape detection from edge segmentation and recombination through manipulating the local feature over an edge image. In this work, canny operator is adopted to obtain edge image. In section 2, we introduce the detail of edge segmentation. Following segmented edges, categorize them into clusters, where initial ellipse detection is achieved. The re-combination process is described in section 3 Section 4 gives the procedure of ellipse estimation. The last section, we give out the conclusion and discussion toward the proposed method.

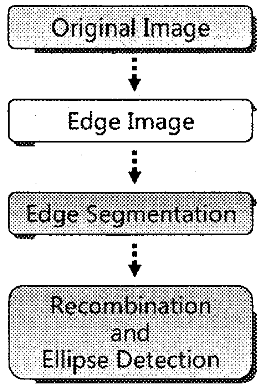


Figure 1. flowchart of the proposed ellipse detection algorithm

## 2. Edge Segmentation

Edge image, as the fundamental input to our method, probably has the undesirable factors, such as noise and rupture of integrity. Detected from canny operator, all edge pixels are valued "1", the others "0". In a labeling issue viewpoint, the result of edge contains only two groups. To achieve ellipse curve clustering, the edge image is thus segmented according to local features.

Local features of edge pixel involved in our algorithm include spatial range, which computes the curvature for each pixel in one concatenated curve, and color range that observes the color intensity of each side of the current pixel. Chain format curvature of a concatenated edge curve reflects the continuity. Because our target is ellipse that is continuously changed its curvature at each point. We assume that one curve segment should satisfy C1 continuity at each pixel, Fig.2. The smoothness constraint is imposed by computing the curvature over a predefined size of window block in the target edge curve. For the constraint in color range, we do not one curve segment have abrupt change at corresponding position in original color image.

## 3. Curve Segments Re-combination

The segmentation step split edge pixels into groups according to local features. However, the discontinuity in the original edge detection result might be a impassable gap of detection of some partially occluded ellipses. We combine the visually concatenated but

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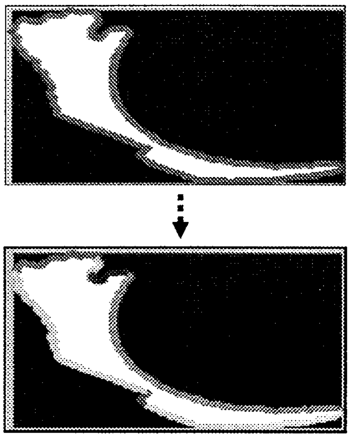

Figure 2. edge segmentation according to local features

spatially separated edge curves into one group. This is achieved by walking along the direction in ellipse curve, in real computation of which we set a certain range instead of an exact value for this direction, of one segmented curve, and seeking the terminal of candidate curve segment that has the similar curvature and gradient value. If found, the validation is computed by observing the following edge pixels curvature and gradient value against the assumption, all these pixels are spatially with consistence of the ones in the expected direction. This is the process of verifying whether "it looks like an elliptical arc".

## 4 Ellipse Estimation

With the re-combination result, we could easily estimate an ellipse if its length are within the pre-defined threshold.

This method can also achieve parametric estimation by fitting an ellipse, Eq.1, over the re-combined edge curve segments.

$$Ax^2 + 2Bxy + Cy^2 + 2Dx + 2Fy + G = 0 \qquad (1)$$

with constraints for an ellipse:

$$\Delta = \begin{vmatrix} A & B & D \\ B & C & F \\ D & F & G \end{vmatrix} \neq 0 \qquad (2)$$

$$J = \begin{vmatrix} A & B \\ B & C \end{vmatrix} > 0 \qquad (3)$$

$$\Delta / I < 0 \qquad (4)$$

where, $I = a + c$.

Specifically, we may adopt a modified RANSAC process: randomly sample five pixels from one re-combined curve segment to build an ellipse model. Distinct from ordinary sampling, in order to avoid degeneration that reasoned by sampled pixels which are nearby to each other, we random sample the pixels in the edge orientation curve. In the edge orientation curve, better sampling with larger variance of sine values, are receiving preference.

With the currently built ellipse model, the weight for edge pixels within the whole image is computed to testify the ellipse model's validity. In traditional RANSAC, validity of a model is testified by simply counting the inlier number, which results in inaccuracy for different application. Thus, instead of inlier number, we compute weights by Epanechnikov function against the distance from edge pixel to ellipse. The shortest distance between a point to an ellipse is computed by the following steps: Applying affine transform to the target pixel as follows:

$$\begin{bmatrix} x_T \\ y_T \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/a & 0 & 0 \\ 0 & 1/b & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -x_c \\ 0 & 1 & -y_c \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \qquad (6)$$

where, the parameters are of accordance with the standard ellipse equation. Thus that it transforms the current ellipse and target pixel to a new coordinate system, where the ellipse becomes a unit circle whose center is the origin of the new coordinate system. Then use the transformed pixel's vector direction $(x_D, y_D)$

$$\begin{bmatrix} x_D \\ y_D \end{bmatrix} = \begin{bmatrix} x_T \\ y_T \end{bmatrix} \cdot \frac{1}{\|(x_T, y_T)\|} \qquad (6)$$

to perform reverse affine transform. The distance between the reversely affine transformed vector direction and the original target pixel is the shortest distance between a pixel to ellipse. If the summation of each weight exceeds a certain threshold, the estimation is treated as valid, thus that current ellipse model is recorded; and its inlier pixels are masked out.

Repeat the above steps until all the pixels in current region are labeled as inliers, or attempts reach a certain number.

## 5 Conclusion and Discussion

In this paper, we proposed a local feature based ellipse detection method, which is based on a three-step algorithm: (1) segment edge pixels by computing the spatial and color range feature. (2) re-combination the "over-segmented" edge curves. (3) ellipse estimation, if necessary, run the parametric detection algorithm to obtain an accurate ellipse. The proposed method has the advantage of dealing with non-concatenated or occluded elliptical arcs detection in a noise image.

## References


[1] Saburo Tsuji, Fumio Matsumoto, "Detection of Ellipses by a Modified Hough," *Transformation. IEEE Trans. Computers*, 27(8): 777-781 (1978)

[2] Xie Y. and Ji Q., "A new Efficient Ellipse Detection Method," *International Conference on Pattern Recognition*, 2002, pp. II: 957--960, 2002