

Mining Corner Points on the Generic Shapes

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ABSTRACT

This paper designs and implements a corner detection algorithm for mining corner points on the generic shapes. The proposed corner detector detects corners by using combination of one rectangle and two ellipses (REE) with different parameter settings in their descriptions. REE combination slides along the boundary of the shape and records number of boundary points in each rectangle and ellipses. REE setup represents both local and global views of the image outline. The proposed technique presents a natural corners detection methodology to detect all true corners accurately. This technique is consistent with human vision system

Keywords: mining; corner points; corner detector; planar curves; generic shapes

1. Introduction

The extraction of corner points is useful for computer applications such as image recognition, segmentation, description, and data compression. Corner points play significant role in the area of computer graphics, pattern recognition, and computer vision. Corner points take part in document types object analysis such as map, chart, grid, table, and graph analysis. These points are used in multi-signal representation, shapes illustration, stereo system visualization, to track the movement of objects, image matching, construction of 2D mosaics [17], and the early phase of contour drawing systems. Many corner detection algorithms have been proposed in the existing literature [3-22].

Rosenfeld and Johnston [8] use k -cosine angle measurement to find corners. Rosenfeld and Weszka [9] introduce some modification of [8] in which the maxima of the difference between successive of the averaged k -cosine angle on a digital curve between the k backward and forward vector were used. Freeman and Davis [6] corner detector contains the chain scanned [8] with line sliding along the contour. The change in local curvature is measured by calculating the difference in angles between consecutive segment locations and detects corners where highest change in curve occurs. The corner detector of Beus and Tiu [3] was modification of [6] which introduces an arm limit value τ to specify the upper bound for length of moving line.

The problem of corner detection can be divided into two types. First one is boundary-based approach and

second one is region-based approach. This paper proposes a new corner detection algorithm using boundary-based approach. It is different from ordinary techniques [3,5,6,8-16,20] which detect cosine angle for change in the boundary curve. The proposed algorithm defines its setting of geometry as a rectangle (R) and two ellipses (EE) for global, intermediate and local views respectively. Hence the setting can be denoted as REE which is different than EER which was defined in [23]. Like in [15,16], it takes different scales/views (global, intermediate, local) of boundary curve with defined set of shapes (REE). Different parameters, in the description of REE determine global, intermediate, and local views of the boundary outline curve of an image. This combination is sliding along the planer curve and curve points are recorded at each move. Recorded curve points at each step are used for corner selection.

The proposed method REE and the method EER in [23] are using two ellipses and a rectangle. But the two methods are very different. In the proposed method, the rectangle used is outside the two ellipses whereas in [23], it is opposite. In addition to the new proposed method based on REE, the paper also makes a comparative study of four popular corner detection algorithms [3,4,6,15] for boundary of shapes presented. The proposed technique is useful to detect corners from generic shape boundaries with or without noise.

The organization of the paper is done as follows. Section 2 gives basic formulation of the technique as well as the design of the proposed corner detection algorithm. Corner detection results are demonstrated in Section 3. A

comparative study, with the existing algorithms in the current literature, is made in Section 4. The paper is finally concluded in Section 5.

2. Proposed Algorithm

Proposed technique of corner detection is based on rectangle R and two ellipses E_1 and E_2 sliding along the given curve. E_1 and E_2 are embedded in R such that $R \supset E_1 \supset E_2$. The geometry of the rectangle and two ellipses is shown in Figure 1. To gather information about the locality of neighboring curve points, proposed technique uses rectangle and ellipses shown having common center at p_i .

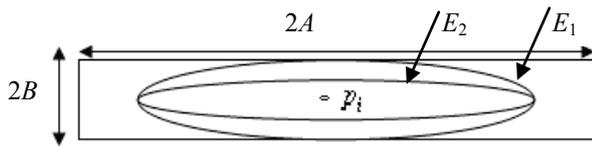


Figure 1. Geometrical structure of NEW Algorithm.

The mathematical relations of R and two ellipses E_1 and E_2 is described in Equation (1). The geometric structure of Figure 1 has been adopted as follows:

- The length and width of the rectangle R are considered to be the lengths $2A$ and $2B$ respectively.
- The semi minor axis and semi major axis of the ellipse E_1 are considered to be the lengths $3A/4$ and B respectively.
- The semi minor axis and semi major axis of the ellipse E_2 are considered to be the lengths $3A/4$ and $B/2$ respectively.

$$\left. \begin{aligned} R_1 &= 2A \times 2B, \\ E_1 &= \pi \times 3A / 4 \times B, \\ E_2 &= \pi \times 3A / 4 \times B / 2, \\ \theta &= \text{slope 'S'} \end{aligned} \right\} \quad (1)$$

The length of rectangle and semi major axes of ellipses lie in the direction of slope 'S'. Hence the width of rectangle and semi minor axes of ellipses lie at right angle to the slope 'S' of the contour with center at curve point p_i , $1 \leq i \leq n$, where n is the total number of contour points. Slope of curve point at p_i is determined along the line drawn by calculating mean of five points (including p_i) on both sides of p_i .

By taking boundary point p_i as center, the direction of rectangle R is adjusted along major axes of the Ellipses. Similarly, ellipses E_1 and E_2 having same center at p_i are configured with same procedure. Thus $R \supset E_1 \supset E_2$.

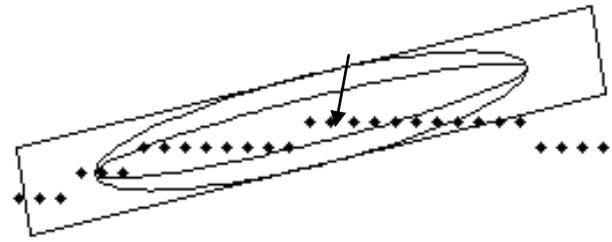


Figure 2. Snapshot of NEW Algorithm.

Combination of rectangle and ellipses slides on given curve and number of adjacent points for rectangle and each ellipse. It is recorded from p_{i-A} to p_{i+A} which lie in the area R , E_1 , and E_2 . Let nR_i , $nE_{1,i}$ and $nE_{2,i}$ describe the total number of curve points in rectangle R , ellipses E_1 , and E_2 respectively, with centers at i^{th} boundary point. For example in Figure 2, $nR_i = 23$, $nE_{1,i} = 18$, and $nE_{2,i} = 15$. Values of nR_i , $nE_{1,i}$ and $nE_{2,i}$, for each boundary point, are finally used while marking the absolute positions of corner points.

Proposed algorithm adopts natural corner detection methodology by combining three levels of views. Combination of one rectangle and two ellipses represents three special views of curve points. It traces number of counts nR_i , $nE_{1,i}$ and $nE_{2,i}$, for each boundary point. It calculates sufficient information to mark the absolute corners. Rectangle R_1 represents global view of boundary points and allowing only those boundary points for which $R_1 - E_1 = 0$. These contour points are represented by set the G as follows:

$$\left. \begin{aligned} G &= \{P = nR_i - nE_{1,i} = 0\} \\ \text{Or} \\ G &= \{P = nR_i - nE_{1,i}\} \end{aligned} \right\} \quad (2)$$

Set G describes wider view of a shape and does not take false corners (at contour noise/irregularities). This is demonstrated in Figure 3 which shows some snapshots with curves noise/irregularity. Center points p_i 's in Figures 3(a) and 3(b) look like corners if the local view of contour is taken, but if we observed the global view (broader part of the curve), these corners are rejected as they do not qualify the Equation (2). In general, $R_1 - E_1 = 0$ pointing with arrows. Curve points in Figures 3(c) and 3(d) are only be considered in group G .

Curve points lying in the set G are corner points in a relative way, they can be considered as candidate corner points. These points describe common region of contour where the actual corner is located as shown in the circled regions in Figure 4. Set G describes connected points that represent a group and there is a possibility that more than one group may exist in set G . For each group, there is only single point which represents actual corner. The curve points in $E_{2,i}$ of values $nE_{2,i}$ less than threshold ' η ' are calculated for every group and smallest value $nE_{2,i}$ is

selected as a corner. If in a group the number of points in $E_{2,i}$ are lower than ' η ' then it means that corner point

does not exist in that group.

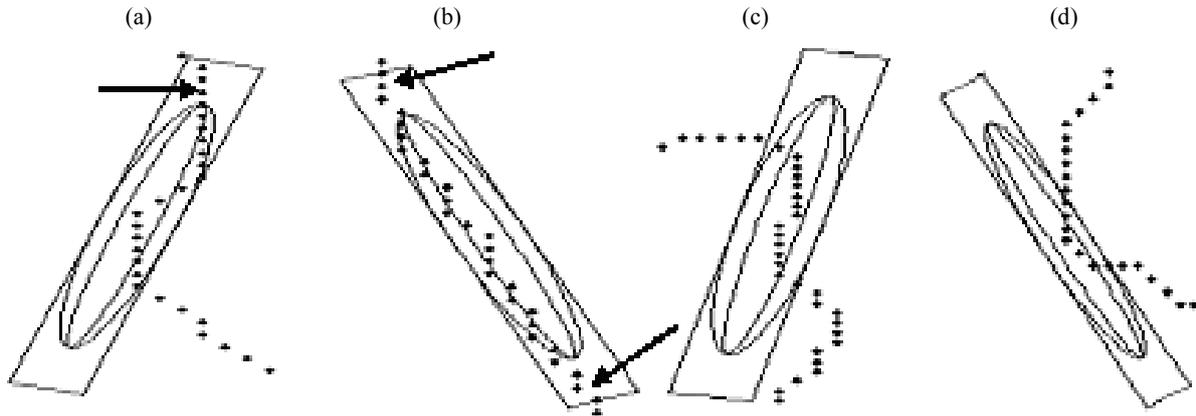


Figure 3. Some snapshots of NEW Algorithm for irregular boundary. (a), (b) are not qualified by G , and (c) is rejected due threshold ' η '.

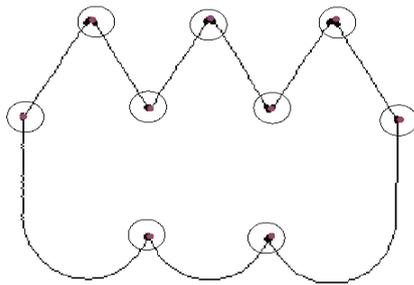


Figure 4. Some shapes marked (bold) with contour points in set G . Corners are marked in grey.

3. Experimental Results

To measure the accuracy of a corner detection algorithm, the absolute location of corner points must be known already. A board of 10 judges was used to mark the absolute position of corner points for standard shapes. Corner positions decided by majority were taken as absolute position of corners [15,16].

These corner positions were used to judge the accuracy of different corner detection algorithms. Detected corners by proposed algorithm NEW are shown in Figure 8. One can see that the corner points, detected by NEW, have happened to be the same as detected by human eyes. It is important to note that this evaluation is based on Accuracy, localization error, noise sensitivity, transformation invariance, single response, parameter setting, and computation time.

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For each contour point  $P_i$ 
Count  $nR_i, nE_{1,i}, nE_{2,i}$ 
End For
 $G = \{P_i : nR_i = nE_{1,i}\}$ 
Make groups of connected points in  $G$ 
For each group  $G_k$ 
     $Corner = \min_{nE_{2,j}} \{G_{k,j} : nE_{2,j} < \eta\}$ 
End For
    
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Figure 5. Algorithm for proposed corner detector.

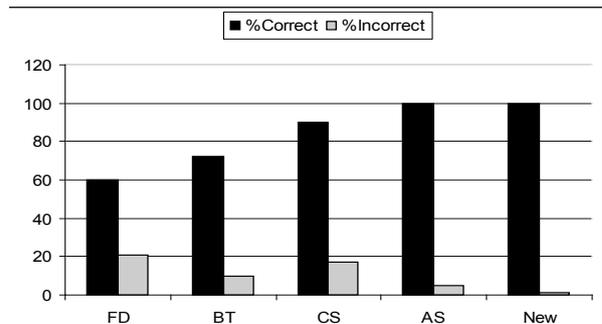


Figure 6. Result comparisons for each corner detector.

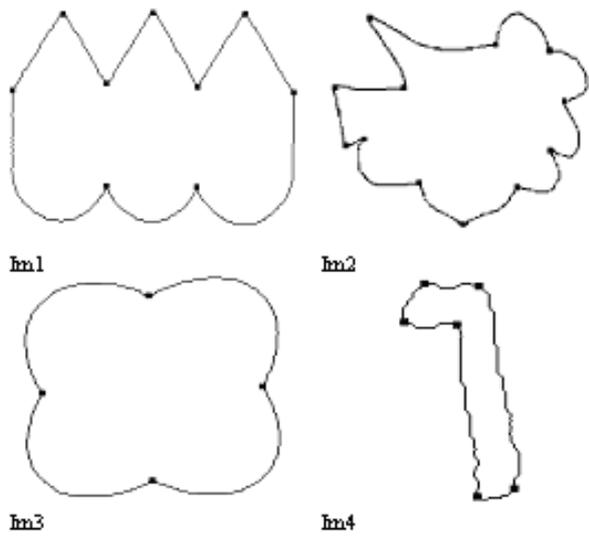


Figure 7. Test shapes with actual corner points [15].

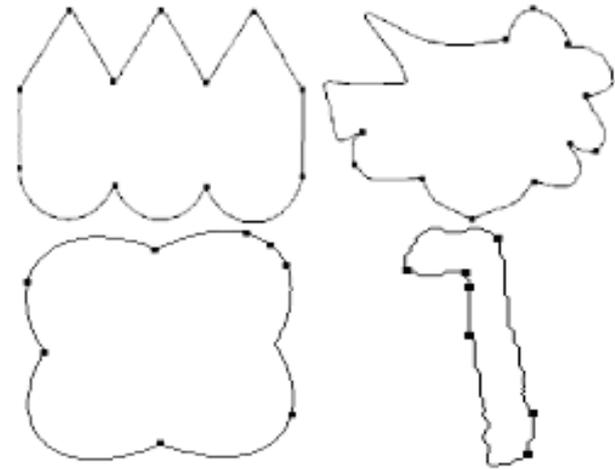


Figure 10. Corner detection by FD algorithm [6].

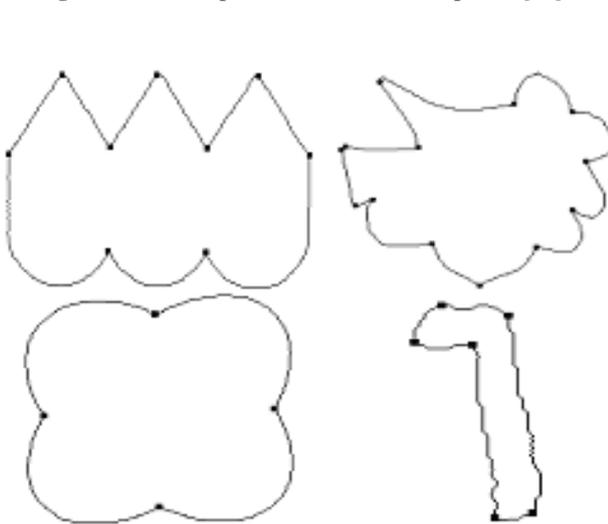


Figure 8. Corner detection by NEW Algorithm.



Figure 11. Corner detection by BT algorithm [3].

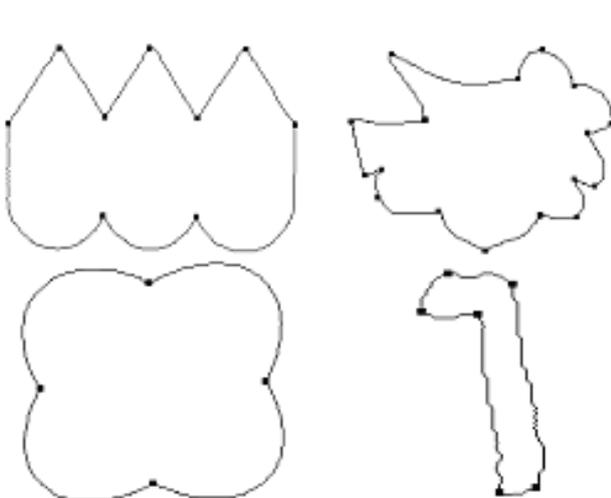


Figure 9. Corner detection by AS Algorithm [15].

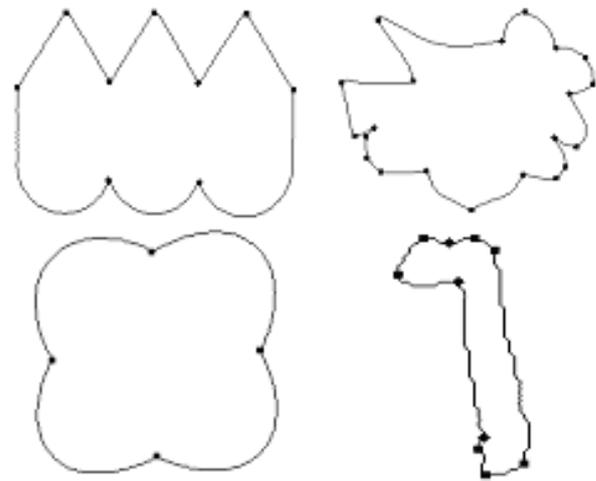


Figure 12. Corner detection by CS Algorithm [4].

4. Comparative Study

Different corner detection algorithms have been presented for digital boundary and their comparison has also been described by different authors. To evaluate a corner detection algorithm, it will properly be tested on variety of shapes. Four proposed Standard shapes, in Figure 7, contain noise/irregularities along the boundary curves, different types of varying curves, and angle sharpness. These types of variations are probable in real time shape contour. These test shapes are used in this paper for comparison/evaluation of different corner detectors. Four popular algorithms, namely BT[3], CS[4], FD[6], AS [15, 16] have been taken for comparison in our study. The proposed algorithm is referred as NEW.

A study of the five algorithms, in the light of the criteria mentioned in Section 3, has been made. Figure 8-12 shows the results of the five algorithms for the proposed test shapes in Figure 7 and their comparative graph is described in Figure 6.

Accuracy results for true corner points detected by FD corner detector were lowest (60%) for standard shapes. It is clearly indicated (in im3 and im4 of Figure 10) that FD corner detector ignores some true corners. Accurate corners marked by BT corner detector is 72% were better than previous corner detector, but it also tends to miss some important corners (in im4 of Figure 11). In case of incorrect corner detection and localization errors, the performance of BT is very good and is less than 10%. CS [4] gives very good results in case of correct corner detection which is 90%, but its false detection rate is high and is 17% which exceeds than BT. Accurate corners marked by AS corner detector are 100%, but it also detects some false corner points (in im2 of Figure 9). Performance of this algorithm is better with respect to localization errors and false detections which is 5%.

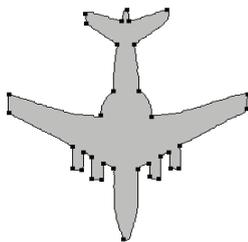


Figure 13. Corner detection by proposed Algorithm.

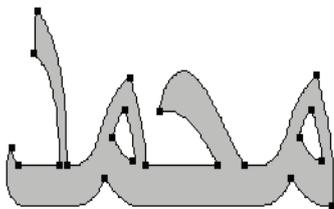


Figure 14. Corner detection by proposed Algorithm.

A considerable improvement can be seen in NEW that correctly marked 100% true corners. Lowest percentage of incorrect detection is 1% (in Figure 8) which is another big advantage of the proposed algorithm. One can hardly find localization error at any detected corner points. Performance of this algorithm must be appreciated in heavy noise conditions as well as complex shapes. No algorithm could accurately find all corners of im2, due to complex shape of the Figure. The proposed algorithm minimizes the incorrect corner(s) detection rate. Figures 13, 14, and 15 show corner detection on some more Shapes.

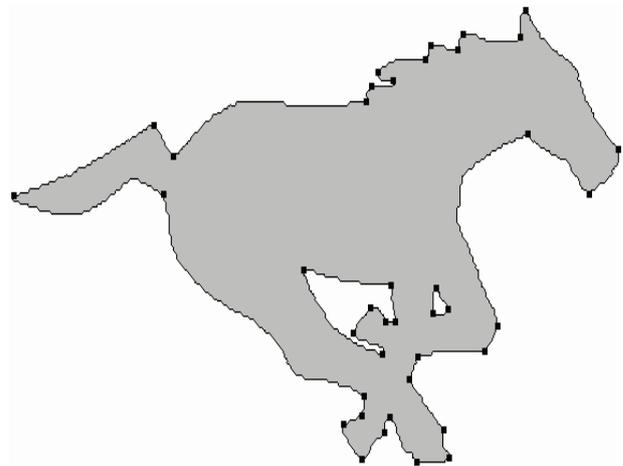


Figure 15. Corner detection by proposed Algorithm.

5. Conclusion

The new corner detection technique is proposed which does not involve curvature analysis and determination of cosine angle, hence making it very efficient. A comparative study of different corner detectors, based on proposed parameters, is given. Proposed corner detector has various advantages over previous corner detectors which are: (1) most consistent with human vision of corners; (2) ratio of false corner detection is extremely low; (3) very efficiently; (4) does not affect with transformation changes (5) highly insensitive to noise/irregularities along the curve; (6) robust to minor changes in size and resolution; and (7) very suitable for natural shapes/objects. Independent tuning of three parameters (A , B and η) for optimum results, once set appropriately, is enough for most of the shapes.

There are various applications where corner detection algorithm can be used. Specifically in vectorizing outlines of images [1] and other curve manipulation applications [2], it is highly useful. The authors intend on such applications and use the proposed algorithm.

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