

# Image Corner Detection Based on Curvature Scale Space and Adaptive Thresholding

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**Abstract:** Corner detection or the more general terminology interest point detection is an approach used within computer vision systems to extract certain kinds of features and infer the contents of an image. Corner detection is frequently used in motion detection, image matching, tracking, image mosaicing, panorama stitching, 3D modelling and object recognition. It is difficult to detect both fine and coarse features at the same time using single-scale corner detection whereas multi-scale feature detection is inherently able to solve this problem. This paper describes a multi-scale image corner detection method based on the curvature scale-space (CSS) representation and adaptive thresholding. This method uses an adaptive local curvature threshold instead of a global threshold. To eliminate falsely detected corner, the angles of corners are checked in a dynamic region of support. The results of the proposed method were compared with the results of some other popular corner detection methods. Experimental results show that the proposed corner detection method gives better results compared to other method.

**Keywords:** Corner detection, Adaptive thresholding, Curvature Scale Space.

## 1. Introduction

Corners in images represent critical information in describing object features that are essential for pattern recognition and identification. Corners in images represent a lot of useful information and they play an important role in describing object features for recognition and identification. There are many applications that are related to successful detection of corners, including motion tracking, object recognition, and stereo matching, among many others. A number of corner detection methods have been proposed in [1-4].

Kitchen and Rosenfeld [2] proposed a corner detection method based on differential operator that determines the first and second partial derivatives of an image, from which corners are identified as local extrema. This method is sensitive to noise, and suffers from missing junctions and poor localization. Moravec [5] observed that the difference between adjacent pixels of an edge or a uniform part of the image is small and the difference is significantly high in all directions at the corner. This method also sensitive to quantization noise and suffers from a loss in localization accuracy. Most of them are single-scaled and suitable for objects having similar size, but not useful for objects containing multiple-size features. To solve this problem, Rattarangsi and chin [6] proposed a multi scale algorithm based on Gaussian scale space. This method can detect corners of planar curves. This method is computationally intensive as it requires a large number of scales. Moreover, it detects false corners on circles. On the other hand, the curvature scale space (CSS) technique is more suitable for recovering invariant geometric features

of a planar curve at multiple scales. Mokhtarian et. Al. proposed two CSS corner detectors [7, 8] for gray scale images. Although multi-scale is used for localization, but still corner detection is in single scale in both method. These methods fail to detect true corners when  $\sigma$  is large and detects false corners when  $\sigma$  is small. Also, performance of these methods is sensitive to a global threshold.

Fang and Huang [9] proposed a method which was an improvement on the gradient magnitude of the gradient-angle method by Kitchen and Rosenfeld. Chen and Rockett utilized Bayesian labeling of corners using a gray-level corner image model in [10]. Wu and Rosenfeld [11] proposed a technique which examines the slope discontinuities of the x and y projections of an image to find the possible corner candidates. Paler et al. [12] proposed a technique based on features extracted from the local distribution of gray-level values. Rangarajan et al. [13] proposed a detector which tries to find an analytical expression for an optimal function whose convolution with the windows of an image has significant values at corner points. Arrebola et al. [14] introduced corner detection by local histograms of contour chain code. Shilat et al. [15] worked on ridge's corner detection and correspondence. Nassif et al. [16] considered corner location measurement. Sohn et al. [17] proposed a mean field-annealing approach to corner detection.

In this paper, we propose an improved corner detection method based on the CSS corner detector. Curvature of each contour is first computed at a relatively low scale to retain all true corners. After determining the corner candidates by the local maxima of absolute curvature function, the curvature of corner candidate are compared with an adaptive local threshold in instead of a single

global threshold to remove the rounded corners. Then the angles of candidate corners are checked to remove any false corners. The proposed detector has been evaluated over a number of images with multiple sizes and compared with two CSS methods as well as other popular corner detectors. It is found that it performs better than any of existing corner detectors for objects with multiple-size, and is more robust and reliable from image to image.

## 2. The Curvature Scale Space Technique

The CSS technique is suitable for recovering invariant geometric features of a planar curve at multiple scales. Curvature is defined as:

$$\kappa(u, \sigma) = \frac{\dot{X}(u, \sigma)\ddot{Y}(u, \sigma) - \dot{X}(u, \sigma)\dot{Y}(u, \sigma)}{(\dot{X}(u, \sigma)^2 - \dot{Y}(u, \sigma)^2)^{1.5}}$$

Where  $\dot{X}(u, \sigma) = x(u) \otimes \dot{g}(u, \sigma)$

$$\ddot{X}(u, \sigma) = x(u) \otimes \ddot{g}(u, \sigma),$$

$$\dot{Y}(u, \sigma) = y(u) \otimes \dot{g}(u, \sigma),$$

$$\ddot{Y}(u, \sigma) = y(u) \otimes \ddot{g}(u, \sigma) \text{ and}$$

$\otimes$  is the convolution operator while  $g(u, \sigma)$  denotes a Gaussian function with derivation  $\sigma$ , and  $\dot{g}(u, \sigma)$ ,  $\ddot{g}(u, \sigma)$  are the 1<sup>st</sup> and 2<sup>nd</sup> derivatives of  $g(u, \sigma)$  respectively.

Original CSS algorithm has the following six steps:

1. Obtain a binary edge map by applying Canny edge detection to the gray level image.
2. Find the edge contours, fill the gaps and find the T junctions.

3. Compute curvature at a high scale for each edge contour.
4. The contours having absolute curvature greater than threshold is considered as local maxima and twice as much as one of the neighboring minima.
5. Track the corners from the highest scale to the lowest scale to improve localization.
6. Compare T junction to other corners and remove one of the two corners which are very close.

## 3. Proposed Method

This paper changes the steps 3 and 4 of the general CSS method. In step 3, this method said that compute curvature at a fixed low scale for each contour to get all true corners. In step 4, this method says that all of the curvature local maxima are considered as corner candidates, including the false corners. Then using adaptive thresholding and true angle corner, the true corners are found.

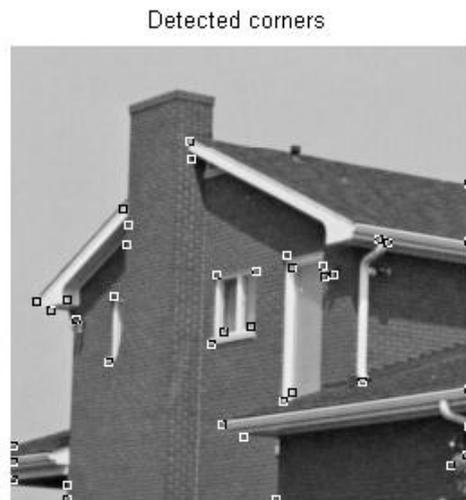
We set the threshold for a candidate according to its neighborhood region's curvature. The local maxima whose absolute curvatures are under its local threshold are eliminated. This adaptive threshold is  $g$  given by:

$$T(u) = C \times \bar{\kappa} = 1.5 \times \frac{1}{L_1 + L_2 + 1} \sum_{i=u-L_2}^{u+L_1} \kappa(i)$$

Where  $\bar{\kappa}$  is the mean curvature of the region of support,  $u$  is the position of corner,  $L_1$  and  $L_2$  are sizes of region of support, and  $C$  is a coefficient whose value is between 1 and 2. If  $C$  is set to 2, no corner is removed and 2 is the boundary value for retaining a corner having standard curvature function. Here, the value of  $C$  was chosen 1.5.



(a)



(b)



(c)

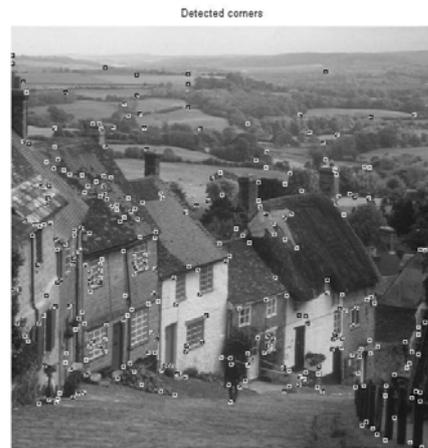


(d)

**Figure 1.** Corner detection over image house. a) Original image, b) Detected corner with CSS c) Detected corners with modified CSS and d) Detected corner with the proposed method



(a)



(b)

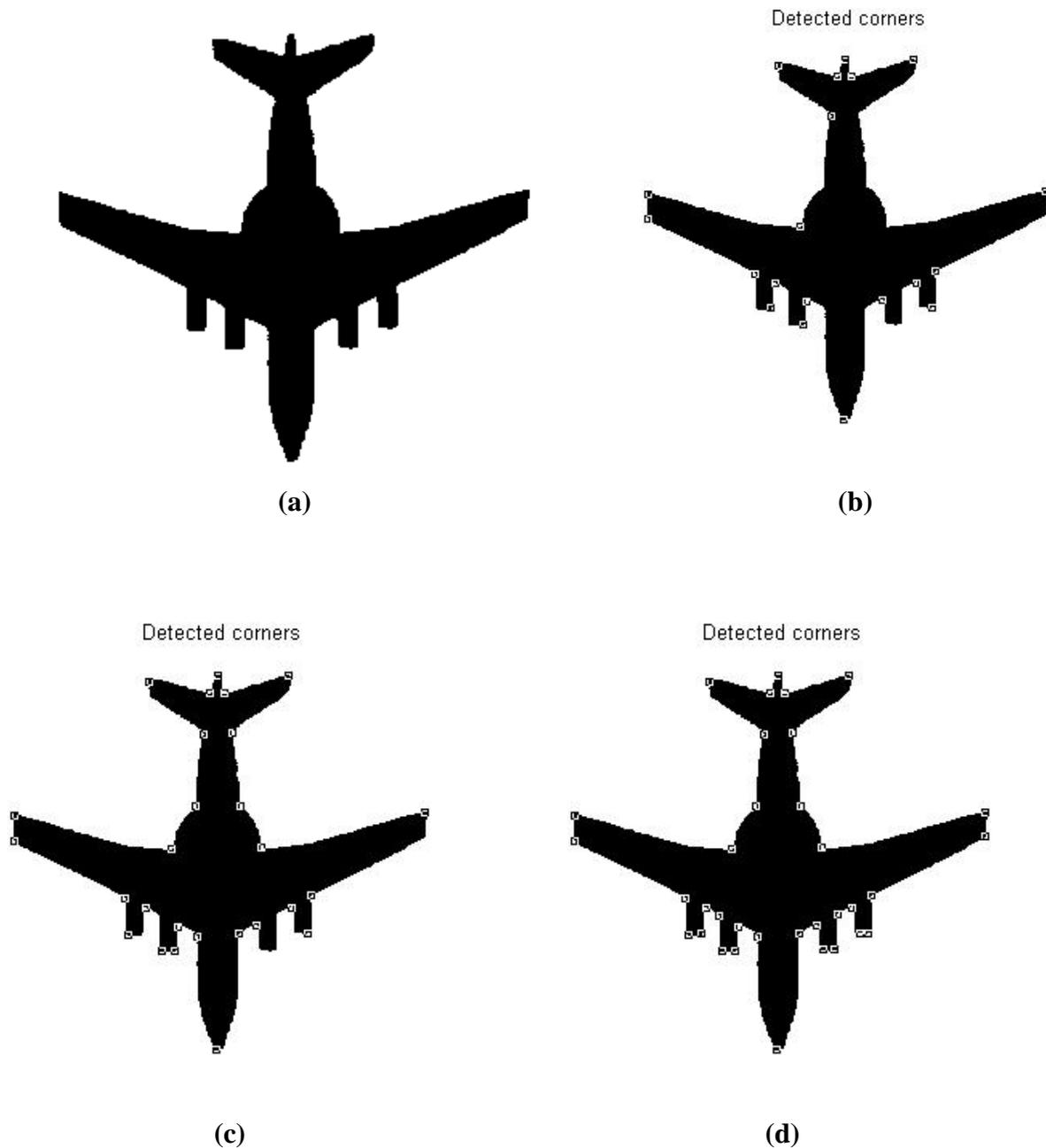


(c)



(d)

**Figure 2.** Corner detection over image hill. a) Original image, b) Detected corner with CSS c) Detected corners with modified CSS and d) Detected corner with the proposed method



**Figure 3.** Corner detection over image airplane. a) Original image, b) Detected corner with CSS c) Detected corners with modified CSS and d) Detected corner with the proposed method

#### 4. Experimental Results

The proposed method was applied over different images and the results of the proposed method were compared with original CSS and enhanced CSS method. Figure 1 compares the results of the proposed method with the two other mentioned methods over image house. It can be observed from this figure that the proposed method can determine the existence of corner more exactly than the other two methods.

Figure 2 compares the results of the proposed method with the two other mentioned methods over image hill. It can be observed from this figure that the proposed

method can determine the existence of corner more exactly than the other two methods.

Figure 3 compares the results of the proposed method with the two other mentioned methods over image airplane. It can be seen from this figure that the proposed method shows better performance for corner detection than the other two methods.

#### 5. Conclusion

This paper proposed a new corner detection method based on the curvature scale-space technique and global threshold. The edges of a real image were extracted using the Canny edge detector. The gaps between two close

contours were examined in order to find T-junction corners or to fill the gap to form a continuous contour. Curvature maxima were extracted at a high scale and the corner locations were tracked at multiple lower scales to improve localization. Then using adaptive thresholding instead of a unique threshold and true angle corner, the true corners are found. The proposed method increases the number of true corners detected and reduces the number of false corners detected. It can be said that the proposed method more suitable than other methods.

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