# Early Jump-Out Corner Detectors

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## Abstract

We present two new corner detectors, one of which works by testing similarity of image patches along the contour direction to detect curves in the image contour, and the other of which uses direct estimation image curvature k along the contour direction. The operators are fast, robust to noise, and self-thresholding. We also present a new interpretation of the Kitchen-Rosenfeld corner operator in which we show that this operator can also be viewed as the second derivative of the image function along the edge direction.

## 1 Introduction

While primitive features such as edges and lines are vital visual clues, intersection of edges such as corners and junctions, commonly referred to as 2D features, provide rich information for examining frame-to-frame displacement characteristics of images. Thus, in applications involving disparity analysis such as motion detection and depth from stereo, we need to identify these 2D features.

## 2 Similarity Corner Detector

If two image patches along a straight edge segment are compared with each other, they will be very similar. If the edge segment is curved, as at a corner, the two image patches will be dissimilar. Thus corners can be detected where the similarity is low between image patches translated along the edge direction.

Apart from the image moise level itself, there are two types of error that need to be allowed for when image similarity is used as a corner test. The first is quantization error, which will cause differences of up to half a pixel distance between the calculated neighbourhood positions and the actual positions at which tests are performed. The second results from noise related non-symmetry of pixel neighbourhoods. When the image gradient is low, noise has a large effect on the calculated contour direction and therefore on the calculated neighbourhood positions.

### 2.1 Early-Jump-Out

Our method makes extensive use of a similarity test that therefore must be fast. In this section, we outline a fast method for determining similarity between pairs of sub-windows.

Barnea and Silverman [1] propose fast image similarity test. In their method, at a randomly chosen sequence of locations within the test window pair, the absolute value of the pixel difference between windows is added to an accumulating difference sum. They define a threshold sequence such that if at any stage in the computation of the difference sum, the partial result is greater than the corresponding value in the sequence, we can "jump out" of the similarity test with the conclusion that the test windows are not similar. We term this the early jump-out technique.

A speed-up factor of 50 is claimed for the above technique when the test window size is $32 \times 32$ [1] in comparison with traditional correlation because the similarity test is in general terminated long before all the test pixels have been visited. The Early Jump-out technique was extended by Cooper, *et al.* [2] to use a second threshold sequence that allows Early Jump-out with the conclusion that the windows are similar when the difference sum is growing slowly. They also showed how to calculate the threshold sequences given the standard deviation of the image noise. Their method is more closely related to the Sequential Probability Ratio Test [3].

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### 2.2 The Image Surface

In [2] it was shown that the rate at which the difference sum grows is proportoional to the magnitude of the image surface curvature along the contour direction. This curvature could be measured if we fitted a quadratic surface to the neighbourhood of the test pixel. Let g be a second-order approximation to the local image surface. We can obtain the component of $g''$ along the contour direction by pre- and post- multiplying $g''$ by a unit vector that is orthogonal to $g'$. Thus after the notation of [4] we have

$$k = \frac{1}{\sqrt{g_x^2+g_y^2}} \begin{pmatrix} -g_y \\ g_x \end{pmatrix}^T \begin{pmatrix} g_{xx} & g_{xy} \\ g_{yx} & g_{yy} \end{pmatrix} \frac{1}{\sqrt{g_x^2+g_y^2}} \begin{pmatrix} -g_y \\ g_x \end{pmatrix}$$

$$= \frac{g_{xx}g_y^2 + g_{yy}g_x^2 + 2g_{xy}g_xg_y}{g_x^2 + g_y^2}.$$

It is interesting to note that the value of k is actually the quantity measured by the Kitchen-Rosenfeld corner operator [4]. While Kitchen and Rosenfeld looked upon the k as the curvature of the contour multiplied by the edge magnitude, we have shown that this value is also the curvature of the image surface along the edge direction. This straightforward interpretation renders corner detection amenable to sequential analysis.

## 3 Direct Estimation of k (DEK)

The value of k in the discussion above could be estimated directly from the image data. If we do this, the errors for which we compensated in Section 2.1 cancel out. The same procedures for generating the Early Jump-out threshold sequences used for the similarity tests can be used here, except for the different value of the noise standard deviation.

## 4 Results

We prepared a sub-image consisting of a standard set of feature types (a saddle point, L, Y and T junctions) and replicated this pattern with reducing contrast. We then added Gaussian noise with different levels of $\sigma$ to create images of different background noise level and varying signal-to-noise ratio. In these images we associated a $5 \times 5$ detection area centered on the corners. Corners detected outside these regions were termed **false positives (FP)** and failure to detect a corner in the region was termed a **false negatives (FN)**. The two corner detectors presented here were compared with the Plessey [5], the Kitchen-Rosenfeld and the Beaudet DET [4] corner detectors with the thresholds for the other corner detectors chosen so that they gave the same numbers of **FP** as the early jump-out detectors.

| image | DEK | | Sim. | | Plessey | | K-R | | Beaudet | |
|---|---|---|---|---|---|---|---|---|---|---|
| noise | FN | FP | FN | FP | FN | FP | FN | FP | FN | FP |
| $\sigma = 6$ | 18 | 6 | 17 | 18 | 18 | 44 | 17 | 33 | 18 | 140 |
| $\sigma = 15$ | 44 | 25 | 43 | 15 | 45 | 56 | 43 | 52 | 41 | 42 |

It can be seen that our detectors compare favorably with the others. In practice our detectors were faster than the Kitchen-Rosenfeld detector and slower than the Beaudet DET detector.

## 5 Summary and Conclusions

We present two new corner detectors, one of which works by using similarity tests along the contour direction to detect curves in the image contour, and the other of which estimates image curvature along the contour direction. The formulation of these operators has allowed the application of sequential analysis techniques [3] which makes them fast, robust to noise and self thresholding if the image noise level is known.

We also present a new interpretation of the Kitchen-Rosenfeld corner operator in which we show that this operator can also be viewed as the second derivative of the image function along the edge direction.

## References


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