

Corner Detection Enhancement Using Steerable Filters

Mahesh, Dr.M.V.Subramanyam

Abstract— This paper proposes a new invariant corner detection algorithm using steerable filters and Harris corner detection. The steerable filters have better orientation selectivity and multi-orientation image decomposition that provide a useful front-end for image-processing and computer vision applications. Corners are important features in a computer vision for object recognition, stereo matching, motion tracking and image registration. These corners are referred as control points or interest points for image registration. In this paper, we examine Harris, SUSAN and propose corner detectors, and compare their performance in terms of consistency.

Index Terms— Corner detection, Steerable filters, Harris, Image registration, SUSAN, Consistency

1 INTRODUCTION

Corner points are formed from two or more edges and usually edges define the boundary between two different objects or parts of the same object. There are number of approaches for detecting corners. However, a successful corner detector should detect all the true corners with well localized. Further, with minimum number of false corners, the detected corners are to be robust to noise and invariant to resolution, scale and orientation.

Kitchen and Rosenfeld [1] corner detector is based on the change of gradient direction along an edge contour multiplied by the local gradient magnitude. This method is sensitive to noise and suffers from missing junctions and poor localization.

Harris[2] corner detector is based on assumption that corners are associated with local maximum functions. Harris corner detector computes a corner value of each pixel in the image. A pixel is declared as a corner if the value is below a certain threshold. This method provides good repeatability under rotation and various illuminations. However, it is sensitive to quantization noise and suffers from loss in localization accuracy. Smith and Brady[3] proposed a SUSAN[3] (Smallest Univalued Segment Assimilating Nucleus) corner detector using a circular mask for corner and edge detection. This corner detector makes a better localization and noise robustness and is better than previous algorithms, but has an average repeatability rate.

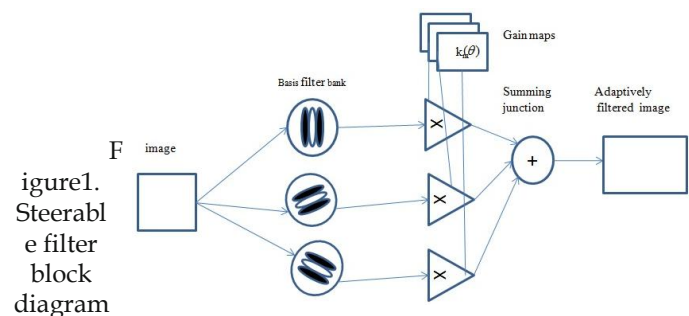
2 STEERABLE FILTERS

Steerable filters, introduced by Freeman and Adelson [4], are

- Research scholar, Department of ECE, Madanapalle institute of technology & science, Madanapalle, AP, India, vka4mahesh@gmail.com
- Professor, Department of ECE, SREC, Nandyal, AP, India. mvsraj@yahoo.com

spatial oriented filters that can be expressed using linear combinations of a fixed set of basis filters. If the transformation is a

translation, then the filter is said to be shiftable or steerable in position; if the transformation is a rotation, then the filter is said to be steerable in orientation or commonly steerable and the basis filters are normally called steerable basis filters. Given a set of steerable basis filters, we can apply them to an image and since convolution is linear, we can interpolate exactly, from the responses of the basis filters, the output of a filter tuned to any orientation we desire.



The basic idea is to generate a rotated filter from a linear combination of a fixed set of basis filters. Figure 1 shows a general architecture for steerable filters, which consists of a bank of permanent, dedicated basis filters that always convolve the image as it comes in. The outputs are multiplied by a set of

gain masks, which apply the appropriate interpolation functions at each position and time. The final summation produces the adaptively filtered image. The steerability condition is not restricted to derivative filters and could be expressed for any signal f as:

$$f^\theta(x, y) = \sum_{m=1}^M k_m(\theta) f^\theta(x, y) \quad (1)$$

where $f^\theta(x, y)$ is the rotated version of f by an arbitrary angle θ , $k_m(\theta)$ are the interpolation functions, $f^\theta(x, y)$ are the basis functions and M the number of basis functions required to steer the function $f(x, y)$.

To determine the conditions under which a given function satisfies the steering condition in Eq. (1), let us work in polar coordinates ($r = x^2 + y^2$ and $\phi = \arg(x, y)$).

The function f could be expressed as Fourier series in polar angle ϕ :

$$f(r, \phi) = \sum_{n=-N}^N a_n(r) e^{jn\phi} \quad (2)$$

where $j = \sqrt{-1}$ and N is the discrete length of coefficients. It has been demonstrated in [5] that the steering condition in Eq. (1) is satisfied for functions expandable in the form of Eq. (2) if and if only the interpolation function $k_m(\theta)$ are solution of:

$$c_n(\theta) = \sum_{m=1}^M k_m(\theta) (c_n(\theta))^m \quad (3)$$

where $c_n = e^{jn\theta}$, and $n = \{0, \dots, N\}$.

From of Eq.(3), $f^\theta(r, \phi)$ is expressed as:

$$f^\theta(r, \phi) = \sum_{m=1}^M k_m(\theta) g_m(r, \phi) \quad (4)$$

where $g_m(r, \phi)$ can be any set of functions.

It has been also demonstrated that the minimum number M of basis functions required to steer $f(r, \phi)$ is equal to the number of non-zero Fourier coefficients $a_n(r)$.

3 HARRIS CORNER DETECTOR

The Harris corner detector is based on an underlying assumption that corners are associated with the maxima of the local function. It is less sensitive to noise in the image since the computations are based entirely on first derivatives. The Harris corner detector computes a corner value, C for each pixel in the image $I(x, y)$. A pixel is declared as a corner if the value of C is below a certain threshold. The value of C is computed from the intensity gradients in the x and y directions as follows:

$$M = \begin{pmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{pmatrix} \quad (5)$$

$$C = \det(M) - k \text{Tr}(M) \quad (6)$$

where I_x and I_y denote the first derivative of the point $I(x, y)$ in the image along the x and y directions respectively. The derivatives are determined by convolving the image by a kernel

of the correspondent derivative of a Gaussian, and k is a constant with a generally assumed value of 0.04. This is a fast and simple detector that is invariant to noise, changes in illumination and rotation.

4 PROPOSED METHOD

The corner detection methods such as Kitchen and Rosenfeld, Harris, and SUSAN detect noise as false corners and miss some fine features or true corners. We propose new corner detection using the steerable filters and Harris algorithm as follows:

1. Decomposition of an image with different orientations using steerable filters
2. Detect the corners in each direction using Harris algorithm.
3. Combine all detected corners by performing logical or operation.
4. Applying dilation to the combined nearby corners to make them into one.
5. Find the centroid of step 4 and identified as corner.

We propose a corner detection algorithm as shown in figure 2 that uses the steerable filters. The experiments carried out with matlab make it clear that if the number of orientations is four it gives better localization and minimum number of false corners detection

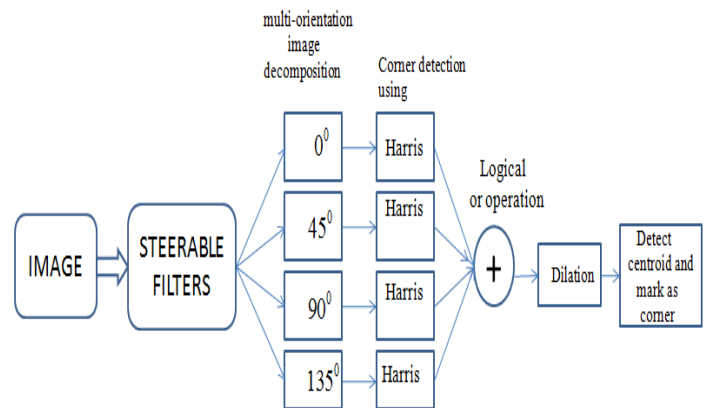


Figure2. Block diagram proposed algorithm

5 RESULT AND DISCUSSION

In this section we implement proposed corner detection algorithm tested for different images. The results are shown in figures 3(a) to 3(i).

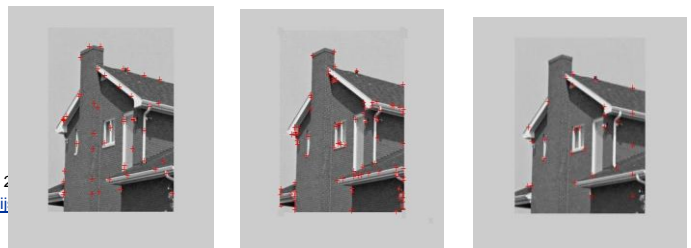
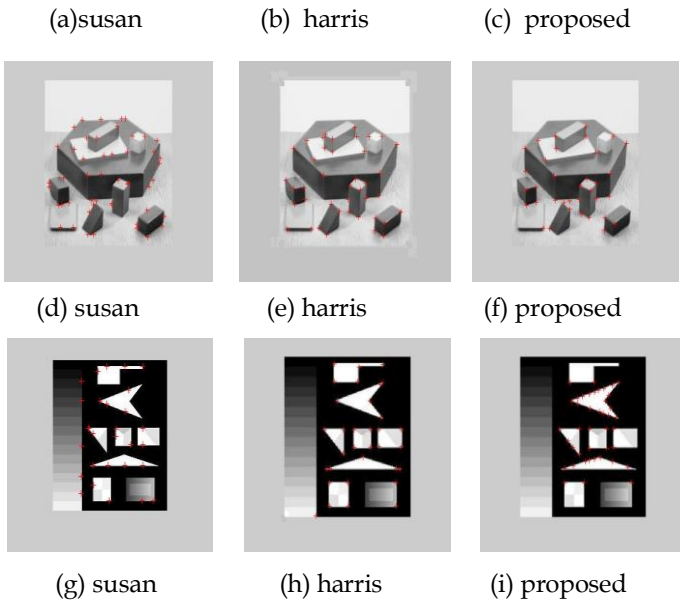


TABLE 2
CORNER RESULTS FOR THE “BLOCK” IMAGE

Rotation	Detector	Detected corners	True corners	Missed corners	False corners
0°	Susan	49	30	28	19
	Harris	45	40	18	1
	Proposed	43	39	18	4
30°	Susan	78	17	37	21
	Harris	224	21	34	1
	Proposed	68	32	26	1
60°	Susan	79	19	38	20
	Harris	222	24	34	1
	Proposed	71	35	23	3



Figures 3(a)-3(i) : corner detection on test images “house” , “block” and “sample”

TABLE 1
CORNER RESULTS FOR THE “HOUSE” IMAGE

Rotation	Detector	Detected corners	True corners	Missed corners	False corners
0°	Susan	49	20	17	22
	Harris	89	35	6	32
	Proposed	37	25	9	12
30°	Susan	82	12	21	32
	Harris	207	37	8	16
	Proposed	65	35	14	3
60°	Susan	80	13	20	32
	Harris	221	36	7	22
	Proposed	73	38	12	6

5.1 Performance Analysis of Corner Detection

The performance is evaluated in terms of number of true, false, and missed corners detected algorithms. Tables 1 and 2 show the detection of corner results summary for rotation 0°, 30° and 60°. The proposed method is compared with SUSAN and Harris. First, an experiment is conducted to detect corners for original “house” , “block” and “ sample” images. Next, original image is rotated with an angle from +90° to -90°. It has been observed that proposed method detected minimum number of false and missed corners and, stable and well localized true corners even after rotation of images.

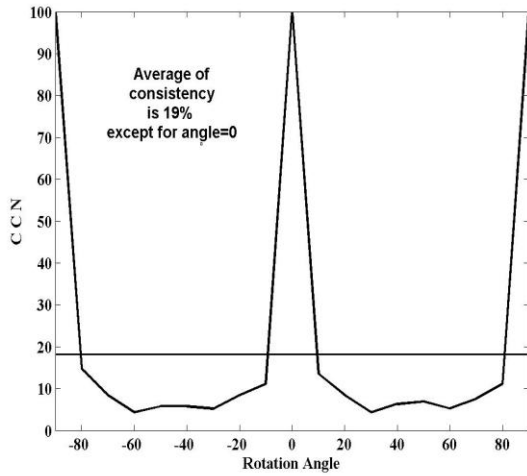
We measure the stability of corner detection algorithms using consistency of corner numbers (CCN)[7]. Consistency means numbers should be invariant to the combination of noise, rotation, uniform or nonuniform scaling and affine transform. Definition of consistency of corner numbers is as follows:

$$CCN = 100 \times 1.1^{-|N_t - N_o|} \tag{7}$$

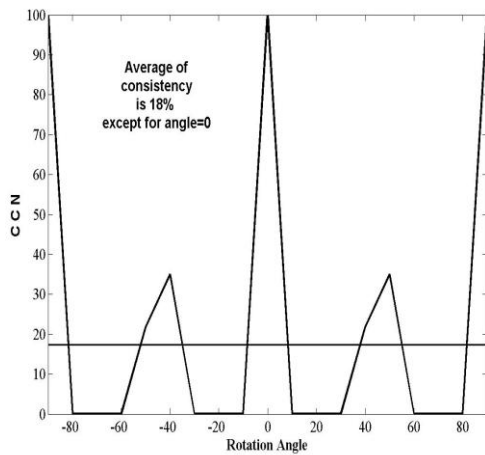
N_o - number of corners detected in original image.

N_t - number of corners in the transformed image.

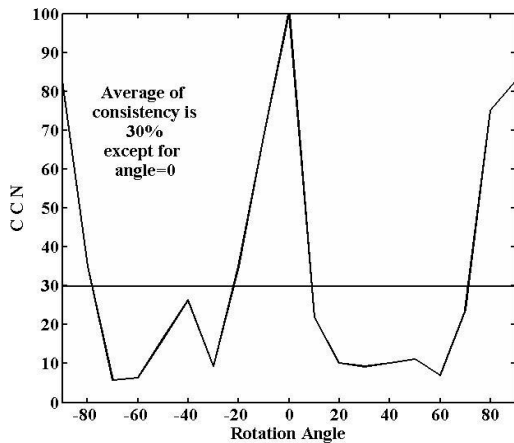
CCN for stable corner detectors should be near to 100%. CCN is near to zero for corner detectors with many false corners. It is observed that CCN measures only number of detected corners without regard to whether they are correct or not.



(a) susan



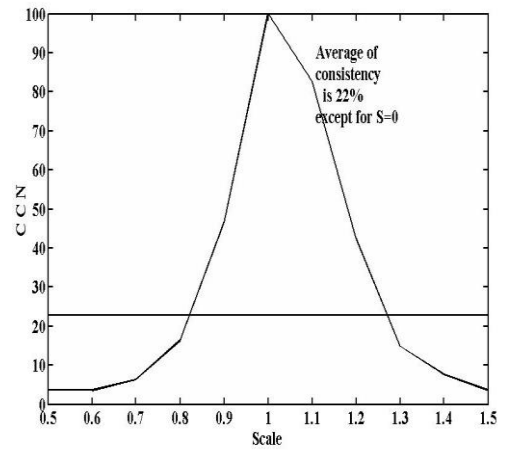
(b) harris



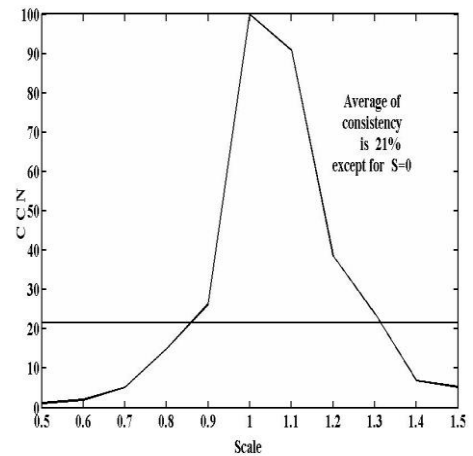
(c) proposed

Figures 4(a)-4(c): consistency of corner numbers for rotation "house" image

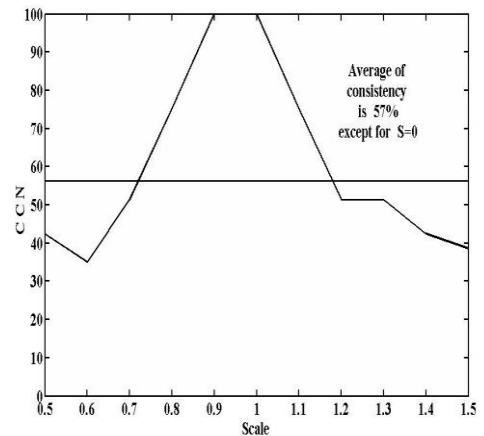
Figure 4 shows experimental results of CCN values for house image. First, corners are detected for original image. Next, original image is rotated with an angle in steps of 10° variations between -90° and $+90^\circ$. It shows that the proposed algorithm performances better than SUSAN and Harris.



(a) susan



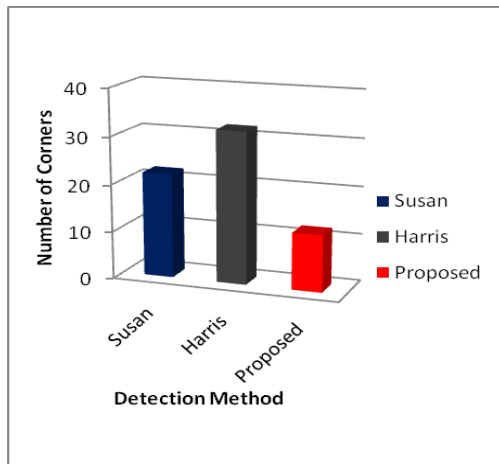
(b) harris



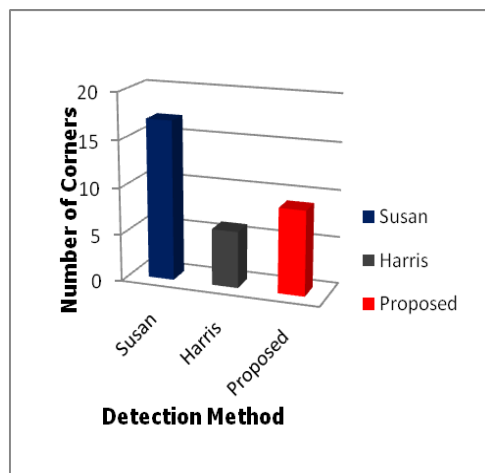
(c) proposed

Figures 5(a)-5(c): consistency of corner numbers for uniform scaling "house" image

Figure 5 shows experimental results of CCN values for house image. First corners are detected for original image. Next, original image is uniformly scaled with variations between 0.5 and 1.5. It shows that the proposed algorithm performances better than SUSAN and Harris.



(a) Number of False corners detected



(b) Number of Missed corners detected

Figure 6 shows corner results comparison for "house" image. It is observed that the proposed method detects the minimum number of false and missed corners.

6 CONCLUSIONS

This paper proposes a new corner detection method based on steerable filters and Harris algorithm. As we know, steerable filters with better orientation selectivity and use of directional and band-limited filters enables us to detect true and stable corners. This new corner detection is based on multi direction levels. This new method detects stable and localized true corners with minimum number of false and missed corners, even after rotation, scaling, and testing number of images

REFERENCES

[1] L. Kitchen, A. Rosenfeld, (1982) Gray level corner detection, Pattern Recognit. Lett. 95-102
[2] C. Harris and M. Stephens, (1988) "A combined corner and edge detector," in *Fourth Alvey Vision Conf.*, pp. 147-151

[3] S. Smith and J. Brady, (1997) "SUSAN – a new approach to low-level image processing," *Int. J. Comput. Vis.* **23**, 1, 45- 48
[4] Freeman, W.T., Adelson, E.H.: The design and use of steerable filters. *IEEE Trans. Pattern Anal. Mach. Intell.* **13**, 891-906 (1991)
[5] Simoncelli, E.P., Freeman, W.T. "The steerable pyramid: a flexible architecture for multi-scale derivative computation" In *Second Int'l Conf on Image Proc.*, vol. 3, pp. 444-447, Washington, DC, October 1995
[6] Simoncelli, E.P., Freeman, W.T., Adelson, E.H., Heeger, D.J. "Shiftable multiscale transform". *IEEE Trans. Inform. Theory* **38**(2), 587-607 (1992)
[7] F. Mokhtarian, F. Mohanna (2006) "Performance evaluation of corner detectors using consistency and accuracy measures" *Computer Vision and Image Understanding* 102 81-94
[8] Z. Zheng et al, " Analysis of gray level corner detection" *Pattern Recognition Letters* 20 (1999) 149-162
[9] Karasaridis, A., Simoncelli, E.: A filter design technique for steerable pyramid image transforms. *Proc. IEEE ICASSP* **4**, 2387-2390 (1996)