15th European Signal Processing Conference (EUSIPCO 2007), Poznan, Poland, September 3-7, 2007, copyright by EURASIP

BIT-PLANE EXTENSION TO A CLASS OF INTENSITY-BASED CORNER DETECTION ALGORITHMS

Ambar Dutta, Animesh Mandal, B. N. Chatterji and Avijit Kar

Department of Computer Engineering, B.I.T., Mesra at Kolkata, 700107, Kolkata, India
Department of Computer Science & Engineering, Jadavpur University, 700032, Kolkata, India
Department of Computer Science & Engineering, B.P.P.I.M.T., 700052, Kolkata, India
Department of Computer Science & Engineering, Jadavpur University, 700032, Kolkata, India
email: adatta@bitmesra.ac.in, mandal.ani@gmail.com, bnchatterji@gmail.com, avijit_kar@cse.jdvu.ac.in

ABSTRACT

Corners are important image features whose detection is very important in many computer vision tasks. In this paper we have evaluated the performance of five intensity based corner detectors with the help of a dozen test images, artificial and real, based on six performance measures of which three are proposed by us. We then propose a new approach, using bit-plane decomposition, in which a grayscale image is first divided into several bit-planes, and then the original corner detectors are applied on all the bit-planes simultaneously and finally using a threshold, all the higher bit-plane corners are recombined up to the thresholded bit-plane to obtain the final set of corners. Using this approach, we have seen that the performance of the algorithms has improved significantly with respect to both detection and time.

1. INTRODUCTION

Corners in an image are those points where a strong two-dimensional intensity change has been observed in all directions. So, corner detection is regarded as a very important research area for many applications in computer vision such as scene analysis, image registration, image matching, object recognition etc. Since 1977 vision researchers developed a number of corner detection algorithms. The performance of a corner detection algorithm depends on the four factors – accuracy, consistency, efficiency with respect to time and robustness with respect to noise. Zheng et al [14] and Mokhtarian et al [9] provided are good literature survey of the existing corner detectors.

Corner detection algorithms can be roughly divided into two categories: boundary based and intensity based. In this paper we restrict ourselves only to intensity-based methods. Moravec [10] detected corners at the locations where a significantly high intensity variation is found in all directions. Kitchen and Rosenfeld [6] derived a cornerness measure by applying differential operators consisting of first and second order partial derivatives of an image to detect corners. Harris and Stephens [5] estimated the cornerness measure based on local autocorrelation using first order derivatives. Deriche and Geraudon [7] detected corners using a scale-space based approach that combined important properties from Laplacian and Beaudet's [2] cornerness measures. Wang and Brady [13] proposed a corner detection algorithm based on the cornerness measurement of the total surface curvature. Smith and Brady [11] proposed SUSAN corner detector using the concept that each image point is associated with a local area of similar brightness. Laganiere [7] presented a morphological corner detector. Trajkovic and Hedley [12] presented a fast corner detector using a mutigrid approach. Zheng, Wang and Toeh [14] presented an extended version of Plessey corner detector. Golightly and Jones [4] presented an algorithm for both corner detection and matching for visual tracking of power line inspection. Mikolajczyk and Schmid [8] proposed a scale and affine invariant corner detector. Alkaabi and Deravi [1] presented a fast corner detection algorithm based on pruning candidate corners.

In this paper we have considered five intensity based methods proposed by Moravec (A1), Kitchen and Rosenfeld (A2), Harris and Stephens (A3), Laganiere (A4) and Alkaabi and Deravi (A5) and observed their performances on a set of dozen images on the basis of six performance measures of which three are proposed by us and three are taken from the literature [4, 9]. We have next proposed an extension to each of these five algorithms using bit-plane decomposition and observed from the graphs that the performance of each of the algorithms has significantly improved. The algorithms BPA1, BPA2, BPA3, BPA4 and BPA5 are the bit-plane extensions to A1, A2, A3, A4 and A5 respectively as referred in the graphs (Graph – 1 to Graph – 4).

This paper is organized as follows. In Section 2, we briefly describe the bit-plane decomposition technique. In Section 3, we discuss our proposed approach. Experimental results are then presented and compared with the original version of the algorithms in Section 4. We, finally, draw our conclusions in Section 5.

2. BIT-PLANE DECOMPOSITION

A bit-plane is a set of bits having the same position in the respective binary numbers. The first bit-plane gives the roughest, but the most critical approximation of values of a medium. The lower the number of bit-plane, the less is its contribution to the final stage. A grayscale image containing a maximum of N gray levels can be decomposed into $\log_2 N$ bit-planes, where N is a power of 2. Our method of decomposition of a grayscale image into several bit-planes is very simple. If F(x, y) is a grayscale image, where $0 \leq F(x, y) \leq N-1$, then

$$B_i(x, y) = \begin{cases} 1 & \text{, if } F(x, y) \wedge 2^i \neq 0. \\ 0 & \text{, otherwise.} \end{cases}$$

where, $B_i(x, y)$ is the i^{th} bit-plane and $i = 0, 1, 2, \ldots, \log_2 N$ and $\wedge$ is bitwise AND operator.

So, the grayscale image is a sum of a number of bit-planes (binary image planes), weighted by their respective grayness (Fig. - 1).

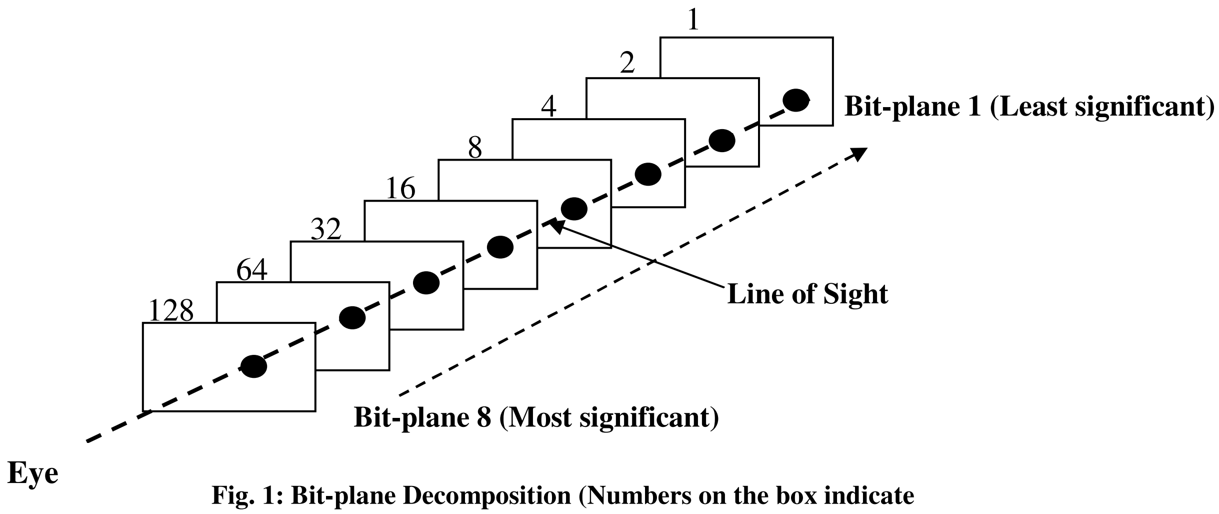


Fig. 1: Bit-plane Decomposition (Numbers on the box indicate grayness weights of each bit-plane)

3. OUR APPROACH

In the literature we have found a number of corner detection algorithms that gave multiple responses for a particular corner in a small neighborhood of that corner. This is basically due to the inherent digital nature of the image. Since corners are the image locations with high information content, they correspond to higher bit-planes. So the pixels belonging to the lower bit-planes only are treated as noise. This is the underlying philosophy of our approach. After the decomposition of the grayscale images into eight bit-planes (binary images), we use an original gray-level corner detection algorithm on all the bit-planes instead of any binary (or boundary-based) algorithm. This is because any boundary-based corner detector requires close boundaries (or contours) and some manual intervention, which will take more computational time. We describe below the improved "bit-plane decomposition" approach for corner detection.

1. Decompose the input grayscale image into bit-planes.
2. Perform original corner detection algorithm on all bit-planes **simultaneously** to obtain the corners in all bit-planes together.
3. Count the number of corners in each bit-plane and observe that the count across bit-planes, from lower to higher, suddenly goes down a steep ramp (Fig. -2).
4. Threshold at this point to ignore all the lower bit-planes.

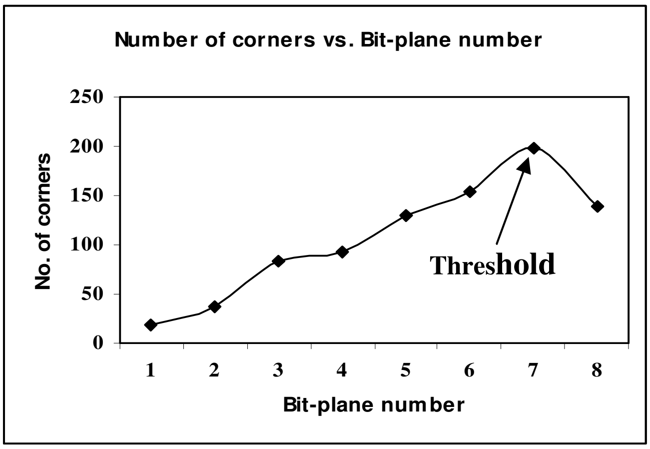


Fig. 2: Position of threshold point

5. Recombine all the higher bit-plane corners up to the thresholded bit-plane by simply OR-ing them.
6. Perform non-maxima suppression to obtain the final set of corners.

4. RESULTS

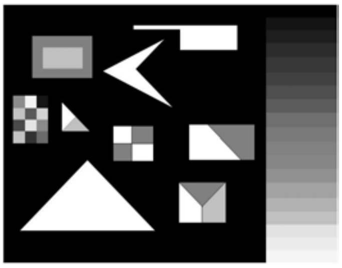
In this section we compare the performance of original corner detection algorithms with our proposed extended versions using “bit-plane decomposition” with the help of a dozen test images (Fig. – 3), synthetic and real, on the basis of six performance measures. Out of these six measures, we have proposed the following three:

(a) Detection Gradient (DG) = $(|N_A - N_D| + |N_M + N_F|)/ N_A$
(b) False Positive Ratio (FPR) = N_F / N_A
(c) False Negative Ratio (FNR) = N_M / N_A

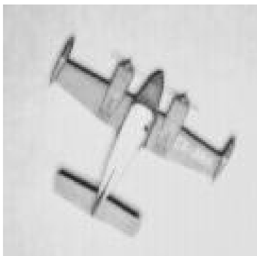
where N_A, N_D, N_F and N_M denote total number of actual corners present in the image, number of truly detected corners, number of extra (false positive) corners and number of missed (false negative) corners respectively. The other three measures taken from the literature [4, 9] are:

(a) Mokhtarian and Mohanna’s Accuracy Measure (ACCU)
(b) Golightly and Jones’ Detection Rate (DR)
(c) Golightly and Jones’ Error Rate (ER).

The results for all the measures are neatly shown with the help of graphs. And from the graphs we have observed that for our extension to the original corner detection algorithms significantly improves the performance of the corner detection algorithms with respect to detection. Due to scarcity of space, we cannot include the graphs for false positive ratio and false negative ratio which also reinforce our concept. In the graphs, the algorithm BPA1 indicates the bit-plane extension to the algorithm A1 and so on.



(a) Replica



(b) Plane

(c) House

(d) Truck

(e) Tank

(f) Jeep – 1

(g) Jeep – 2

(h) Jeep – 3

(i) Road – a

(j) Road – b

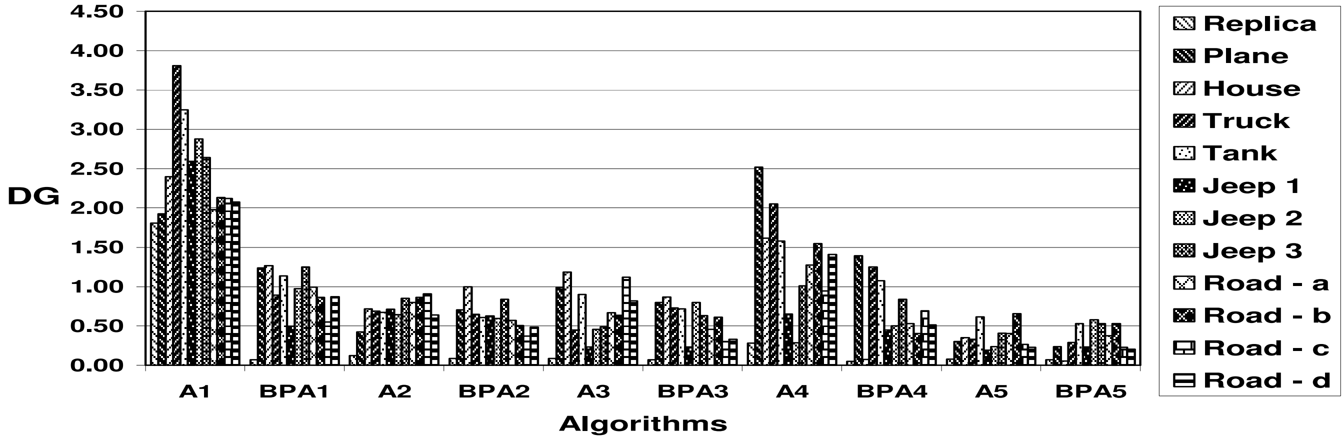
(k) Road – c

(l) Road – d

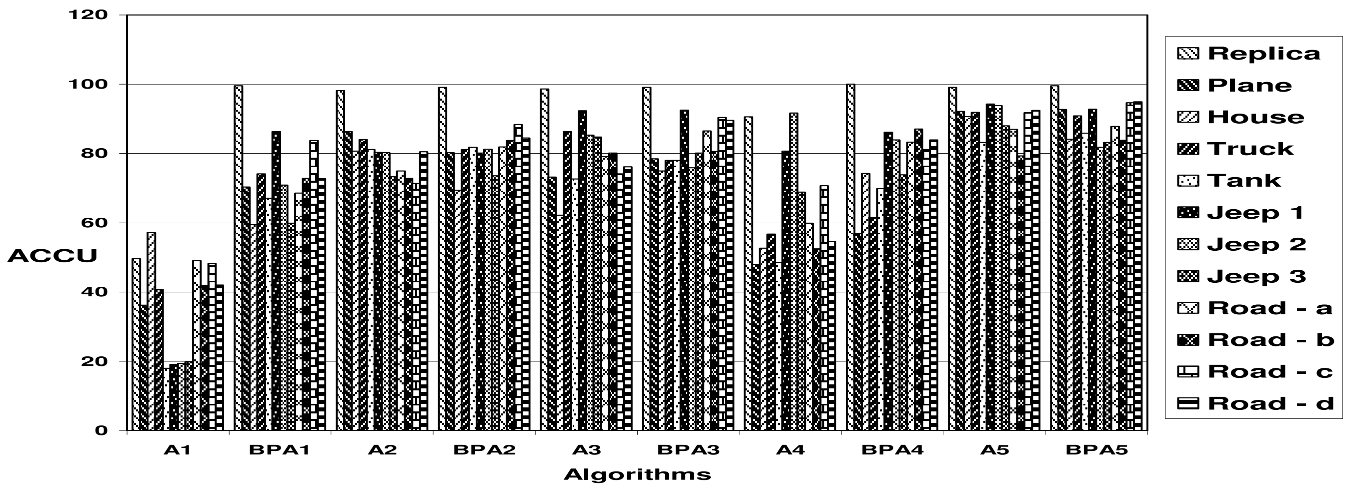
Fig. 3: Test Images (a – l)

5. CONCLUSION

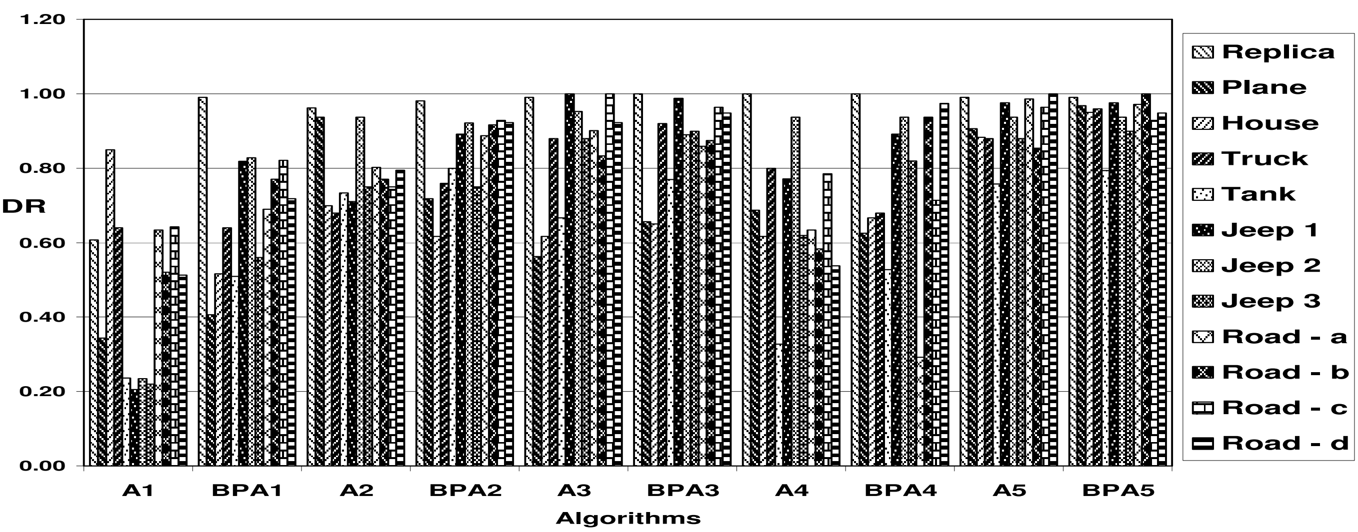
In this paper, we have presented a new approach using “Bit-plane Decomposition” to improve the performance of the existing corer detection algorithms. Our approach consists of decomposition of the grayscale image into eight bit-planes (binary image), performing the existing corner detection algorithms simultaneously on all bit-planes to extract corners in each bit-plane and finally the desired set of corners is obtained by recombining the higher bit-plane corners up to the thresholded bit-plane followed by non-maxima suppression. The superiority of our approach over the original corner detectors can be seen with the help of any of the graphs. Our approach is also very fast because we operate the corner detection algorithms on binary images (bit-planes) instead of grayscale images.



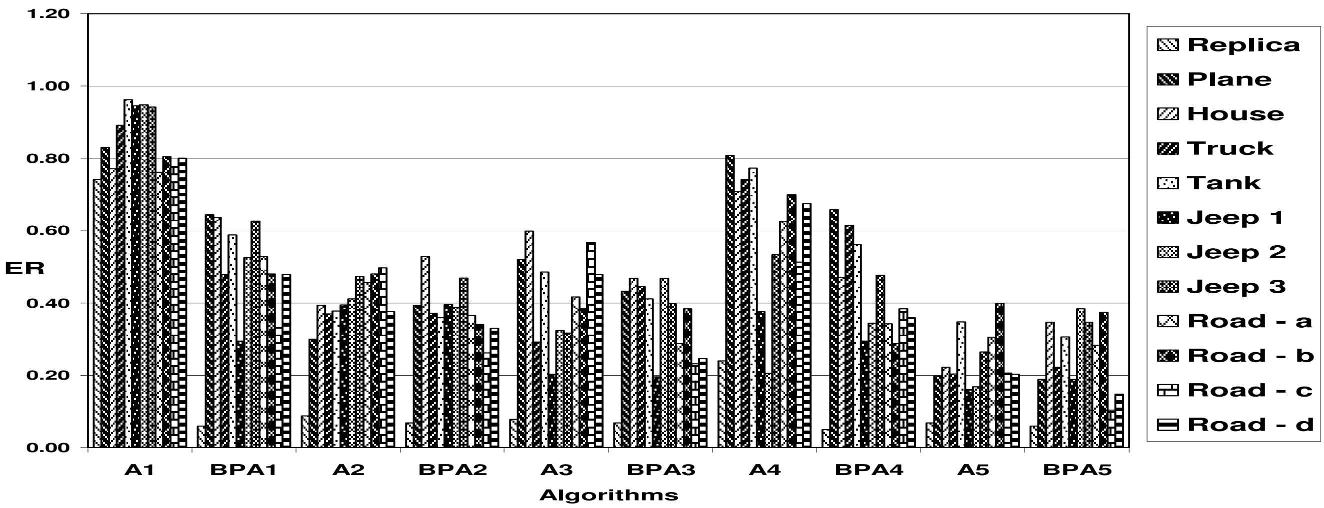
Graph – 1: Detection Gradient vs. Algorithms (The lower the value, the better is the performance)



Graph – 2: Accuracy Measure vs. Algorithms (The higher the value, the better is the performance)



Graph – 3: Detection Ratio vs. Algorithms (The higher the value, the better is the performance)



Graph – 4: Error Ratio vs. Algorithms (The lower the value, the better is the performance)

ACKNOWLEDGEMENT

The work is partially supported by a CARS grant of DRDO, Government of India.

REFERENCES

[1] S. Alkaabi, and F. Deravi, "Candidate Pruning for Fast Corner Detection", *Electronic Letters*, Vol 40, Issue 1, pp. 18–19, 2004.

[2] P. R. Beaudet, "Rotationally Invariant Image Operators", *Proc Int. Joint Conf. Pattern Recognition*, pp. 579–583, Kyoto, 1978.

[3] R. Deriche, and G. Giraudon, "A Computational Approach for Corner and Vertex Detection", *International Journal of Computer Vision,* Vol. 10(2), pp. 101 – 124, 1993.

[4] I. Golightly, and D. Jones, "Corner Detection and Matching for Visual Tracking during Power Line Inspection", *Image and Vision Computing*, Vol. 21, pp. 827–840, 2003.

[5] C. Harris, and M. Stephens, "A Combined Corner and Edge Detector*", 4th Alvey Vision Conf.,* pp. 147–151, Manchester, UK, 1988.

[6] L. Kitchen, and A. Rosenfeld, "Gray Level Corner Detection", *Pattern Recognition Letters*, pp. 95–102, 1982.

[7] R. Laganiere, "A Morphological Operator for Corner Detection", *Pattern Recognition*, Vol. 31 No. 11, pp. 1643–1652, 1998.

[8] K. Mikolajczyk and C. Schmid, "Scale and Affine Invariant Interest Point Detectors", *International Journal of Computer Vision,* Vo. 60, No. 1, pp. 63 – 86, 2004.

[9] F. Mokhtarian, and F. Mohanna, "Performance Evaluation of Corner Detectors using Consistency And Accuracy Measures", *Computer Vision and Image Understanding*, Vol. 102, pp. 81 – 94, 2006.

[10] H. P. Moravec, "Towards Automatic Visual Obstacle Avoidance", Proc. 5th Int. Joint Conf. Artificial Intelligence, pp. 584, Cambridge, Massachusetts, 1977.

[11] S. M. Smith, and J. M. Brady, "A New Approach to Low-Level Image Processing", *Int. Journal of Computer Vision*, Vol. 23, No. 1, pp. 45 – 78, 1997.

[12] M. Trajkovic, and M. Hedley, "Fast Corner Detection", *Image and Vision Computing*, Vol. 16, No. 2, pp. 75–87, 1998.

[13] H. Wang, and M. Brady, "Real-Time Corner Detection Algorithm for Motion Estimation", *Image and Vision Computing*, Vol. 13, No. 9, pp. 695 – 703, 1995.

[14] Z. Zheng, H. Wang, and E. K. Teoh, "Analysis of Gray Level Corner Detection", *Pattern Recognition Letters*, Vol. 20, pp. 149–162, 1999.