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Local Information Based Approach to Corner Detection

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ABSTRACT

For many years feature detection has played an important role in computer vision. In computer vision, the corners of an object play a vital role as features for shape representation and analysis. But corner detection, particularly in real scenes, is still a challenge. In this paper, an improvement to existing corner detection algorithms is presented using information theory where corner detection algorithm is applied to only those regions containing more information that is more intensity variations. The proposed approach substantially reduces the computational time as well as reduces the number of false positive corners. The experimental results are provided to illustrate the effectiveness of the algorithm.

Keywords: Corner detection, information content, performance measures, region, threshold

1. INTRODUCTION

Corner detection in an image is essential for many tasks in computer vision, including scene analysis, motion and structure from motion analysis, image registration, image matching, object recognition, etc. Corners are those points in an image that show a strong two-dimensional intensity change; hence, they are well-distinguished from neighboring points. Very many corner detection algorithms have been proposed by vision researchers. These methods can be broadly divided into two main classes: intensity-based and boundary-based [1, 2]. Intensity-based methods estimate some cornerness measure directly from the image gray values, whereas boundary-based methods first find the image boundaries and then calculate the maximum curvature or inflection points along those boundaries. Zheng et al. [3], Mokhtarian and Mohanna [1], Sebe et al. [4] and Dutta et al. [5] provide good comparative studies on existing corner detection algorithms. Efficient corner detection has a variety of applications such as image registration and image matching [6, 7, 8, 9]. In this paper, an information theoretic approach to corner detection is proposed in which corner detection algorithm will be carried on those regions only where a significant amount of information is present, rather than on the entire image. This approach helps to reduce the number of false positive corner detection (key requirement in corner matching). Moreover, the proposed approach reduces the computational cost as complex calculations required for corner response function involving intensity values of pixels and their derivatives are performed only on a few of the selected regions, not on the entire image. The rest of the paper is organized as follows. In Section 2, a brief literature survey of existing corner detection algorithms is presented along with different performance measures. In section 3, proposed region-based information theoretic approach is discussed. Experimental results are then provided to compare the existing corner detectors with the proposed extension in Section 4. Finally conclusions and future scope for work are discussed in Section 5.

2. RELATED WORK

2.1 Brief Literature Review

Since 1977 when Moravec [10] gave his idea of “points of interest” to find the corners, a large number of corner detection algorithms are found in the literature. Each of these algorithms relies on calculating a corner response function based on pixel intensity values of an image and their derivatives. Local maximum of this cornerness measure followed by non-maximum suppression isolates the corners. Kitchen and Rosenfeld [11] calculated a cornerness measure using differential operators containing first and second order partial derivatives of an image to detect corners. Zuniga and Haralick [12] presented a corner detector using facet model. Harris and Stephens [13] used local autocorrelation using first order derivatives to compute the cornerness measure. Wang and Brady [14] used cornerness measurement of the total surface curvature to detect corners. Smith and Brady [15] used the concept that each image point is associated with a local area of similar brightness to propose the SUSAN corner detector. Laganiere [16] presented a morphological corner detector using asymmetric opening and closing operators. Trajkovic and Hedley [17] presented a fast corner detector using a multi-grid approach. Zitova et al. [18] proposed a two-stage method for the detecting the feature points in which all possible candidates are found first and then the desirable number of resulting significant points is selected among them by maximizing the weight function. Zheng, Wang and Toeh [3] improved and extended Plessey corner detector. Lv and Zhou [19] extended of Kitchen-Rosenfeld detector based on the perception of human vision system and proposed modified cornerness measure to make the detector effective in variable illumination scenes. Bae et al [20] extracted corners using two oriented cross operators. Golightly and Jones [21] proposed an algorithm for corner detection and matching for visual tracking of power line inspection. Mikolajczyk and Schmid [22] proposed corner detector which is invariant to scaling and affine transformation. Alkaabi and Deravi [23] presented a fast corner detection algorithm based on pruning candidate corners. Kenney et al [24] used an axiomatic approach to detect corners. Vincent and Laganiere [25] proposed a two-step feature point detector which first performed a simple segmentation based on the intensity values found in the vicinity of each considered point, and then, fitted a simple wedge corner model to the resulting segmented area. Coleman et al [26] extended an existing edge detection method to corner detection using the Linear Gaussian product operator. Sebe et al. [4] gave a detailed comparison of four different algorithms in terms of invariance and distinctiveness of the extracted regions and computational complexity; and proposed a color based corner detection algorithm. Dutta et al [27, 28, 29] presented a number of corner detection algorithms to improve the performance of the existing algorithms.

2.2 Performance Measures

To compare the performance of corner detection algorithms, the actual number of corners in the image, the number of true corners detected, the number of missed corners and the number of extra corners detected are very important. Many performance measures for corner detectors can be found in the literature. Dutta el al. [2] used three measures, detection gradient (DG), false positive ratio (FPR) and false negative ratio (FNR) to compare the efficacy of a set of dozen popular corner detectors. In the best case, the value of the detection gradient is zero, which signifies that all the corners are correctly detected without any missed or false corners; the same is true for FPR and FNR. We used our proposed measures in conjunction with four existing measures, Golightly and Jones's [21] detection rate (DR) and error rate (ER) and Mokhtarian and Mohanna's [1] accuracy (ACCU) measures. The value of DR, ER and ACCU should be close to 1, 0 and 100 respectively for efficient corner detectors. The higher the value of DR and ACCU, the better will be the corner detector, whereas, a low value close to 0 is desirable for ER for a corner detector.

3. PROPOSED APPROACH

3.1 Underlying Philosophy

Corner detection algorithms tend to produce a large number of false positive corners when they are applied on real, noisy scenes with many other features present in the image along with the object of interest which is not desirable in many image processing applications. In such applications, if corner detection algorithm is applied on the entire image, then it will detect a number of extra undesirable corners. Moreover, since a complex corner response function containing image intensities and their derivatives is required to be calculated on the whole image instead of the small region of interest, it will take longer computational time. But, in order to deal with these applications, it is extremely essential to identify the region of interest properly where a significant amount of intensity variation is present. It is known that in a uniform region of the image, the information content is nearly zero. The more the intensity variation is present in a region, the more is the chance of existence of an edge and hence corners in that region, as the corners may be present in an image at the intersection of two or more edges or straight line segments. Corners are those image points with high information content and they exist in an image in those regions with high intensity variation. Thus, instead of applying the corner detectors over the entire image, it is applied to those regions with high information content.

3.2 Proposed Algorithm

The proposed algorithm is as follows –

1. The whole image I into a number of n regions R_1, R_2, …….. , R_n of equal size where the value for n will be determined from the size of the image I.
2. Calculate the standard deviation of the intensity values within each region R_i, i=1, 2,……. , n.
3. Calculate the information content within those regions only for which the standard deviation is greater than a suitable threshold.
4. If the information content of the region is again above a pre-determined threshold, then perform corner detection algorithm on the region.

4. EXPERIMENTAL RESULTS

In order to establish the efficiency of the proposed information theoretic region-based approach, extensive experiments are conducted on a large number of real and synthetic images. Due to the shortage of space, only a representative set of test images is provided in Figure 1.

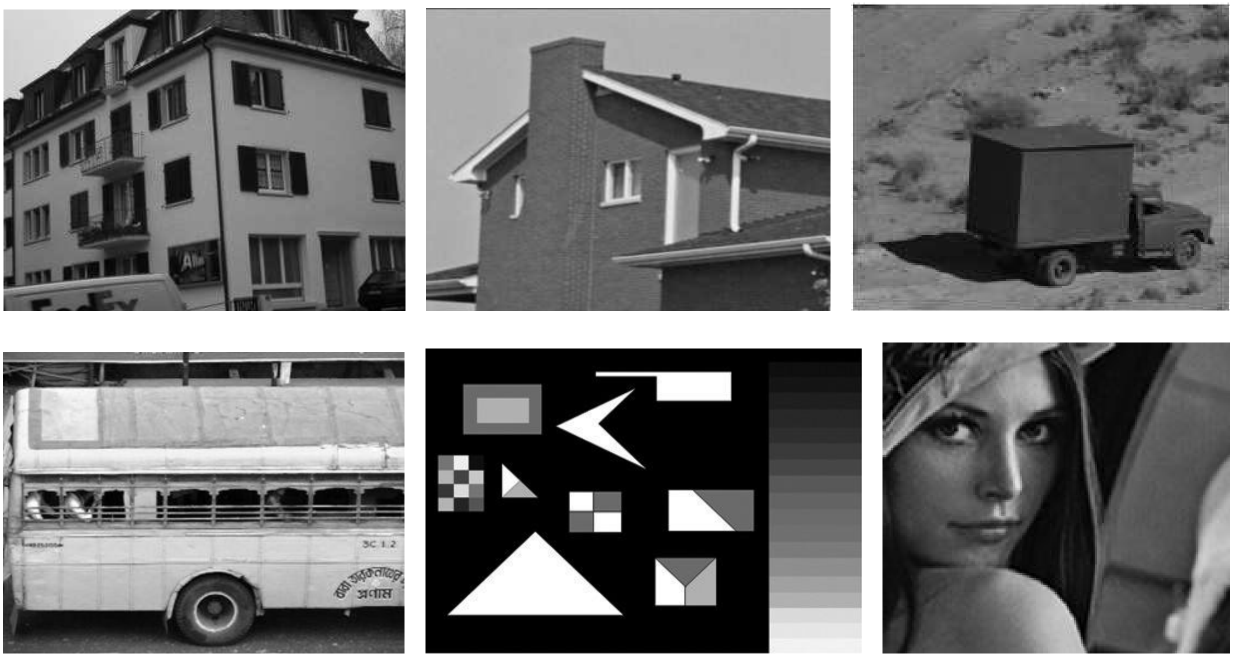

Figure 1 Representative Set of Test Images

In their study, Dutta et al [5] suggested the corner detector proposed by Alkaabi and Deravi [23] outperformed the other corner detectors under the consideration. Hence, in this paper corners are obtained in desired regions by [23]. It is observed that proposed region-based approach to corner detection is computationally more efficient compared to original corner detectors as it is applied on smaller regions in which there are significant high intensity variations and information content (see Figure 2 – 4). On the other hand, since original corner detectors involved in calculation of a complex corner response function containing image intensities and their derivatives on the whole image instead of the small region of interest, they will take longer computational time. Improvement in the efficiency with respect to the computational time is also observed from Figure – 5.

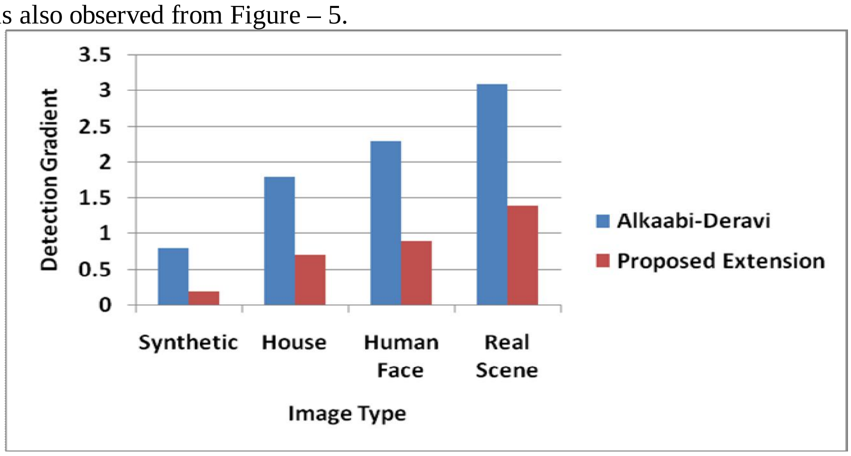

Figure 2 Improvement with respect to Detection Gradient

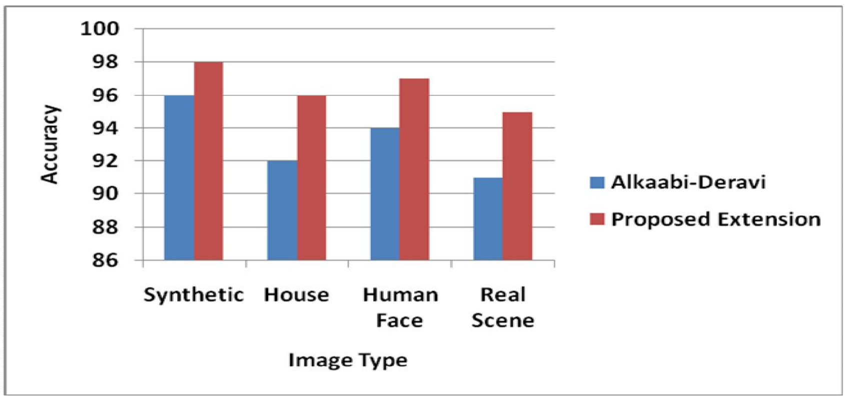

Figure 3 Improvement with respect to Accuracy measure

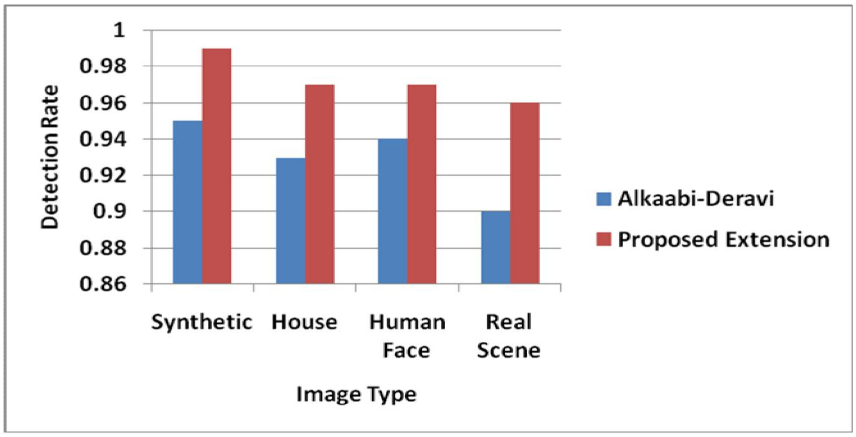

Figure 4 Improvement with respect to Detection Rate

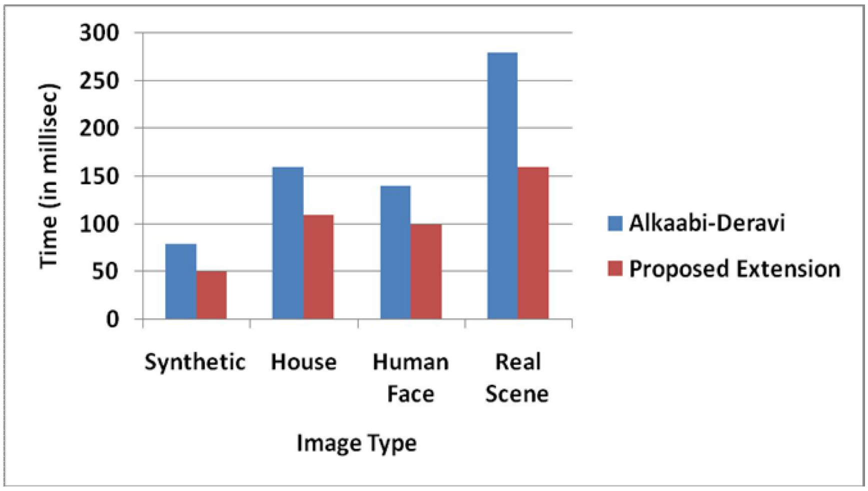

Figure 5 Improvement with respect to Computational Time

5. CONCLUSIONS

In this paper, a novel region-based information theoretic approach to corner detection algorithm is presented which is an extension to existing corner detection algorithms using the concept of region splitting. The image is partitioned into a number of regions and those regions are investigated for significant intensity variations and high information content, as a corner is an image point with high contrast along all the directions. Moreover, it may be assumed that a region containing at least one corner should have high information content as corners are found at the intersection of at least two edges. Corner detection algorithm is then applied to the reduced portion of the image to improve computational efficiency and to reduce the number of false positive corners in the image which will be one of the necessary requirements for feature (corner) matching problem. The performance of the algorithm is heavily dependent on the threshold that indicates how much variations we are allowing in the region containing corners and what is the minimum information content of a region. The work is in progress on these thresholds.

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